Competition, Shifting Leadership, and Industry Progress

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ABSTRACT

How does competition impact firm performance and technological progress? Both economic and behavioral theories have stressed the incentive effects of competition: competition triggers search or eliminates monopoly rents necessary to for investments in technology. Using a simple formal model, we show that competition also impacts the effectiveness of learning and imitation processes. Competition between firms with initially similar levels of performance will lead to increased progress compared to the case when there is initially one superior firm with much higher performance. The mechanism is that competition between firms with similar levels of initial performance leads to a shifting set of leaders exposing firms to diverse practices, which improves the process of imitation. Our result provides a novel reason for why exposure to competition can be beneficial for firm and advances our understanding of how the process of competition impacts the efficiency and accuracy of vicarious learning.

Keywords:
Organizational Learning; Evolutionary Routines, Imitation, Transfer & Replication; Information Aggregation and Processing

1. Introduction

Understanding how competition impacts firm performance and industry progress is central to the economic sciences as well as to strategic management. Competition between firms have often be viewed as a crucial stimulus for progress, but the arguments for why vary. Classical economic theory emphasize how competition reduces opportunities for collusion. Behavioral accounts focus on how competition triggers search (Nelson and Winter, 1982; Barnett and Hansen, 1996) and eliminates x-inefficiency (Leibenstein, 1966). Others have argued that competition may reduce technological progress, because it does not allow firms to make the necessary investments (Schumpeter, 1950). This debate about the impact of competition has important implications for strategic management. If competition reduces the scope for collusion, firms should avoid competition (Porter, 1980). If competition is an essential trigger for improvements and search, firms who are exposed to competition may do better in the long-run (Barnett, 1997; 2008; Porter, 1990).

We contribute to this debate about the impact of competition by emphasizing a seldom appreciated mechanism: how competition benefits imitation by generating a changing and diverse set of industry leaders. Many behavioural and economic accounts of the impact of competition stress its motivational effects. Firms are motivated to search for improvements if performance falls below aspirations as a result of competition (Cyert and March, 1963; Barnett and Hansen, 1996; Barnett, 2008). Alternatively, isolating mechanisms, such uncertain imitability or switching costs, reduce the motivation to compete with the leader because rivals believe that overtaking the leader is not feasible (Lippman and Rumelt, 1982; Farrell and Klemperer, 2007). Using a formal model, we show that even if firms are always motivated to search and improve, competition has an important effect on the effectiveness of the imitation process. Specifically, we show that competition between firms with initially similar levels of performance will lead to increased progress compared to the case when there is initially one superior firm with much higher performance than the others. In other words, our model shows the importance of a "level playing field" which generates a shifting set of industry leaders, for industry progress.

How does a level playing field impact industry performance if competition does not impact the motivation to search or to improve? Using a simple computational model, we show that competition also impacts the efficiency of imitation by generating a shifting and diverse set of leaders. Competition between firms with similar levels of initial performance leads to a shifting set of leaders: the firm with the highest level of performance tends to change over time. When firms mainly pay attention to the highest performing firms and imitate their practices (Strang and Macy, 2001; Denrell, 2003), a shifting set of industry leaders imply that firms will be exposed to diverse practices. In contrast, when one firm is initially superior, and continues to lead for a considerable time, firms that pay attention to successful others will be mainly exposed to and copy the practices of this one leader. If all firms adopt the practice of the leading firm, they will all improve their performance, but the resulting convergence in practices among firms will reduce the scope for further progress. The reason is that beneficial practices among firms with inferior performance will disappear from the population as these firms copy the inferior practices of firms with overall superior performance (Fang et al, 2010, Pozen et al, 2013).

Our model illustrates a novel mechanism for how competition in an industry can lead to increased technological progress. Even if competition does not impact motivation, it enhances the effectiveness of the imitation process by exposing firms to a diverse set of industry leaders. This mechanism provides an alternative account for why a level playing field is beneficial for industry progress. Our mechanism does not focus on *motivation*, i.e., on how the presence of superior firms decrease of increase the motivation of managers to invest in innovation or to search for superior solutions. Rather, our mechanism focuses on their collective *ability* to make progress by learning from each other.

More generally, our model helps to advance our understanding of how the process of competition impacts the efficiency and accuracy of vicarious learning. While there is a large literature both on the impact of competition and on the effects of imitation and learning, our understanding of how competition impacts imitation is still in its infancy. It is makes intuitive sense that having access to a diverse set of firms with varying practices should make identification of superior practices easier. Our model shows how competition between several firms who initially have similar levels of performance comes closer to this ideal than competition in an industry where there is one dominant firm.

