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The Power of Imperfect Imitation

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Abstract

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time to time, enables follower firms to surpass superior firms. Our model demonstrates this dynamic process increases the average performance of all firms in the industry relative to that achieved if firms were perfect imitators. This finding suggests that there is an adaptive role to mechanisms, such as bounded rationality, that make perfect imitation difficult.

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ABSTRACT

We examine the power and limitations of imitation. A naive intuition may hold that the efficacy of imitation would be diminished by imperfections in copying high-performing firms. Employing a computational model, we find that imperfect imitation can generate unexpectedly good outcomes for follower firms - indeed better than the outcomes achieved if they were perfect imitators. Imitation, from time to time, enables follower firms to surpass superior firms. Our model demonstrates this dynamic process increases the average performance of all firms in the industry relative to that achieved if firms were perfect imitators. This finding suggests that there is an adaptive role to mechanisms, such as bounded rationality, that make perfect imitation difficult.

Keywords:

Imitation, Search, Heterogeneity, Bounded Rationality, Industry Evolution

"It is better to fail in originality than to succeed in imitation."
-Herman Melville, American novelist

INTRODUCTION

Is imitation underrated? Imitation is often viewed as a strategy pursued by inferior firms attempting to catch up with market leaders. Moreover, a naive intuition would perhaps hold that the efficacy of imitation would be further diminished by imperfections in copying high-performing firms. We examine the efficacy and the potential of imitation when firms are bounded in their ability to imitate. We argue that there are a broad range of conditions under which imperfect imitation may lead to unexpectedly good outcomes - indeed better than those that can be achieved via perfect imitation.

The issue of imitation lies at the heart of the strategy field. At the intersections of strategy and industrial organization, classical research embodies an implicit assumption that unprotected knowledge diffuses rapidly, and imitation is relatively simple and easy. As such, it leads to price competition and the erosion of imitatees' profits (we refer to the target of imitation as an "imitatee"). As a mechanism to blockade such imitative erosion, the notions of entry/mobility barriers and other isolating mechanisms gained significant attention (Caves and Porter, 1977; Lippman and Rumelt, 1982; Peteraf and Shanley, 1997), while pushing the role of imitation to the background. As a consequence, research does not actively explore the potential and the underlying mechanisms of imitation.

Yet the notion that imitation happens rapidly seems inconsistent with a broad set of studies. For example, Greve (2009), in his study of the diffusion of Post-Panamax and double-hull ships, finds that these performance-enhancing designs spread only "slowly and selectively" even though matching rivals by adopting these designs appears to be trivially simple. The literatures in organization theory and strategy increasingly have suggested that imitation may be more complex and difficult than previously assumed, and have focused on various dimensions of bounded rationality (Simon 1957; Cyert and March 1963). It may be difficult to know ex ante what to imitate due to lack of prior knowledge (Cohen and Levinthal, 1990), uncertainty in evaluation (Greve 2009), interdependence among attributes (Ethiraj and

Levinthal 2004; Gavetti, Rivkin and Levinthal 2005; Levinthal, 1997; Rivkin 2000), and causal ambiguity (Lippman and Rumelt, 1982; Ryall, 2009). Furthermore, imitation might be partial and error prone due to limited absorptive capacity (Cohen & Levinthal, 1990), and knowledge tacitness (Zander and Kogut, 1995).

Embracing the conclusion that imitation is complex and difficult, recent research in the computational tradition has begun to focus on the dynamics of imitation (e.g., Csaszar and Siggelkow, 2010; Ethiraj and Levinthal, 2004; Ethiraj, Levinthal, and Roy, 2008; Rivkin 2000). Building on this burgeoning literature, we treat firms as consisting of bundles of attributes (e.g., products, resources, etc.), and we set up our model such that firms search for a better configuration of attributes by attempting to imitate the best firm in their industry. However, because they are bounded in their ability to identify and imitate superior firms, their imitation efforts are imperfect.

Our study shows that the efficacy of imitation is enhanced rather than hindered by imperfections in imitation. This result stems from the dynamic relationship between imitation and intra-industry heterogeneity. On the one hand, intuition suggests that imitation reduces heterogeneity between the imitatee and the imitator - and as such, superior firms need to pursue efforts to deter or blockade imitation. This is reflected in the copycat image of imitators. Our results indeed show that under perfect imitation, intra-industry heterogeneity vanishes rapidly as all firms exactly copy the attributes of the market leader. By simply (and perfectly) imitating the market leader, followers neither differentiate themselves from their rivals nor lead them. On the other hand, *imperfect imitation* serves to prolong intra-industry heterogeneity. This would seem to benefit leading firms alone. Yet imperfect imitation and prolonged intra-industry heterogeneity have a less well-known consequence – from time to time, it enables follower firms to surpass the leader and generates superior average long-run industry performance.

What explains the power of imperfect imitation? Interest in this question dates back to Alchian (1950) who conjectured that imperfect imitation improves performance, when by chance it leads to the creation of new attributes. This idea has been reflected in a long line of research (c.f., Frery 2006; Winter and Szulanski 2001; Cyert and March 1963; Nelson and Winter 1982; Feldman and Pentland 2003). We argue that imperfect imitation is still very powerful even in the absence of this Alchianian mechanism.

The mechanism identified in our model functions with the assumption that under boundedly rational imitation, even poor performing firms may, from time to time, harbor attributes useful to other (even superior) firms. When these useful and rare attributes are preserved in a low-performing firm's repertoire - and when they are mixed with a subset of attributes obtained through attempts to imitate superior firms - imperfect imitation may enable the low-performing firm to surpass the leader. Thus, our focus is not on the good fortune associated with an imitator's random creation of new attributes. Rather, we focus on the existing rare, useful attributes of low-performing firms that would be ruthlessly neglected and discarded under perfect imitation. The diffusion of these rare, useful attributes in low performing firms is the driver of the performance improvements associated with imperfect imitation. As a consequence, while imitation has been underrated and imitators derided as copycats, imperfect imitation may both improve firm performance and shift outward the performance frontier.

This paper is organized as follows. First, we review the logical underpinnings of prior work on imitation. Second, we develop a computational model of firm imitation when imitation is imperfect. Next, we numerically examine how imperfections in imitation affect firm and industry performance over time. We conclude by discussing the implications of our findings for management and future research.

DYNAMICS OF IMITATION

Imitation traditionally has been underrated. It has been viewed as simple and easy. Moreover, it has not been seen as an appropriate way for a firm to surpass the market leader or to differentiate itself from its rivals. This caricature of imitation was formed at the dawn of the strategy field, largely influenced by the IO economic tradition (for a review, see Rumelt, Schendel, and Teece, 1991).

In this early IO tradition, an industry was treated as a set of homogeneous firms. Firms with inferior attributes were assumed to leave the industry or choose to stay in business by (easily) imitating the market leader. In this conceptual framework, imitation is implicitly understood as a main driver of the convergence of firm attributes in an industry, leading to price competition and the erosion of profits.

This homogeneity assumption was relaxed to allow for the existence of groups protected by structural barriers that limit firms' ability to move from one group to another (Caves and Porter, 1977). The implicit assumption is that competition in the absence of such mobility barriers would quickly eliminate intra-industry heterogeneity (Schmalensee, 1985). Barriers to entry or mobility, then, are thought of as mechanisms that protect profits from imitative erosion.

It seems worthwhile to consider the logical underpinnings behind this classical view, and why imitation has been underrated. The classical view assumes that firms are unboundedly rational actors. The firm is assumed to be smart enough to know all the future consequences of alternative courses of action and is able to choose the best one. Under this assumption, theorists need not worry about the details of firm choices at intermediate points in time (e.g., whom or what to imitate). Instead, the focus is on static features like industry structure, which are understood to determine long-run industry and firm performance. Details of any transient process before the market system reaches equilibrium are treated as trivial or simply uninteresting.

Although the impressive contributions of this static tradition are evident in the strategy literature, it has shortcomings with respect to our understanding of imitation. It has left research in strategy relatively silent on the details of imitation processes.

Intra-industry heterogeneity is of central importance because the ability of imitation to lead to performance improvement is clearly a function of the set of attributes in the industry available to imitation. To the extent that imitation is simple and easy, and all firms perfectly copy the attributes of the market leader, then the details of the dynamic process may be ignored. Indeed, under perfect imitation, intra-industry heterogeneity is rapidly eroded as all firms quickly become identical. After this point, imitation will generate the same outcome again and again.

To the extent that imitation is complex and difficult, intra-industry heterogeneity may persist, potentially leading to unexpected results. The dynamics of imitation rest on the iterative process of the imitative attempts made by the set of firms over time. In this process, each firm imitates another, and the outcome of these imitation attempts then forms the basis upon which subsequent rounds of imitation build. The outcome of this sort of process is sometimes sensitive to seemingly minor bias that occurs during early periods of industry evolution, and even small changes in one period can lead to large changes in subsequent periods (Holland, 1998; Strogatz, 2001; Waldrop, 1992). For instance, errors and bias in selecting a target of imitation, and copying its attributes, may lead to loss of useful attributes in the industry. Once lost, these attributes are non-recoverable. This sort of dynamic can lead to results that are not easily anticipated in the static tradition.

Efforts to formalize a dynamic model of firms and markets dating to Winter (1971) embraced the assumption that firms are boundedly rational. As a consequence, instead of choosing the best alternative once and for all, firms *search* until they find a sufficiently good alternative (Simon, 1957; Cyert and March 1963). Nelson and Winter (1978; 1982) advance this model by focusing on two forces that spur competition over time. The first force, innovative search, is the firm's effort to create new ways of doing things which serves to create value and push outward the performance frontier. The second force, imitative search, is the firm's effort to imitate the market leader. However, Nelson and Winter's (1982) focus is on innovative search. Imitative search is a secondary consideration — a strategy by which a follower can catch up with, but not exceed, the market leader. In contrast to Nelson and Winter (1982), our primary focus is on imitation.

Why does imitation matter? It matters because, when imperfect, it serves not only as a mechanism by which followers can match the performance of market leaders, but also, as a mechanism by which both firm and industry performance gains may be achieved. The efficacy of imperfect imitation lies in the power of partial imitation of attributes that have worked well in the past. From time to time, a useful but rare attribute may reside only in a low performing firm. In an imperfect imitation attempt, a laggard firm may mix this rare, useful attribute with useful attributes of a leading firm, giving rise to the possibility that an imitator surpasses the leading firms. In a dynamic system, this leapfrogging transports a useful attribute from a poor firm to a good firm. This, in turn, preserves useful attributes and dramatically enhances the possibility that the attribute will diffuse widely in the population. We show that this dynamic process improves performance.

In the next section, we develop a computational model to examine the potential of imitation under various levels of bounded rationality, which gives rise to imperfect partial imitation. Our model builds directly on the theoretical foundations of the literature discussed above.

MODEL

Our model is designed to investigate imitation as a search strategy and explore the implications of bounded rationality for the efficacy of imitation. Following the "keep-it-simple" principle, we model firm behavior as imitation constrained by bounded rationality in a task environment characterized by interdependence across attributes. The model consists of three main entities: reality, firm, and industry.[1]

1. Reality. Reality R is a m-dimensional vector $\{r_1, r_2, \ldots, r_m\}$ with each element r_i set to either 0 or 1. For instance, the reality vector may represent the set of consumer preferences.

2. Firm. A firm faces m decision problems (selecting attribute states) corresponding to the m elements of reality. For example, a firm makes decisions about m features of a particular product (e.g. color, size, etc) in its attempt to match consumer preferences. Thus, a firm has a configuration of attributes, X, which is an m-dimensional vector $\{x_1, x_2, \ldots, x_m\}$, with each attribute x_i set to 0 or 1 (Rivkin, 2000; Ethiraj and Levinthal, 2004).

3. Industry. In the industry, there are N firms that search for better performing configurations of

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1 This model employs the basic structural form of Holland (1975), March (1991), and Bruderer and Singh (1996).

attributes. The search strategy will be discussed later.

Performance: Performance is a function of the number of matches between reality and firms' attributes. There are several ways to specify this function (e.g., Hinton and Nowlan, 1987; March, 1991; Fang et al., 2010). In this paper, we use a generalized form that parameterizes the difficulty of the search problem in terms of the interdependence across attributes, with a tunable parameter k. Let $Y(X)$ denote the normalized performance of a firm with attribute vector X. Formally, $Y(X)$ is represented as follows,

$$Y(X) = f(R,X) = \frac{1}{m}\sum_{i=1}^{m}\left(\delta_i \cdot \prod_{d \in D_i} \delta_d\right) \in [0,1] \qquad (1)$$

where $\delta_i = 1$ if the i-th element of the attribute vector X matches the corresponding element of the reality vector R (i.e., $x_i = r_i$); otherwise $\delta_i = 0$.

Specifically, each of the m attributes is interdependent with k other attributes (specified by the set D_i) which are randomly chosen. Thus, k ranges from 0 (no interdependence) to $m-1$ (maximal interdependence). An attribute gets a partial payoff of $1/m$ if it and all of its k dependent attributes match the values in reality. If the attribute itself or any of the dependent attributes are incorrect, the partial payoff of the attribute is zero. In the case of maximum interdependence ($k = m-1$), if any of the m attributes is wrong, the payoff for the configuration of attributes becomes zero.

For instance, consider the case of maximum interdependence where $k = 4$ for a search problem with five dimensions ($m = 5$). If a firm identifies the correct attribute for each of the five decision problems, its performance is 1 (= 5/5). But, when a firm selects four correct attributes and one incorrect attribute, its performance is zero. In contrast, if $k = 0$, when a firm has four correct decisions and one incorrect one, its performance is 4/5.

This payoff function is analogous to that of the NK model in that it parameterizes the complexity of a search problem in terms of interdependence among decision variables (Kauffman, 1993; Levinthal, 1997; Gavetti and Levinthal, 2000; Ethiraj and Levinthal, 2004; Rivkin, 2000). We employ this simplified payoff function because our focus is on the implications of bounded rationality for inter-firm imitation rather than the complexity of search itself.

Search Strategy: In our model, firms search for a better performing configuration of attributes via imitation. If, as the literature typically highlights, the objective is to imitate the attributes of the market leader (e.g., Apesteguia, Huck, and Oechssler, 2007), then firms must: (a) identify the set of firms in the industry; (b) identify the best firm from the set; (c) select the attributes to imitate; and (d) accurately reproduce the attributes. Imperfection in imitation may occur in each element of the imitation process.

For the purposes of our model, we focus on two of these elements. In particular, we define perfect imitation in two dimensions: (1) a firm is able to process the information of all the other firms in the industry to identify the leading firm; and (2) a firm correctly copies all attributes of the imitatee. Building on the Carnegie School tradition (Simon, 1957; Cyert and March, 1963), we define imperfect imitation by relaxing any of these two assumptions. First, a firm might be boundedly rational in processing the information about all the firms in the industry. Limited resources and cognitive constraints may lead a firm to construct a limited consideration set of potential imitatees. We operationalize this by allowing firms to access a set of randomly chosen firms of the size b_s ($b_s \leq N$) and imitate the best in that set. As a consequence, from time to time, a superior performer may imitate an inferior performer. This is more likely when $b_s = 1$ (random imitation), but as b_s increases (firms become more effective imitators), the probability of imitating an inferior firm rapidly approaches zero. Second, a firm might be bounded in its ability to discriminate correct from incorrect attributes of the imitatee ex ante. As such, the firm copies imitatee's attributes without considering the merits of a particular attribute. In particular, we assume that a firm blindly copies p_m fraction of the imitatee's attributes in a time period (e.g., March, 1991; Rivkin, 2000; Ethiraj and Levinthal, 2004). If $p_m = 1$, a firm copies all of the imitatee's attributes.

Model Properties: The model described above is closely related to prior modeling of the imitation process. For purposes of comparison, we focus on three representative studies: March (1991), Rivkin (2000), and Csaszar and Siggelkow (2010). We examine each study on four dimensions: (a) target of imitation, (b) nature of the imitation process, (c) interdependence between attributes, and (d) focal construct. The main features are summarized in Appendix C. We proceed to discuss each dimension below.

An important difference between the models in these papers is the choice of the target of imitation. Rivkin (2000) and Csaszar and Siggelkow (2010) focus on identifying and imitating the best firm. Our paper shares this imitation objective. In contrast, March (1991) focuses on imitation of what can be considered a set of best practices, rather than targeting any particular agent for imitation. The best practices are encapsulated in the "organizational code," which consists of the majority view of the set of superior agents.

Central to these papers is the mechanism that limits the process of imitation. These papers share one element of bounded rationality – incomplete (partial) imitation of the set of attributes of the imitatee. However, the papers differ in terms of the ability of the imitator to identify the target of imitation. Rivkin (2000) and Csaszar and Siggelkow (2010) assume imitators are able to correctly identify and imitate the best firm in the entire market. This sort of imitation rule is known to be "greedy," meaning it over-exploits the attributes of a few superior firms. To counter this over-exploitation, Rivkin (2000) and Csaszar and Siggelkow (2010) allow for the Alchainian type of random creation of new attributes. March (1991) also allows for the inflow of new attributes in the form of hiring. In contrast, our model assumes that firms are bounded in their ability to identify and imitate superior firms. To clearly isolate the re-combinative effects from other confounding effects, our model does not allow for the random creation of new attributes.

An important common feature of these papers is the construct of the degree of interdependence. Rivkin (2000) and Csaszar and Siggelkow (2010) adopt the NK model, which incorporates interdependence of attributes in affecting performance. In contrast, March's (1991) model sits at the polar extreme, assuming attributes are independent of one another. As such, March's model gives rise to a much simpler payoff structure. Like the NK model, our model incorporates interdependence. The parameters in our model, m and k, are analogous to N and K in the NK model, where N represents the number of decisions and K represents their interdependence.

We sought a parsimonious model to capture the essence of the imitation process, in a context were performance improvement was moderately difficult. The NK model is too complex to identify and track the flow of useful knowledge at the micro-level. The NK model is considered complex because as N and K increase, it becomes harder to explicitly determine and control the number of peaks and the height of the global peak. In contrast, the absence of interdependence in the March (1991) model makes the search problem too easy, and, as such, performance differences are attenuated. Our model employs a simplified version of the payoff structure that shares key properties of the NK model (indeed, we examine robustness to a full NK structure).

We choose this simplified payoff structure because the process of imitation rests on the extent of variation in the population of firms. This in turn is predicated on the existence of a sufficient number of firms, and a sufficiently large number of attributes.[2] Thus, an advantage of our payoff structure lies in its computational efficiency, especially in dealing with high dimensional search problems (i.e., a high value of N) with a substantial degree of interaction (a high value of K). In such a setting, the NK model becomes computationally expensive—this problem is known as a "NP hard" problem in computer science. In our setup, the computational cost of increasing the number of firms, and the dimension m and interdependence k in our payoff function, is reduced. This in turn better enables us to directly examine the dynamics of imitation.

Finally, each of the comparison papers has a different focal construct. These differences are reflected in the differing modeling assumptions above. Rivkin (2000) focuses on interdependence as the focal construct, and the effect of interdependence in deterring imitation by rivals. Csaszar and Siggelkow (2010) focus on the performance implications of the breadth of imitation under conditions of complexity and context similarity. March (1991) focuses on the effect of learning rate on organizational performance.

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[2] Imitation is neither effective nor interesting if, for example, there are two firms, each with two attributes.

We control for this mechanism. As such, our model includes a variable for the imitation rate, which plays a role analogous to March's (1991) learning rate (we examine this explicitly in the sensitivity analysis). Holding the imitation rate constant, the key parameter of interest in our model is boundedness in search, which gives rise to imperfect imitation.

SIMULATION RESULTS

We numerically examine how imperfections in imitation affect firm and industry performance over time. In particular, we try to address the question of the efficacy of imitation under conditions of bounded rationality. We model an industry of initially heterogeneous firms endowed with random attributes. Firms try to improve their performance by searching for the best performer and imitating it. We conduct three experiments. In experiment 1 (baseline model), we examine the efficacy of imitation under various levels of its imperfection that arise because firms are bounded in search scope. Here, we assume that all firms in the industry are equally bounded. In experiment 2, we relax this assumption by allowing for intra-industry heterogeneity in search boundedness. Here, we examine the implications of this heterogeneity for the efficacy of imitation. In experiment 3, we further explore intra-industry heterogeneity by assuming that the industry consists of two separate groups of firms with asymmetric initial knowledge levels. Here, we examine the implications of a permeable between-group barrier to imitation for the efficacy of imitation.

The reported results are computed by averaging over 500 simulation runs with different random seeds. Each simulation run contains 50 firms. We compute each simulation run until steady state performance is reached. The parameter values are specified in Appendix A.

Experiment 1. Imperfection in Imitation due to Bounded Rationality (Baseline Model)

We examine the efficacy of imitation when firms are bounded in search scope (b_s)—more specifically, the number of other firms each firm considers for determining the best target for imitation. There are two extreme cases. First, when b_s = 50, each firm is unbounded in its consideration set; it examines all other firms in the industry and chooses to imitate the best performer. Second, when $b_s = 1$, each firm randomly selects only one other firm and imitates it. We believe that reality lies in the middle ground between these two extremes. In general, a decrease in b_s implies that firms are more bounded in search scope and engage in more imperfect imitation. Figure 1 shows the typical evolution of the industry over time at varying levels of imperfection in imitation. For all but perfect imitation, b_s is as noted, and $p_m = 0.3$ (e.g., copy 30 percent of attributes). For perfect imitation, $b_s = 50$ and $p_m = 1$. As each firm attempts to search for and imitate the best performer in its consideration set, the average performance improves over time, eventually reaching a steady state.

The simulation result shows that bounded search is not a limitation but a virtue in enhancing performance through imitation. When firms are very good imitators ($b_s = 50$), they easily identify the global best firm in the industry, and long-run performance is only moderate. Moreover, performance is worse when firms are perfect imitators. At the other extreme, when firms are purely random imitators ($b_s = 1$), performance is at its lowest level. These results stand in stark contrast to those of moderate imperfection in imitation. When firms are moderately bounded in search scope ($b_s = 5$), the long-run performance is better than either the perfect or random imitation cases.

<Insert Figure 1 about here>

Why do we observe superior imitation performance under the bounded search condition? The extant literature suggests that preservation of diversity in the population matters (e.g., Campbell, 1965; Kauffman, 1993; March, 1991; Fang, Lee, and Schilling, 2010). Thus, the simplest conjecture is that the observed difference in performance stems from the system's ability to preserve knowledge diversity across firms. Diversity in the industry is the primary source of learning through which a firm replaces incorrect attributes with correct attributes. Consider the extreme case of homogenous firms such that all firms are identical on all attributes. Imitation will generate the same solution over time and cannot enhance performance. Thus, the existence and maintenance of a sufficient *quantity of diversity* across firms in the industry is a prerequisite for the effective functioning of imitation as a search strategy.

Figure 2 shows how diversity changes over time for different levels of boundedness. Diversity is measured via a pair-wise comparison of all firms. For each pair of firms, the *m* attributes are compared. The diversity measure is then the average sum of squared differences. The results of examining the quantity of diversity, however, do not fully explain the results of long-run industry performance. As shown in Figure 1, the industry performs worst when $b_s = 1$. However, the results in Figure 2 demonstrate that under this condition we observe the largest quantity of diversity. Thus, the quantity of diversity in the industry does not always serve to enhance performance.

<Insert Figure 2 about here>

Why does the quantity of diversity fail to fully explain the long-run performance of the industry? We suggest that this *quantity* of diversity misses an important characteristic of diversity. We propose a new measure of diversity reflecting *quality*, incorporating the degree to which firms in the industry collectively preserve useful knowledge (i.e., correct attributes match reality) about the true state of the world. Figure 3 presents this quality measure, which counts the number of correct attributes in the industry. The industry has a correct attribute in a period if at least one firm matches the state of the attribute to the true state in the reality vector. Consider the example in which the reality vector is of size $m = 100$. If the level of useful knowledge is 90, then the industry contains at least one firm with the correct attribute on each of the 90 dimensions of the reality vector. On the remaining 10 dimensions, no firms have correct attributes. Thus, this measure represents how much non-redundant correct knowledge is preserved in an industry. As shown in Figure 3, the level of useful knowledge in the industry is highest when imitation is imperfect. In contrast, when firms are random imitators, the industry loses, over time, potentially useful knowledge even though the quantity of diversity (as in Figure 2) remains high. To understand this result, we investigate the underlying dynamics of the imitation process at the firm level.