2. Competition, Progress, and Imitation

2.1 Competition as a spur to progress: There is a large literature on how competition spurs progress and how the presence of a leading firm impacts competition. Neoclassical models of competition focus on how an increase in the number of firms increases market efficiency because when each firm share of the total output is small each firm is closer to a price taker. In the Cournot model of output competition, for example, an increase in the number of firms leads to a reduction in the equilibrium price and an increase in the equilibrium quantity. Competition, in the sense of a larger number of firms in an industry, thus reduces industry profitability but increases market efficiency (by reducing the deadweight loss associated with pricing above marginal costs). Models in industrial organization have also noted how the presence of a dominant firm can impact collusion. The economic literature on price leadership shows that the presence of one firm with a large market share can facilitate collusion, thus increasing profits although decreasing efficiency (Markham, 1951; Bain, 1960; Scherer, 1970).

While the early literature in neoclassical economics focused on competition between homogenous firms, Austrian economists emphasized the process of competition and how market competition provides entrepreneurs with incentives to discover superior products and ways of organizing (Schumpeter, 1934; Hayek, 1945; Kirzner, 1973). The more recent economic literature on dynamic competition and endogenous growth incorporates some of these elements into economic models of how competition impacts the incentive to engage in research and development (Romer, 1990). Inspired by Schumpeter (1950), who argued that market concentration benefitted innovation, early models of dynamic competition showed that competition decreases the incentives to innovate by reducing the expected monopoly rents (Aghion and Howitt, 1992). Models of patent races also demonstrated how incentives to invest in R &D may depend on whether rival firms can expect to leap-frog the current leader. If the leader in a technology race is sufficiently far ahead, lagging rivals may give up since the chance that they will win is low (Gilbert and Newbery 1982; Fudenberg, Gilbert, Stiglitz and Tirole 1983; Anderson and Cabral, 2007). Models of contests where payoffs depend on relative performance and contestants have heterogeneous abilities have demonstrated a similar effect: if contestants differ substantially in ability, the weaker contestant may give up and the level of effort induced will be low (Stein, 2002, Baik 1994). The prediction is that a "level" playing field, where contestants have similar abilities, will provide stronger incentives (Brown, 2011; Gross, 2020). The model of uncertain imitability developed by Lippman and Rumelt (1982) has a similar implication: because of the costs of trying to develop a superior product, rival firms avoid to enter if the market leader is sufficiently profitable and likely has a sufficiently superior product.

Behavioral models of competition emphasize the effect competition and reduced performance on firms' tendencies to search for improvements (Barnett, 2008). In the behavioral tradition firms are assumed to satisfice and do not constantly search for improvements (Cyert and March, 1963; Nelson and Winter, 1982; Hart, 1983). Search is problem driven and triggered by performance falling below an aspiration. If competition impacts performance, competition can thus also impact the propensity to search for improvements (Barnett and Hansen, 1996; Barnett, 1997; 2008). "At some point, this increased competitive intensity may reduce performance in other organizations enough to trigger search in these organizations." (Barnett and Mckendrick, 2004, p. 540). The prediction is that exposure to competition should make an organization more viable (Barnett, 2008). Porter (1990) made a related argument about the impact of competition on progress: "active pressure from rivals stimulates innovation as much from fear of falling behind as the inducement of getting ahead," (Porter, 1990, p. 118). The argument that competition provides incentives to improve is an old one, however, that goes back to Leibenstein's (1966) discussion of "X-efficiency" and related ideas of the lazy monopolist.

2.2 Imitation and vicarious learning: A largely separate literature has examined how imitation and vicarious learning among firms impact technological progress and firm profitability. For the most part, the assumption is that imitation and vicarious learning is beneficial, as it leads to the diffusion of superior practices (Foster and Rosenzweig, 1995; Baum and Ingram, 1998; Argote, 1999; Lieberman and Asaba, 2006). Imitation of superior performers could potentially lead to adoption of inferior practices, however, as a result of bandwagons (Bikhchandani, Hirshleifer, and Welch, 1992; Staw and Epstein, 1990) or selection bias (Strang and Macy, 2001; Denrell, 2003). It is also possible that copying one practice from a superior firm will reduce performance because this particular practice is in fact detrimental to performance. This problem of "hitchhiking" is especially challenging when the performance effects of using a specific practice depends on the others practices. In such "rugged" performance landscapes (Levinthal, 1997), effectively imitating superior firms can be very challenging (Rivkin, 2000). In these cases, partial copying of the practices of superior firms can be detrimental, especially if these firms operate in different circumstances (Csaszar and Siggelkow, 2010). Even in such settings, however, a modest amount of imitation may improve firm performance the long-run, because changing practice, as a result of imitation, can broaden a firm search process and increase the level of exploration (Lennox et al, 2006; Csaszar and Siggelkow, 2010).

While imitation may be rational at the firm level, it can nevertheless have a negative impact on industry progress. The problem is that imitation reduces diversity and may crowd out other activities that contribute to learning. If most firms engage in imitation and very few learn by themselves, there is little knowledge available in the population to imitate (Rogers, 1988). Consistent with this, recent computational models have shown that high levels of imitation can lead to lower levels of profit and less technological progress than lower levels of imitation (Lennox et al, 2006). The reason is that if all firms imitate the best performer, valuable practices used by inferior firms will get lost. The population will quickly reach the performance of the initially superior performer but will not advance very much beyond this. The potential advantages of recombining different practices will then be lost (March, 1991; Fang et al, 2008; Posen et al, 2013). The disadvantages of a high level of imitation imply that industry performance can be higher if firms only have access to information about the performance and practices of a few other firms (Bala and Goyal, 1998; Lazear et al, 2007; Posen et al, 2013). Such limited access effectively limits imitation and preserves a diverse set of practices (Fang et al, 2010).