< Insert Figure 3 about here >

Why is the quality of diversity best maintained when firms are bounded in their search? Our result suggests that bounded search does not hinder, but rather facilitates firm-level learning via imitation. The efficacy of imitation is a function of both the quantity and quality of diversity. Importantly, the quantity and quality of diversity are not static; at any point in time, they are the outcome of the dynamic process of imitation. Imitation relies on the existence of diversity in the population of firms, and also shapes that diversity – both its quantity and quality.

To illustrate this process, Figure 4 represents firm-level learning via imitation for different levels of boundedness in search. Specifically, it measures the total count of firm attributes that change (flip from 0 to 1 or from 1 to 0) due to imitation (averaged over 80 periods). The count is categorized by the relative performance of the imitatee (superior or inferior) and the correctness of the change (correct or incorrect). For example, if a firm copies a correct attribute (i.e., matching reality) of a superior firm and replaces its own incorrect one, it is categorized as a single correct event of learning from a superior. The result explains why industry performance is highest when firms are imperfect imitators (b_s = 5). As shown in Figure 3, the amount of firm-level correct learning less incorrect learning (replacing a correct attribute with an incorrect attribute) is largest when imitation is imperfect.

< Insert Figure 4 about here >

When firms are (near) perfect imitators (b_s = 50), they copy only the current best firm in the industry. The knowledge of those firms that are not identified as the best is ignored although they may have some useful knowledge (i.e., correct attributes matching reality). As a consequence, in the process of imitation, the useful knowledge possessed by low (or even reasonably good) performers will be quickly driven out of the system. But the diffusion of the best firm's good attributes comes at an additional cost - any incorrect attributes of the best firm are also likely to diffuse rapidly.

When imitation is purely random (b_s = 1), all firms have an equal probability of being selected as an imitatee. Because the pool of imitatees is large and firms continuously change their imitatees, there is substantial replacement of current attributes with the corresponding attributes of the imitatee. However, the performance of a randomly selected imitatee might be superior or inferior to the imitator. A higher performer would have more correct attributes while a lower performer would have more incorrect attributes. Because of this symmetry, the correct learning from superiors is completely offset by the incorrect learning from inferiors. Consequently, the amount of correct learning less incorrect learning is zero in the long run (as in Figure 4). Performance does not improve (as shown in Figure 1) even though industry-level diversity remains highest over time (as shown in Figure 2). Thus, while the quantity of diversity is very high, the quality of diversity is low.

Imperfect imitation capitalizes on the advantages of both cases: the higher probability of learning from higher performers and the non-zero possibility of useful knowledge percolating upward from lower performers. This may happen in two ways. First, a high-performing firm may imitate a rare correct attribute of a low performer. Second, a low-performing firm may imitate a superior firm, and in doing so, become a high performer by acquiring superior attributes through imitation and mixing them with any rare, good attributes it already possesses. In either case, once the rare, good attribute is in a good firm, it will diffuse rapidly throughout the industry because the probability of a high performer being imitated is relatively high.

To what extent does useful knowledge in low-performing firms contribute to the performance gains from imperfect imitation? We designed an additional experiment to answer this question. We deliberately control the diffusion of useful knowledge from low-performing firms. Specifically, we marked the bottom-x% of firms at the beginning of the simulation run, and forced firms not to consider them as a target of imitation although they are in the consideration set. This restriction partially removes the benefit from upward percolation of useful knowledge in the bottom-x% firms. The results of this examination, available in Appendix B Panel 1, demonstrate that as the restriction increases, there is a significant drop in the level of performance over time. This result implies that rare, useful knowledge in low-performing firms is a significant driver of the power of imperfect imitation.

The dynamics of this diffusion process explain why the amount of learning (correct less incorrect) is largest in the case of imperfect imitation. As shown in Figure 4, under imperfect imitation, some useful knowledge percolates upward from inferior firms. Once assimilated by a superior firm, it is then widely diffused back down to inferior firms. This dynamic process is at the core of the power of imperfect imitation.

The dynamic process above relies, in part, on the possibility that an inferior firm can periodically mix its rare, useful attribute with good attributes acquired by imitating superior firms. Can a laggard, then, outperform a market leader solely through imitation? Figure 5 presents data on the frequency of laggard firms surpassing the performance of the market leader. First, when firm imitation is purely random (b_s = 1), the possibility of surpassing the market leader is very low. The amount of correct learning less incorrect learning is zero at the firm level and it is difficult to develop better solutions and improve performance. Second, we exclude from the graph the case of perfect imitation of the best firm because it removes the possibility of surpassing the leader - all firms instantly match the best firm, but cannot surpass it. Third, when firms are near perfect imitators (b_s = 50), the market leader turnover rate is high only in the early periods and then decreases rapidly. Finally, the results show that the probability of surpassing the leader via imitation is highest when b_s = 5. The cumulative number of leader changes (the size of the area under the curve) is maximized under imperfect imitation.

< Insert Figure 5 about here >

Experiment 2. Heterogeneity in Boundedness of Search Scope

In the prior experiment, firms are homogeneous in their boundedness. In this and the subsequent subsections, we relax this assumption to explore the implications of intra-industry heterogeneity. In particular, in this experiment, we examine an industry consisting of firms that are heterogeneous in their boundedness in search scope (b_s). Some firms may be more bounded than others as a result of exogenous heterogeneity or costly investment in information processing capacity. As a simplest possible setting, we consider a case in which half of the firms in the industry are near perfect imitators (e.g., less bounded) with b_s = 50, while the other firms are imperfect imitators (i.e., more bounded) with b_s = 5. Figure 6 compares the average performance of less bounded imitators with that of more bounded imitators.

< Insert Figure 6 about here >

The results show a significant short-run heterogeneity in performance across the two sets of firms. As expected, the less bounded imitators perform better than the more bounded imitators. This result implies that firms with more perfect imitation achieve superior performance, if other factors are held constant. As such, firm heterogeneity in search boundedness may be a source of intra-industry performance heterogeneity in the short run.

What then is the long-run implication for overall industry performance in the presence of a subset of firms who are near-perfect imitators? Would this near-perfect subgroup enhance industry performance in the long run? To address these questions, we compare the results of the heterogeneous industry above with that of a homogenous industry in experiment 1 (i.e., N firms with $b_s = 5$). Figure 7 represents the performance gain of the less bounded firms, the more bounded firms, and the industry as a whole, as a percentage of the performance of a homogenous population of more bounded firms. In the short run, the industry benefits from the existence of the less bounded firms because these firms drive fast performance improvement. However, in the long run, the industry performs significantly worse than the homogenous industry case. This result is explained by the rationale discussed in experiment 1. The performance gain from near perfect imitation by half of the population comes from the intensive exploitation of currently best solutions. But this limits the potential for the diffusion of rare, useful knowledge in low-performing firms and drives such knowledge out of the system. The ignored, useful diversity reduces the amount of firm-level learning, and drives the industry toward lower long-run performance.

< Insert Figure 7 about here >

In sum, while an individual firm's performance is enhanced by efforts to become a more effective imitator, the industry as a whole is negatively impacted. In the next experiment, we examine a setting in which individual firm effort to become a more effective imitator is conducive to improvement in industry performance.

Experiment 3. Between-Group Barrier to Imitation

In experiment 2, we divided the industry into two types of firms – those that are more bounded versus those less bounded in their ability to imitate. In this experiment, we hold constant the extent of boundedness and, instead, divide the industry into two groups varying the extent of imitation across groups. In this way, we further explore the implications of intra-industry heterogeneity.

We assume that an industry consists of two different groups of firms endowed with asymmetric levels of knowledge. This kind of group structure is consistent with the literature on strategic groups, which suggests that managers tend to view their industries as groups of firms and they partition their environment to reduce uncertainty and to cope with bounded rationality (Peteraf and Shanley, 1997). Such a barrier may exist in the context of, for example, geographical/relational distance (Greve, 2009; Lieberman and Asaba, 2006), cognitive distance (Peteraf and Shanley, 1997), or strategic/technological difference that may make within-group imitation easier than between-group imitation. Consequently, firms are more likely to search for imitatees within their own group. This preferential within-group imitation reflects an additional mechanism that engenders imperfect imitation. As such, a key parameter of our interest in this experiment is the height (strength) of a barrier to between-group imitation.

In particular, the model structure is as follows: The industry consists of two groups of 25 firms, a leader group and a laggard group, where all firms are equally bounded in imitation (b_s = 5). The firms in the leader group are initially endowed with 55 correct attributes, while laggard group firms have only 45 correct attributes. The two groups are not fully overlapping in their initial attributes. We divide the entire set of attributes (m = 100) into three subsets. The first subset of 10 attributes is used uniquely by one group, while the second subset of 10 attributes is used uniquely by the other group. The third subset of 80 attributes is available to both groups. In this way, ten percent of the attributes are initially unique to each group.

We define the imitation barrier (v), which ranges from 0 to 1, as the tendency of a firm to select candidate imitatees from its own rather than the other group (e.g., across the group boundary). When v = 1, there is a 'perfect barrier' and a firm forms its consideration set with candidate imitatees exclusively from its own group. When v = 0, there is 'no barrier' and a firm identifies its consideration set independently of the group affiliation of potential imitatees. We define two intermediate cases. The 'near-permeable barrier' corresponds to the case of v = 0.98. Finally, we label as a 'semi-permeable barrier' the case where v = 0.8.

Figure 8 presents the difference between the average performance of the firms in the leader and laggard groups. For the leader group, a perfect barrier to between-group imitation presents the seemingly best-case outcome, because the laggard group never catches up to it. Indeed, the performance gap between the groups grows rapidly over time. In contrast, when a between-group imitation barrier is absent, the two groups become identical in performance.

< Insert Figure 8 about here >

A more interesting case is that of a near-impermeable barrier to imitation. Here, firms in the leader group are exposed to a risk of losing their leadership position to the laggard group. The observed long-run risk of group level leadership change (at around period 43) stems from the dynamics of the imitation process and an endogenous asymmetry in imitation between the two groups. Recall that the rate of between-group search for candidate imitatees is the same for both groups. However, the probability that a firm in the leader group chooses to imitate a firm in the laggard group is rather low because the laggard group candidate likely underperforms the leader group candidates in the imitation consideration set. This natural asymmetry is not due to any different assumptions on search behavior. Rather, it stems from the general search assumption that imitation is directed toward market leaders. Thus, the interaction between between-group search and within-group evaluation generates an endogenous asymmetry in imitation between two groups of different average performance. This in turn serves as the mechanism that drives group level leadership change. Once the group performance reverses, the direction of the imitation asymmetry also flips, and the lagging (originally leading) group once again starts to learn from the leading (originally lagging) group.

We also examine the average industry performance. The results are presented in Figure 9. First, when the barrier to between-group imitation is perfect, industry performance improves over time, but is still rather poor. This industry performance result stands in stark contrast to the earlier observation that the perfect barrier generates the biggest performance difference between the leader and laggard groups.

< Insert Figure 9 about here >

Second, when the barrier to between-group imitation is near-impermeable, we observe the highest industry performance. What explains the difference in performance between the perfect barrier and the near-impermeable barrier cases? In both cases, the isolation of groups allows each group to harbor and preserve attributes unique to the group. However, in the near-impermeable barrier case, the possibility remains that an imitator will cross the group boundary from time to time. This crossover provides a mechanism to obtain useful attributes absent in the focal group. In turn, this improves the group performance as well as industry performance.

Finally, when there is no barrier to between-group imitation, we observe only moderate performance. Here, the lack of isolation limits the preservation of group-specific attributes, as cross-group imitation ruthlessly neglects and discards group-specific attributes.

Sensitivity Analysis

In addition to exploring the role of heterogeneity in boundedness and barriers to between-group imitation, we examined sensitivity on six factors: (1) the rate of imitation, (2) changes in the level of interdependence across attributes; (3) imitation that is augmented by trial and error learning, (4) environmental change, (5) inter-temporal heterogeneity in boundedness, and (6) number of firms.

First, a key parameter of theoretical interest in models of social learning is learning rate—fast or slow learning (March, 1991). We develop an additional set of simulations to illustrate that our results are insensitive to changes in the learning rate. In our main models, we set and hold fixed the learning rate at $p_m = 0.3$ (the only exception is perfect imitation, where $p_m = 1$). Here, we examine the performance of our model of imperfect imitation across different learning rates. The results, available in Appendix B Panel 2, show that faster imitation (a higher value of the imitation rate, p_m) preserves a lower quantity of diversity and leads to lower performance. More importantly, the results of this experiment demonstrate that, even across different learning rates, there are large differences in the performance of imperfect imitation relative to more (and less) perfect imitation. This finding suggests that imperfect imitation functions independently of the learning rate.

Second, we examine the implications of imperfect imitation at varying levels of interdependence across attributes. Our baseline model held the level of interdependence constant at $k = 5$. We examine interdependence at moderate levels ranging from $k = 0$ to 20, where the system is not too complex (as shown in Appendix B Panel 3). The literature suggests that moderate levels of complexity reflect many real-world problems (Rivkin, 2001; Kauffman, 1993). The problem of identifying good attributes became more challenging at higher levels of interdependence, resulting in decreasing performance at all levels of boundedness of imitation. Nonetheless, imperfect imitation continued to dominate in performance and the findings in experiment 1 remain unchanged. At sufficiently high levels of interdependence, the context becomes too difficult and no adaptation is possible (Kauffman, 1993). In addition, we examined the robustness of the power of imperfect imitation to different payoff structures. The results of employing both the March (1991) and the NK models, presented in Appendix B Panel 4, show that the power of imperfect imitation is insensitive to the payoff structure.

Third, in the previous experiments, we assume that firms engage in imitation, but do not employ other learning mechanisms. We do so because we wish to separate the contribution of imperfect imitation from other confounding effects. Here, we relax this assumption by allowing firms to engage in trial and error learning, which occasionally creates new attributes unavailable in the industry at that time. We start with the simple model setting of experiment 1. We modify the experiment by adding a number of alternative forms of trial and error learning, which substantially increases the complexity of the model.[3] Although not reported here, the results demonstrate that underlying mechanism of experiment 1 continues to positively affect performance. Imitation is effective when it is sufficiently imperfect to preserve and diffuse useful but rare attributes in poor performing firms.

Fourth, we examine the robustness of our results to the possibility of exogenous environmental change. We revise the simulation code to accommodate two new experiments designed to examine the impact of environmental change. We take into account two attributes of external shocks: magnitude and frequency. Specifically, the magnitude of a shock is conceptualized as the share of the reality (i.e., a portion of the m dimensions) that is altered (randomly reset to either 0 or 1), and the frequency of shocks operationalized as the inter-shock period. We examine discrete and repeated shocks of various magnitudes. Although not reported here, our results are robust to both of these model extensions, showing that the efficacy of imitation is highest when firms are imperfect imitators in changing environments (as in a stable environment). This pattern is robust across the range of the magnitude and frequency of external shocks we examined.

Fifth, in the main models, we examine imitation where the scope of boundedness of an individual firm is constant over time (pure type imitation). We run additional sensitivity analyses allowing the scope of boundedness to change over time (mixed type imitation). Our results show that pure type imperfect imitation outperforms mixed type imitation. To provide some intuition for this result, consider a case where each firm adopts perfect imitation until period 10, then switches to imperfect imitation (b_s = 5). In the early periods, perfect imitation rapidly reduces variation as firms converge on increasingly similar sets of attributes. Variation that is lost during these early periods of perfect imitation

[3] Our objective in this paper is to examine the underlying dynamics of the imitation process. Modeling the joint processes of imitation and innovation substantially increases the complexity of the model because of the diverse ways to characterize innovation and its interaction with imitation. The set of innovation implementations examined includes: trial a (1a) single new attribute or (1b) set of several new attributes; and adopt (2a) with evaluation or (2b) without evaluation. This complexity tends to hinder the discovery of meaningful simplicity. As such, we defer more detailed discussion of the interaction between imitation and innovation for future work.

is non-recoverable. The later switch to imperfect imitation generates only modest performance improvement. As such, our results are robust to this alternative specification of the model.

Finally, in the main models, we examine industries made up of fifty firms. Here, we examine the performance results for industries of different sizes. The results with regard to the power of imperfect imitation are robust to this re-specification of the model. The benefits of imperfect imitation tend to improve with increasing numbers of firms. As the number of firms increases, initial industry diversity increases. Given abundant diversity, the chance of losing rare, useful attributes in the imperfect imitation process is further reduced.

DISCUSSION

In this study we examine the power and limitations of imperfect imitation. We find that the efficacy of imitation is enhanced rather than hindered by these imperfections. When firms engage in perfect imitation of market leaders, good attributes in bad firms are quickly driven out of the industry, resulting in only moderate performance improvements. In contrast, when firms imitate imperfectly, average performance increases substantially. It is the ability of imperfect imitation to facilitate the preservation and diffusion of good attributes in bad firms that accounts for the performance gain.

Under-Explored Role of Imitation

Our findings speak to research on imitation, which is central to the strategy literature. Much of the literature takes the perspective of the imitatee (target of imitation) and focuses on the problem of deterring or blockading imitation. This focus is reflected in the taken-for-granted image in the literature of an imitator as a copycat. We suggest that undue emphasis on the perspective of the imitatee has led to disinterest in the potential power of imitation.

We attempt to examine the under-explored potential of imitation from the imitator's perspective. Recently, research has begun to explore the potential of imitation as a strategy (e.g., Csaszar and

Siggelkow, 2010; Ethiraj and Zhu, 2008; Rivkin 2000). In our opinion, this is a positive trend in the sense that the volume of research on imitation as a strategy is limited relative to the prevalence of the practice of imitation in firms and industries (Apesteguia, Huck, and Oechssler, 2007). Little is known about what may constitute an effective imitation strategy, whereas there are abundant prescriptions for firms seeking to protect their knowledge and positions from imitation.

Our study identifies a powerful role of imitation related to intra-industry heterogeneity that has been neglected in the strategy literature. The literature has long suggested that firm heterogeneity derives primarily from innovation that contributes to advances in technology and value creation (Schumpeter, 1934; Nelson and Winter, 1978, 1982; Lee, 2003). In contrast, imitation is typically seen as playing a secondary role and as causing the erosion of heterogeneity. As such, imitation has not been seen as an appropriate method for creating value and differentiating a firm from its rivals.

Our work builds on an exception to this characterization of imitation. Alchian (1950) conjectured that imperfect imitation increases intra-industry heterogeneity when by chance it leads to the creation of new attributes. In this Alchianian sense, imperfect imitation functions like innovation. However, our focus is not on the good fortune associated with an imitator's random creation of new attributes. As such, in order to clearly demonstrate how our mechanism works, we constructed our model to preclude the Alchianian mechanism.

In our model, imperfect imitation serves two functions: (a) to preserve rare, useful attributes that reside only in low-performing firms, and (b) to diffuse these attributes throughout the industry. These functions are predicated on the assumption that under boundedly rational imitation, even low-performing firms may, from time to time, harbor attributes that are useful to other (even superior) firms. Under perfect imitation of superior firms, where all firms exactly copy the attributes of the market leader, these rare useful attributes would be ruthlessly neglected and discarded.

The diffusion of these rare, useful attributes in poor-performing firms rests on the dynamics of imperfect imitation over time. Each firm imitates another, imperfectly, and the outcomes of these imitation attempts form the basis upon which the subsequent rounds of imitation may build upon. Consider a useful and rare attribute preserved in a low-performing firm's repertoire. When this attribute is mixed with a subset of attributes obtained through attempts to imitate superior firms, the low-performing firm may move up the performance ranking. As the firm moves up, this rare, useful attribute percolates upwards with the firm. This firm is then more likely to be imitated by others – and this rare, useful attribute is increasingly likely to diffuse widely.

Our results speak to the literatures that highlight the importance of diversity. For example, in the evolutionary literature, the extent of adaptability of an evolving system has generally been explained by reference to the *quantity* of diversity preserved in the population (Campbell, 1965; Csaszar and Siggelkow, 2010; Fang et al. 2010; Holland 1975; March, 1991). We find that an ample *quantity* of diversity is indeed necessary for evolutionary processes of imitation to function effectively. But a focus on the quantity of diversity alone is not sufficient to understand the efficacy of imitation. Consider a simple example in which a firm selects a competitor at random and copies its attributes. In this case, the *quantity* of diversity (intra-industry heterogeneity) will be very high and will be preserved over time. Yet, this extreme version of random imitation will make little contribution to the enhancement of average firm performance.

We highlight the important role of the *quality* of diversity, defined as the extent to which the population harbors useful (correct) information about the true state of the world.[4] In the above example, the *quality* of diversity is low because each good attribute is sparsely distributed across firms, and the population of firms harbors many incorrect attributes. In contrast, consider another simple example in which all firms perfectly imitate the leading firm. In this case, the quantity of diversity drops dramatically as good (and bad) attributes of the leading firm diffuse widely. This broad diffusion drives to extinction all of the attributes of laggard firms that are not held by the leading firm, even though those attributes may be useful. Imperfect imitation, which sits between these examples of random and perfect imitation, better

[4] We assume that the state of the world remains constant. As such, quality of diversity can be defined vis-à-vis this stable state. On the other hand, the quantity of diversity is not state dependent.

maintains both the *quality* and *quantity* of diversity. It does so because it is better able to preserve and diffuse the rare, useful attributes that reside only in low-performing firms.

Mobility Barriers and Intra-Industry Heterogeneity

To gain further insight into the implications of imperfect imitation for intra-industry heterogeneity, we examine the outcome of dividing firms into two groups, one superior and one inferior in average performance, separated by a barrier to cross-group imitation. Our results demonstrate that the performance difference between the two groups is maximized when there is a perfect barrier to cross-group imitation. Consider the implications of this result for the literature on strategic groups (e.g., Caves and Porter, 1977; Cool and Schendel 1987; Lee, Lee, and Rho, 2002; Peteraf and Shanley, 1997). The basic tenet of this literature is that between-group barriers impede imitation and thus protect the current position of firms in the leader group. At its most basic level, our results support this tenet.

But the benefit that firms in the leader group derive from a perfect barrier comes at a significant cost. A perfect barrier reduces the long-term performance of firms in the leader group, as well as the entire industry, relative to their achievement in the absence of the barrier, because leader group firms tend to ignore and under-exploit the useful attributes possessed by firms in the laggard group. As such, leader-group firms can increase their performance by occasionally crossing the group boundary. The best performance is indeed achieved when the barrier is sufficiently high to permit only infrequent cross-group imitation.

Consider the case of Proctor & Gamble. When P&G entered the Japanese market, it ignored its Japanese rivals. At the time, P&G was already a global market leader, feeling no need to monitor and imitate their attributes. In the 1980s, after years of declining performance in Japan, P&G decided to establish an R&D team whose primary objective was to benchmark its local rivals. This effort allowed P&G to roll out numerous new successful products, some of which eventually became global products. For example, P&G introduced the Swiffer across its global markets in 1999. The product was the result of imitating Koa, a Japanese firm that produced a floor-cleaning implement with disposable duster sheets. The introduction of this product might not have been possible unless P&G decided that its Japanese rivals might indeed harbor useful attributes worth imitating. Over time, other western rivals imitated P&G's Swiffer, and the basic design diffused widely throughout the industry.

This example of P&G in Japan seems inconsistent with one of our results — less-bounded firms enhance their own short-term performance but reduce long-term industry performance. Under what conditions does a less-bounded imitator improve its own performance as well as long-term industry performance?

Our analysis suggests that the extent of between-group isolation is a key condition that separates the two different outcomes. P&G reflects an example of a less-bounded firm in terms of its willingness or ability to imitate across the group barrier. Our theory suggests that the geographic and cultural isolation of the Japanese market from the ones in which P&G competed is central because it engenders imperfect imitation. This imperfect imitation nurtures intra-industry heterogeneity, and is particularly important when a useful but rare attribute resides only in a firm in the low performing group. We believe that this isolation allows Japanese firms to harbor and preserve rare, useful knowledge without being burdened by tough competition that forces them to match the products of their western multinational rivals. Given this sort of sufficient level of isolation, cross-group imitators can harvest the fruit of this enriched intra-industry heterogeneity by capturing useful knowledge in the laggard group.

In sum, our theoretical perspective on imperfect imitation and between-group isolation suggests a new way of thinking about strategic groups. In the past, attention has primarily focused on the higher-performing group protecting its position from imitative erosion. Imitation was seen as not only reducing heterogeneity, but also reducing the performance of the leader group. Our model suggests an alternative perspective. We view mobility barriers across strategic groups as a mechanism that engenders imperfect imitation. In this sense, mobility barriers are not simply a means to protect the profits of leading group firms, but also to enrich intra-industry heterogeneity, thereby enhancing the performance of the leader group as well as the industry.

Limitations and Conclusions

There are limitations to our work. Our model assumes the simplest possible setting. For example, there is only one market with one kind of payoff structure, there is no innovation, and there is no entry or exit. Furthermore, with the exception of our model of groups separated by a semi-permeable barrier, our firms are not embedded in any form of social structure. Recent studies of intra-organizational learning, however, suggest that structures that constrain information flows may have an important impact on such learning (e.g., Fang, Lee, and Schilling, 2010; Miller et al., 2006). Finally, we treat the environment as exogenously given and stable. Although the environment might better be described as an ecology of inter-dependent competitors, and thus a firm's knowledge and strategies may, at least in part, shape the environment (Miller and Lin, 2010). In this paper, these simplifying assumptions allow us to focus narrowly on the main effects of the role of imitation. These assumptions may be prosperously relaxed in future work.

In sum, imitation is a powerful mechanism to enhance performance. The power of imitation derives not from its ability to accurately copy the attributes of other firms, but rather, from the inability to do so accurately. Simon (1957) argued that actual behavior of economic agents deviates from the rationality assumption. Bounded rationality is one mechanism that gives rise to imperfections in imitation. We show that there is an adaptive role to such deviation.

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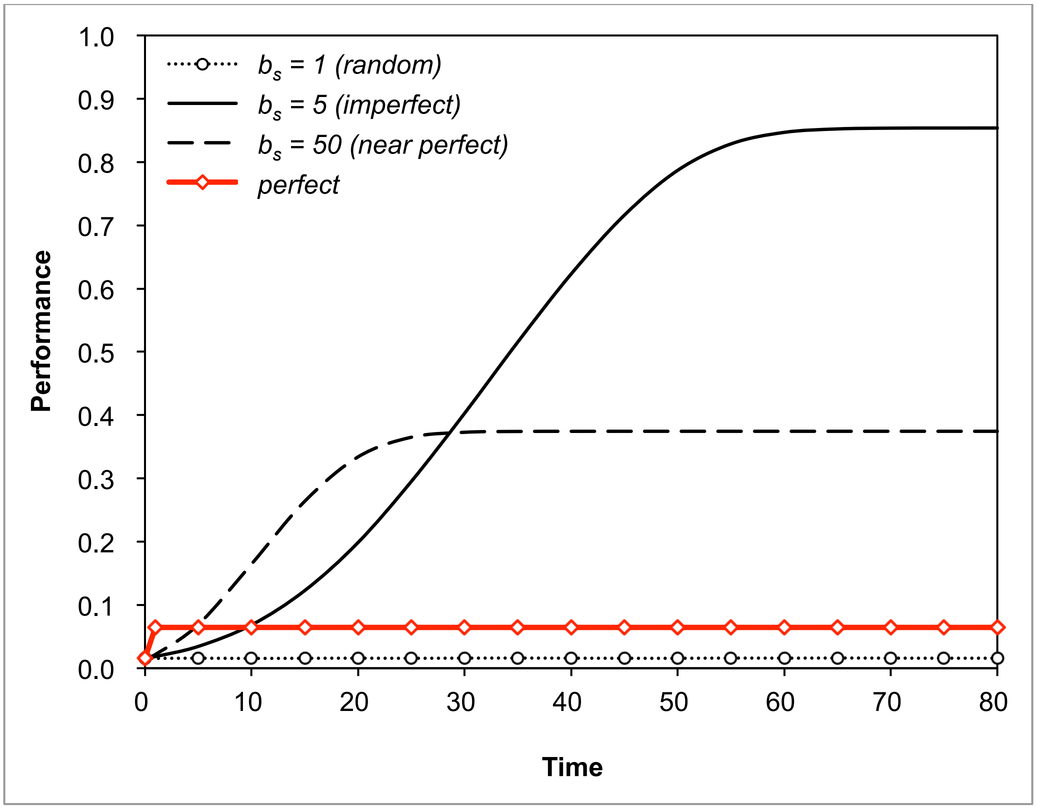
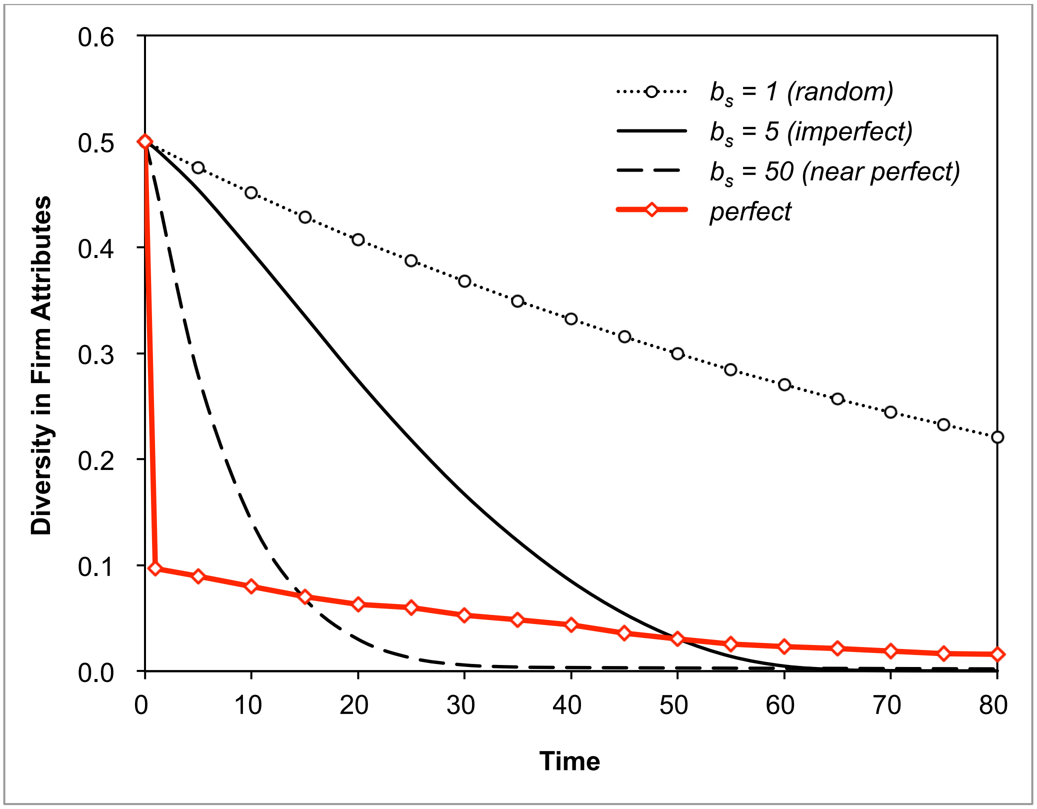
FIGURE 1. Effects of Imperfection in Imitation on Industry Performance



Description. This figure represents the average normalized performance of the firms in the market over time. In the 'perfect' imitation case, firms are not bounded in information processing and copying the strategy of their imitatee – i.e., b_s = 50 and p_m = 1. In the other three cases, b_s is as noted and p_m = 0.3.

Interpretation. An industry consisting of imperfect imitators with bounded search scope (b_s = 5) achieves higher long-run performance than an industry consisting of more or less perfect imitators.

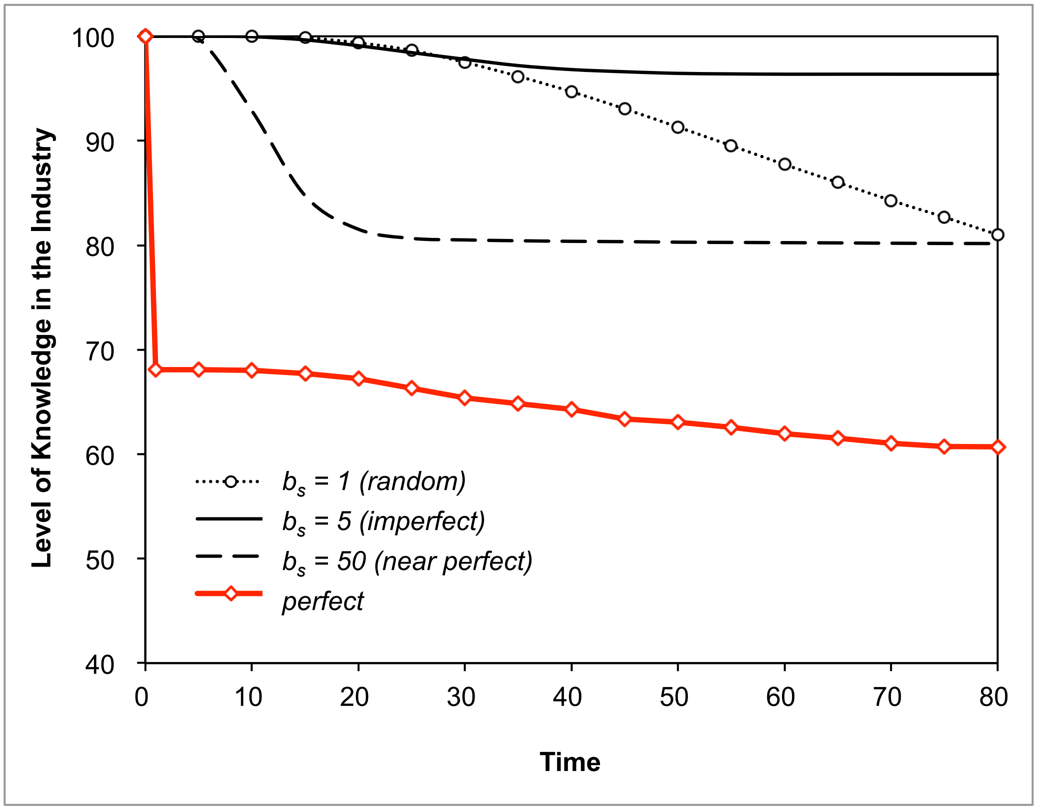
FIGURE 2. Quantity of Diversity in Firm Attributes



Description. The vertical axis represents diversity measured via a pair-wise comparison of all firms. For each pair of firms, m attributes are compared. The diversity measure is then the average sum of squared differences.

Interpretation. As inter-firm imitation proceeds, firms come to resemble one another and the extent of diversity declines. It is through random imitation (b_s = 1) that the quantity of diversity in attributes is best preserved.

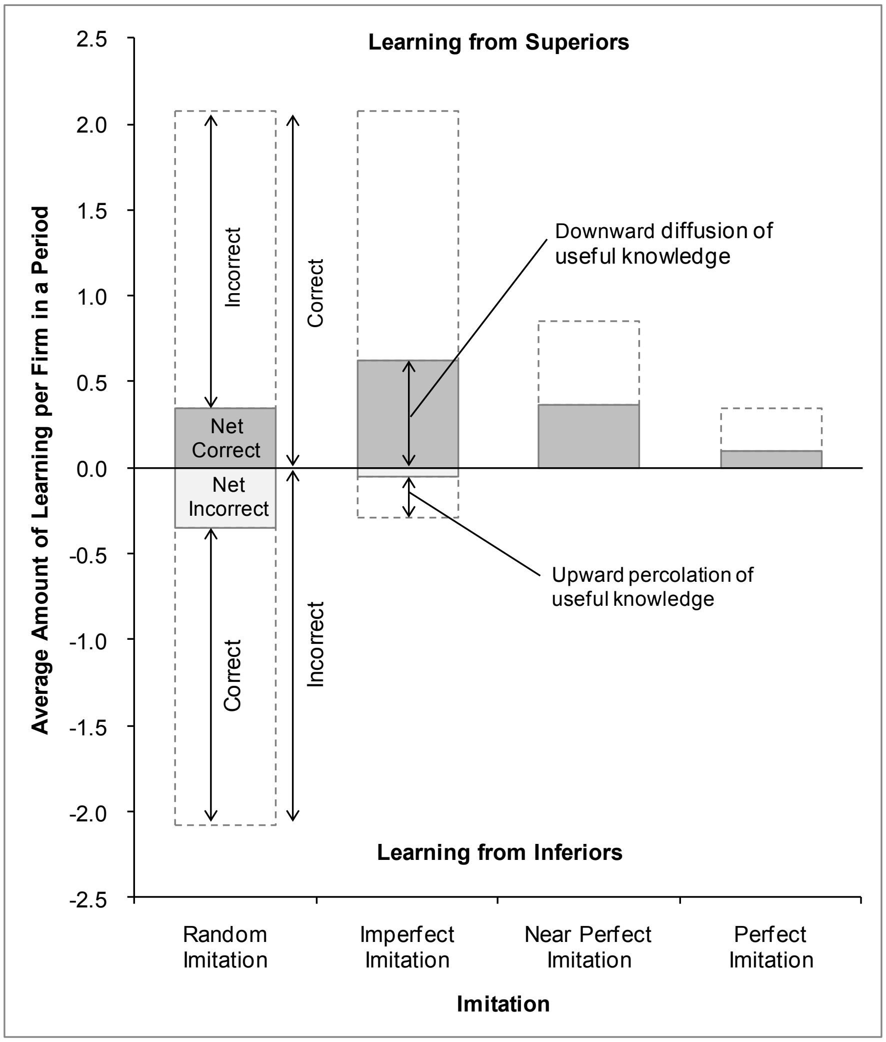
FIGURE 3. Quality of Diversity: Level of Knowledge in the Industry



Description. The vertical axis represents the level of useful knowledge in the industry as a metric of the quality of diversity. This measure counts the number of correct attributes in the industry. That is, the industry has a correct attribute in a period if at least one firm has the state of the attribute matching the true state in the reality vector.

Interpretation. The level of useful knowledge in the industry is highest when imitation is imperfect. In contrast, when firms are random imitators, the industry loses potentially useful knowledge over time even though the quantity of diversity (as in Figure 2) remains high. When firms are perfect imitators, the level of useful knowledge is lowest.

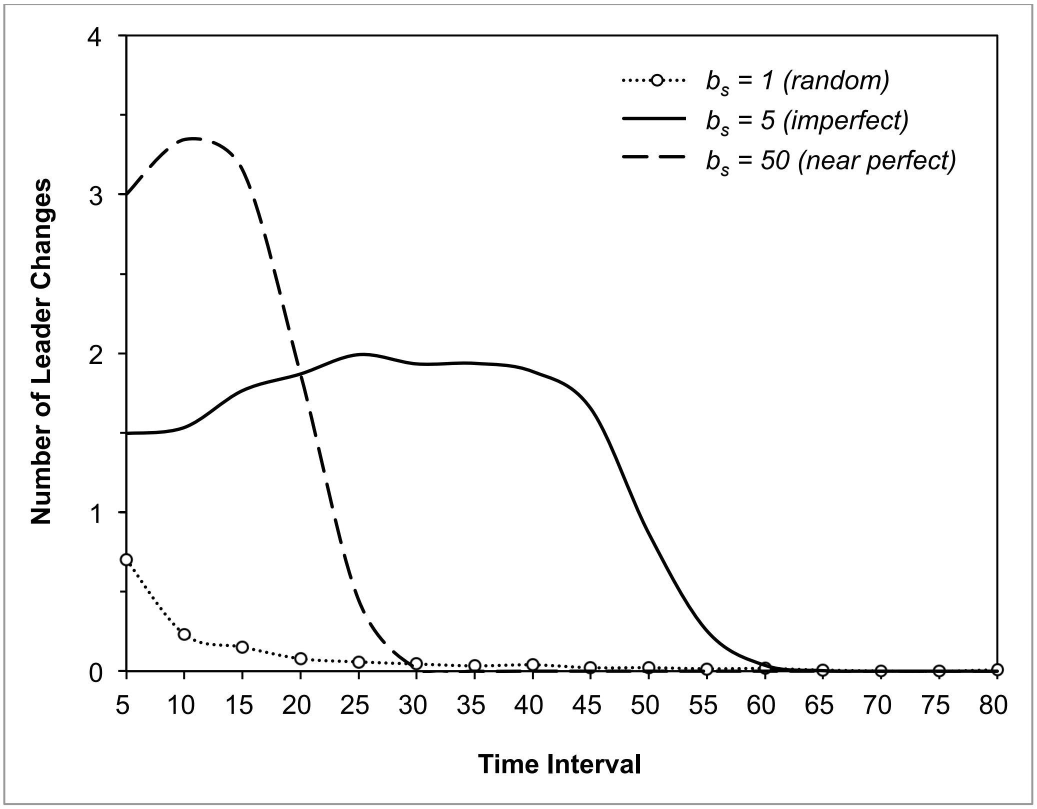
FIGURE 4. Amount of Firm-Level Learning from Superiors and Inferiors in a Period



Description. The vertical axis represents the total count of firm attributes that change (flip from 0 to 1 or from 1 to 0) due to imitation (averaged over 80 periods). The count is categorized by the relative performance of the imitatee (superior or inferior) and the correctness of the change (correct or incorrect). For example, if a firm imitates a correct attribute (i.e., matching reality) of a superior firm and replaces its own incorrect one, it is categorized as a single correct event of learning from a superior.

Interpretation. When firms are imperfect imitators, the amount of firm-level correct learning less incorrect learning (replacing a correct attribute with an incorrect attribute) is largest. When firms are perfect (or near perfect) imitators, there is no learning from inferior firms. When firms are random imitators, incorrect learning from inferior firms offsets correct learning from superior firms.

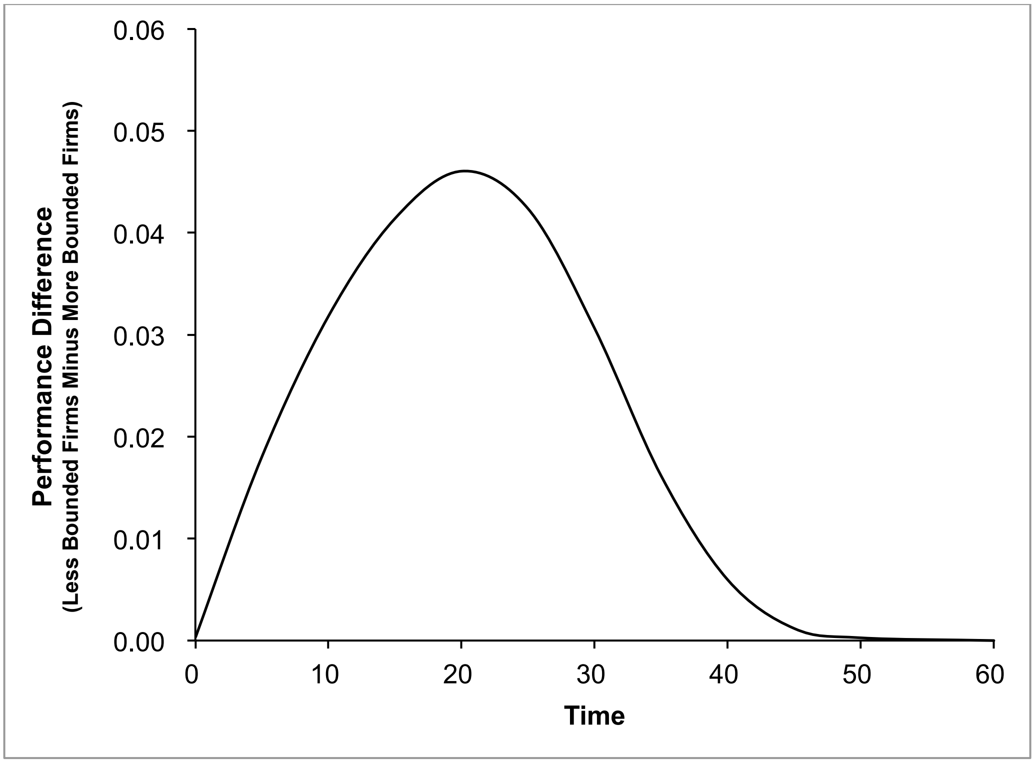
FIGURE 5. Rate of Leader Changes with Record-Breaking Performance



Description. The vertical axis represents the frequency of laggard firms surpassing the performance of the market leader. Technically, it measures the number of time periods in a given time interval (5 periods) where the historically best performance record is broken by the firms that were non-leader(s) in the previous period. Note that there are no leader changes in the case of perfect imitation because all firms quickly become identical to the best firm.

Interpretation. The probability of surpassing the leader via imitation is highest when imitation is imperfect since the cumulative number of leader changes (the size of the area under the curve) is maximized. When firms are near perfect imitators, the market leader turnover rate is high only in the early periods then decreases rapidly. When firm imitation is purely random, the possibility of surpassing the market leader is very low.

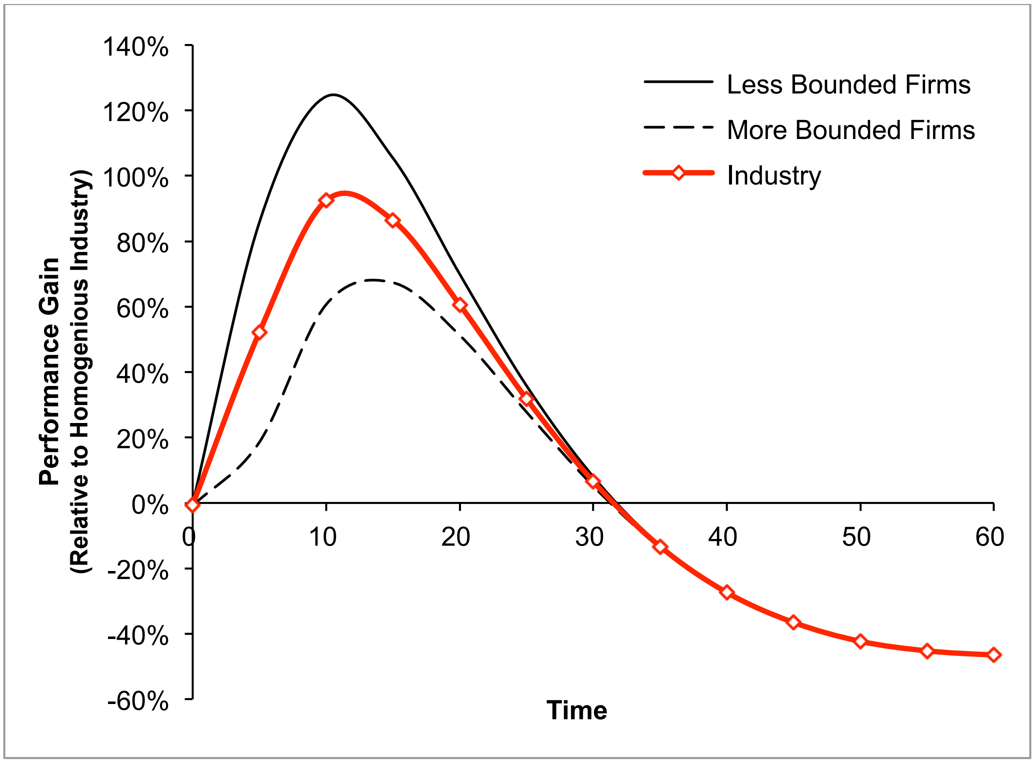
FIGURE 6. Performance Difference in an Industry Consisting of More and Less Bounded Firms



Description. We assume intra-industry heterogeneity in boundedness of search scope. This figure compares the performance of firms that are heterogeneous in their imperfection in imitation (25 firms with $b_s = 5$ and 25 firms with $b_s = 50$). In particular, it compares the average of the less bounded firms to the average of the more bounded firms.

Interpretation. When firms are heterogeneous in their imperfection in imitation, less bounded imitators do better than more bounded imitators in the short run.

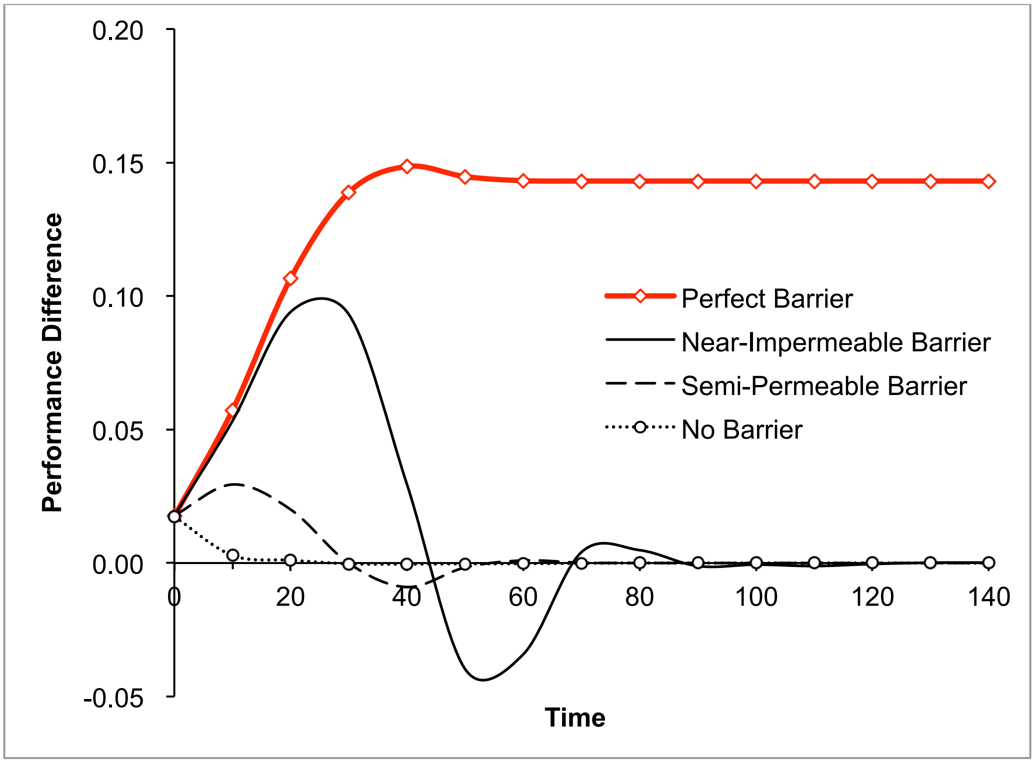
FIGURE 7. Effects of Reducing Imitation Imperfections (b_s) on Industry Performance



Description. This figure compares the performance of the industry where firms are heterogeneous in their imperfection in imitation (25 firms with $b_s = 5$ and 25 firms with $b_s = 50$) with that of an industry where firms are homogenous (50 firms with $b_s = 5$). The vertical axis represents the percentage difference between the two industry states. This performance difference is the performance gain of the less bounded firms, the more bounded firms, and the industry as a whole, as a percentage of the performance of a homogenous population of more bounded firms.

Interpretation. Heterogeneity in the imperfection of imitation enhances early performance (relative to the homogeneous case), but this comes at a substantial long-run cost. That is, the heterogeneous industry performs substantially worse than the homogenous industry in the long run.

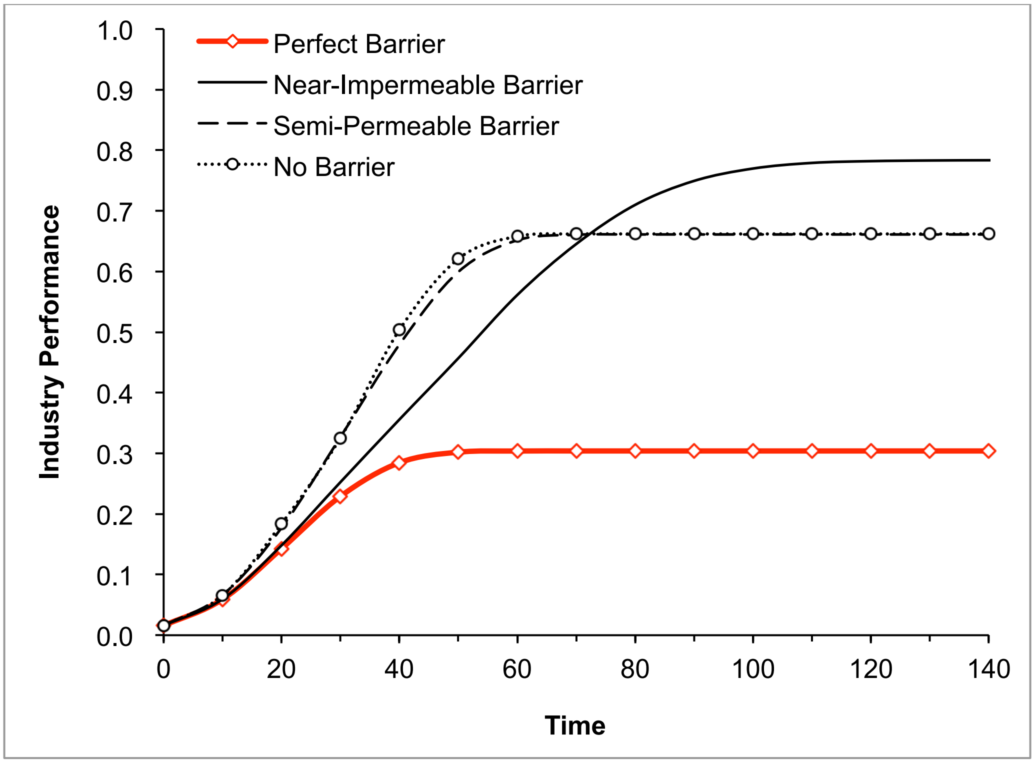
FIGURE 8. Effects of Imitation Barrier on Performance Difference Between Leader and Laggard Groups



Description. The industry consists of two groups of 25 firms, a leader group and a laggard group, where all firms are equally bounded in imitation (b_s = 5). The firms in the leader group are initially endowed with 55 correct attributes, while laggard group firms have only 45 correct attributes. The two groups are not fully overlapping in their initial attributes. We divide the entire set of attributes (m = 100) into three subsets. The first subset of 10 attributes is used uniquely by one group, while the second subset of 10 attributes is used uniquely by the other group. The third subset of 80 attributes is available to both groups. In this way, ten percent of the attributes are initially unique to each group. We define imitation barrier (v), which ranges from 0 to 1, as the tendency of a firm to select candidate imitatees from its own rather than the other group (e.g., across the group boundary). When v = 1, there is a 'perfect barrier' and a firm forms its consideration set with candidate imitatees exclusively from its own group. When v = 0, there is 'no barrier' and a firm identifies its consideration set independently of the group affiliation of potential imitatees. We define two intermediate cases. The 'near-permeable barrier' corresponds to the case off v = 0.98. Finally, we label as a 'semi-permeable barrier' the case where v = 0.8.

Interpretation. For the leader group, a perfect between-group barrier to imitation generates maximum long-run performance difference relative to the laggard group. If the imitation barrier is imperfect, the leader group faces a long-run risk of losing their leadership.

FIGURE 9. Effects of Imitation Barrier on Industry Performance



Description. This figure represents the average performance of the firms in the industry over time for different levels of between-group barrier to imitation. The model setting is the same as in Figure 8.

Interpretation. The industry performance is substantially reduced by the presence of a perfect barrier to imitation. The isolation of groups allows each group to harbor and preserve attributes unique to the group, but the perfect barrier does not allow cross group knowledge flows. In the near-impermeable barrier case, the possibility remains that an imitator will cross the group boundary from time to time. This crossover provides a mechanism to obtain useful attributes absent in the focal group. In turn, this improves the group performance as well as industry performance. In contrast, when there is no barrier to between-group imitation, we observe only moderate performance. Here, the lack of isolation limits the preservation of group-specific attributes, as cross-group imitation ruthlessly neglects and discards group-specific attributes.

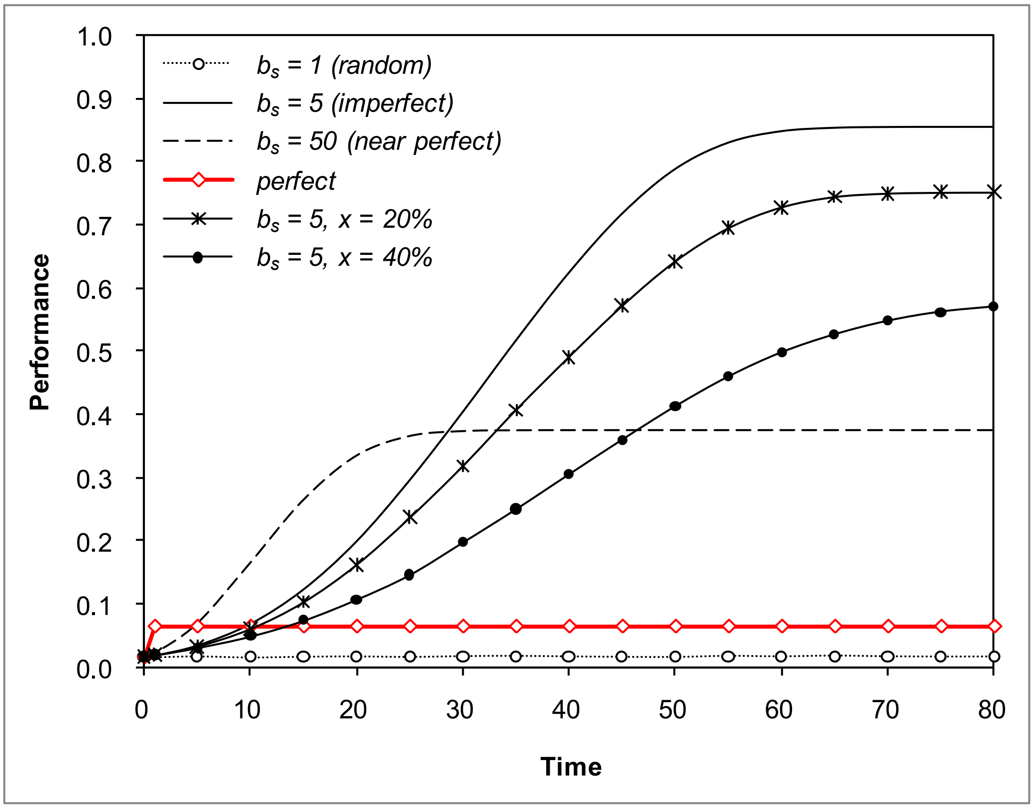
Appendix A. List of Parameter Values

	m	***k***	***N***	b_s	p_m	**Industry Population**
FIGURE 1	100	5	50	1, 5, or 50	0.3 or 1	50 homogeneous firms in b_s and p_m
FIGURE 2	100	5	50	1, 5, or 50	0.3 or 1	50 homogeneous firms in b_s and p_m
FIGURE 3	100	5	50	1, 5, or 50	0.3 or 1	50 homogeneous firms in b_s and p_m
FIGURE 4	100	5	50	1, 5, or 50	0.3 or 1	50 homogeneous firms in b_s and p_m
FIGURE 5	100	5	50	1, 5, or 50	0.3 or 1	50 homogeneous firms in b_s and p_m
FIGURE 6	100	5	50	5 and 50	0.3	25 less and 25 more bounded firms
FIGURE 7	100	5	50	5 and 50	0.3	25 less and 25 more bounded firms
FIGURE 8	100	5	50	5	0.3	Leader and laggard groups (25/25)
FIGURE 9	100	5	50	5	0.3	Leader and laggard groups (25/25)

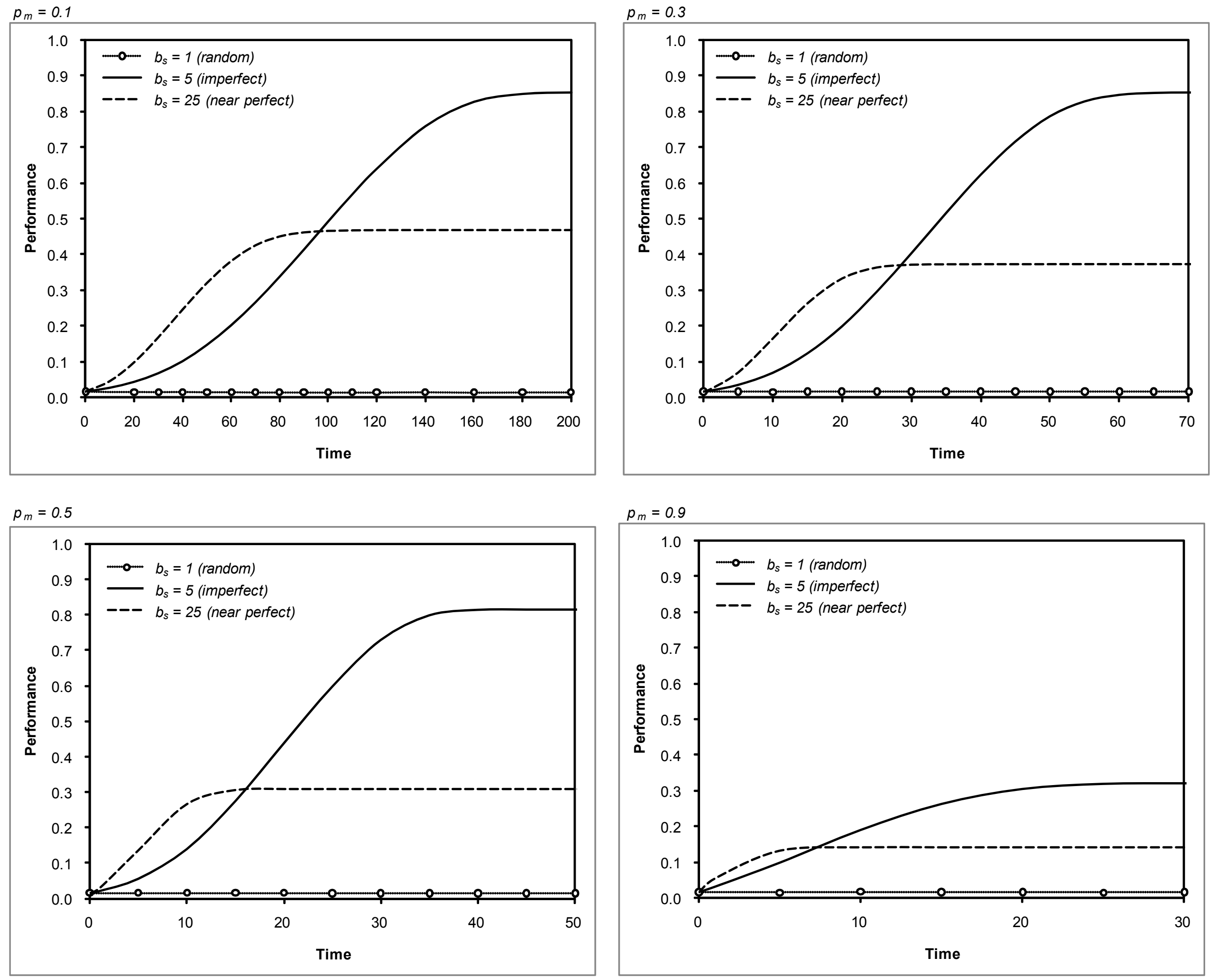
Note. m = dimensions of the reality, k = interdependence of attributes, N = number of firms, b_s = boundedness in search scope, and p_m = imitation rate.

Appendix B. Sensitivity Analyses

Panel 1: Effects of the Restriction on the Upward Percolation of Useful Knowledge

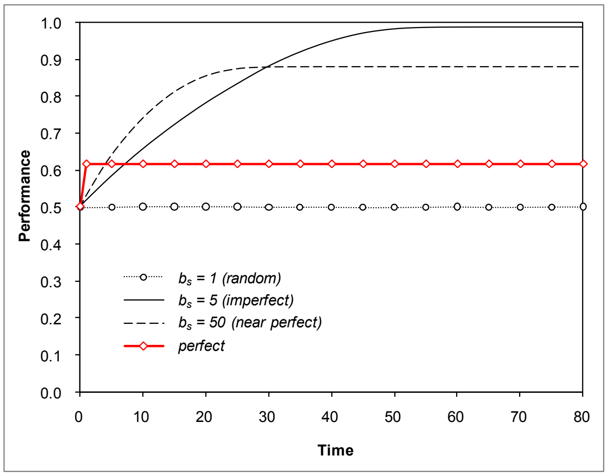


Panel 2: Effects of the Rate of Imitation (p_m)

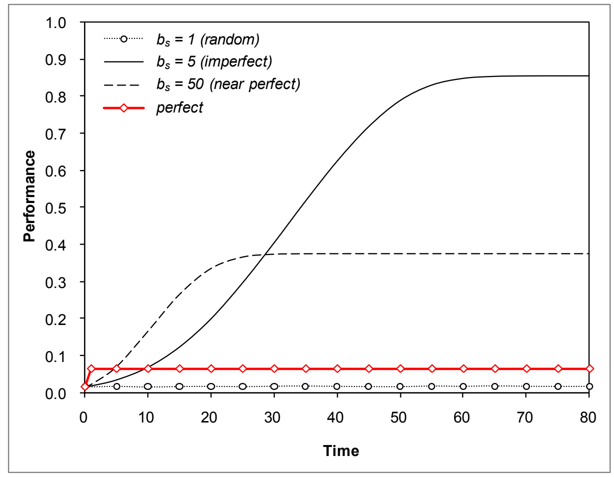


Panel 3: Sensitivity to Differences in the Level of Interdependence (k)

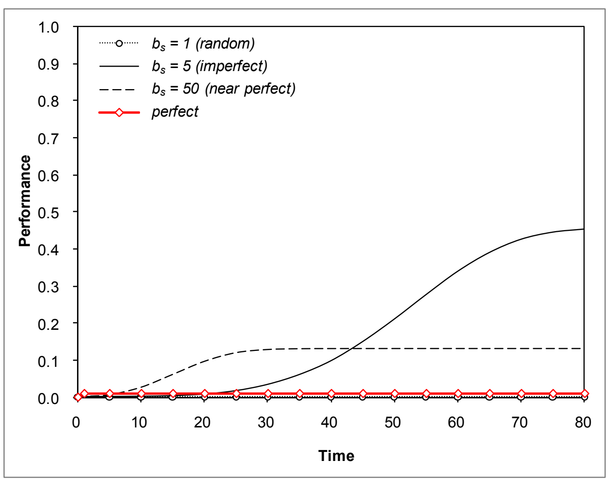
$k = 0$



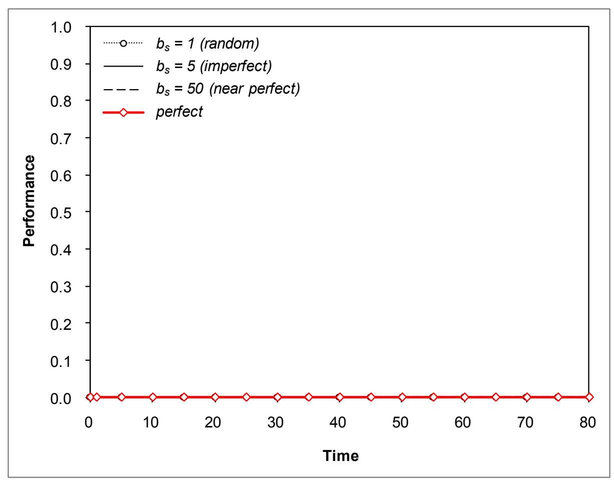
$k = 5$



$k = 10$

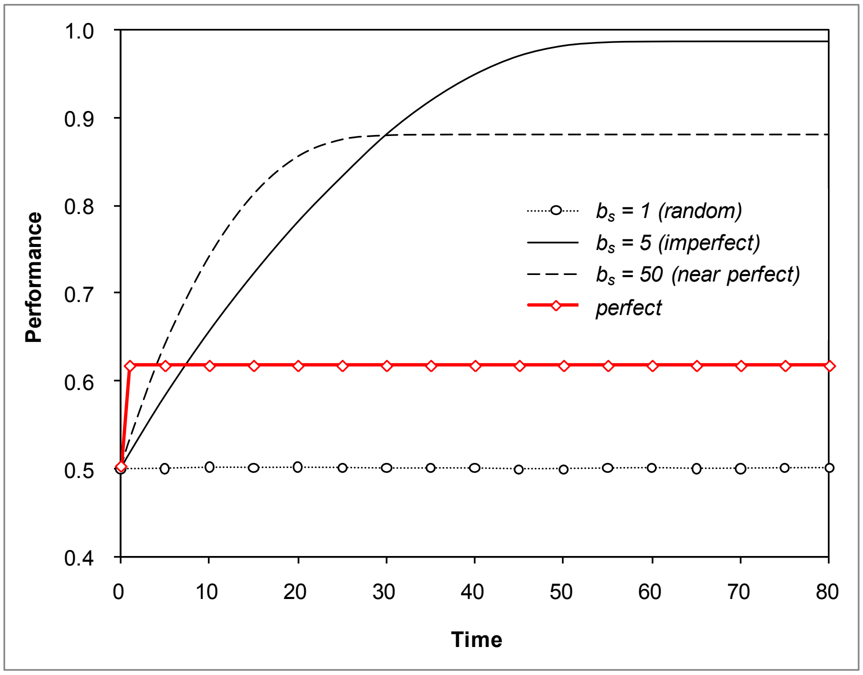


$k = 20$

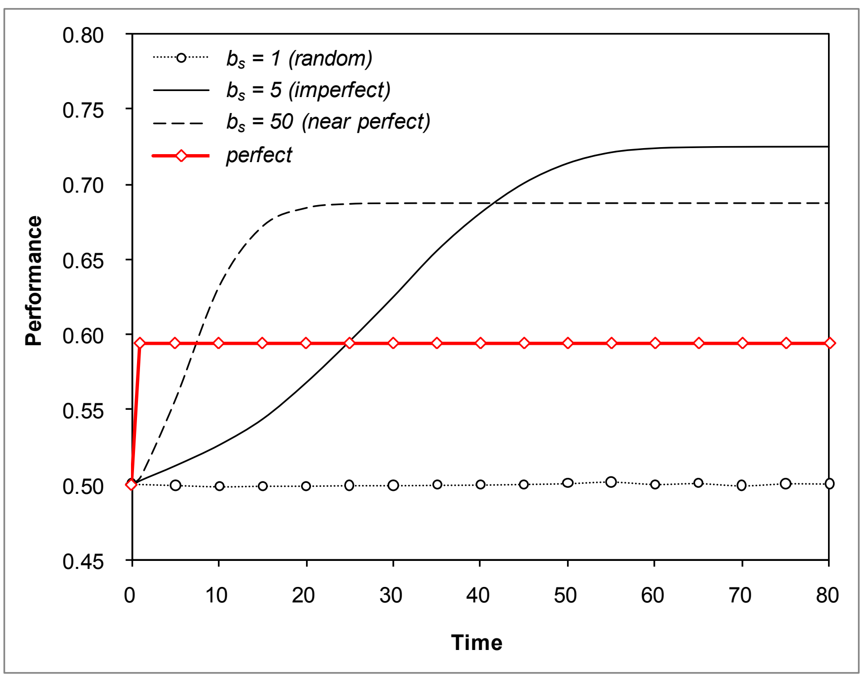


Panel 4: Performance Across Different Payoff Structure

(a) On March Model



(b) On NK Model



NOTE: The number of attributes and the level of interdependence are set to be the same with that of our basic model (N=100 *and K*=5).

Appendix C. Theoretical Studies on Imitation

	Target of Imitation	Imitation Process	Inter-dependence	Focal Construct
March (1991)	Best practices (as embodied in the "organizational code")	Incomplete imitation of attributes	Absent	Speed of learning on organizational performance
Rivkin (2000)	Best firm	Perfectly identify best firm, Incomplete imitation of attributes, Random creation of new attributes	Present	Interdependence in deterring imitation by rivals
Csaszar and Siggelkow (2009)	Best firm	Perfectly identify best firm, Incomplete imitation of attributes, Random creation of new attributes	Present	Breadth of imitation under conditions of complexity and context similarity
Our Study	Best firm	Imperfect identification of best firm, Incomplete imitation of attributes, No random creation of new attributes	Present	Imperfect imitation