2.3 Competition and the effectiveness of vicarious learning: The literatures on the impact of competition and about imitation are surprisingly disconnected. Arguments about the impact of competition mainly focus on the motivation to innovate or to improve. Discussions about imitation mainly focus on the benefits and potential disadvantages of imitation. Less explored is the impact of competition on the efficiency of imitation and vicarious learning. Intuitively, being able to compare performance and practices with a range of competing firms should make learning and improvement easier compared to the case when a firm only knows about its own performance and perhaps a handful of others (Cambell, 1965; Delacroix and Rao, 1994; Csaszar and Siggelkow, 2010). Case studies of how firms learn from others in the same industry (Sako, 1996; Zuckerman, and Sgourev, 2006) or in regional clusters (Jacobs, 1961; Porter, 1990; Sabel, 1994) illustrate the advantages of being able to compare practices with others. Theorists have discussed the advantages of having a diverse set of firms for industry progress (e.g., Tisdell, 1999), because it makes the industry less sensitive to external shocks and allows exploration of a wider range of the technological space, and these ideas have been incorporated into models (Knott, 2003). Moreover, Terlaak and Gong (2008) examined how observing the decisions of homogenous versus a heterogenous group of competing firms can improve inferential accuracy (see also Csaszar and Siggelkow, 2010). Compared to the numerous models of the impact of competition on motivation, however, we lack a solid theoretical understanding how the number and diversity of competitors can impact industry progress via by improving the efficiency of imitation and learning. The purpose of this paper is to improve our understanding of the link between competition and imitation by emphasizing a novel mechanism through which competition or the lack of it impacts the efficiency of the imitative process.

3. Model

3.1 Set-up: To understand how competition and the existence of a dominant firm can impact the process of imitation, we use a computational model following in the Carnegie Tradition (Cyert and March, 1963; Nelson and Winter, 1982; Fang et al, 2010; Posen et al, 2013). Building on past models, including Posen et al (2013), we model a population of n firms who each try to improve their performance by copying practices of firms with superior performance. Performance depends on choices along m dimensions. Along each dimension, a firm can choose between k options. We assume there is an ideal vector of choices, which maximizes performance. For simplicity, we set this ideal vector to choosing option 1 along each dimension. The performance of a firm is the number of choices corresponding to the ideal vector, i.e., the number of choices of option 1. Maximum performance is thus m and the minimum is zero. Thus, in contrast to prior models (e.g. Fang et al, 2010; Posen et al 2013), the performance impact of any given choice on dimension j does not depend on the choices on other dimensions: there are no interactions and the landscape is not "rugged". We focus on this simple case to highlight the impact of competition in the simplest possible set-up.

At the start of the model, firms choose randomly, among the k options, for each dimension. The probability that a firm i chooses the correct option for dimension j is thus $1/k$. Subsequently, firms try to improve by imitating the choices of firms with superior performance.

We assume that firms identify the firm or firms with the highest level of performance, examine their practices along some dimension, and copy these practices.

Specifically, in each period t the following happens for each firm *i*

- The firm *j* with the highest level of performance is identified. If there is more than one, one of them is selected at random.
- If the performance of firm *i* is below that of the best firm(s), then firm *i* copies the choice of firm *j* along dimension r with probability *p*.

We assume that the probability *p* of copying is quite low. The motivation is that firms cannot easily make substantial changes to its practices in a short period without disrupting ongoing business (Hannan and Freeman, 1984). Firms thus make incremental changes to its practices (Cyert and March, 1963; Levinthal, 1997) in our model rather than radical overhauls. In addition, isolating mechanisms makes it difficult to identify the sources of superior performance and costly to change (Rumelt, 1984).

To examine the impact of a dominant firm in this model, we modify this simple model in the following way: we set the initial level of performance for firm 1 to a specific value. In the above model the initial level of performance of a firm is random, given by the number of correct choices that the firm makes (the probability of making a correct choice is $1/k$ along each dimension). To vary the initial level of performance for firm 1, we instead choose the number of correct choices for firm 1. For example, suppose the number of dimensions is $m = 100$. We can then set the initial number of correct choices for firm 1 to 40, giving firm 1 an initial performance of 40. Given the choice of the initial performance, we then randomly select which dimensions firm 1 will be correct on.

Our model is deliberately simplified and excludes many other mechanisms. We have assumed that firms are always looking for ways to improve performance. In reality, search for improvements may be triggered by poor performance (Cyert and March, 1963) or be motivated by expectations of monopoly rents (Aghion and Hewitt, 1992). We have excluded such motivational mechanisms to focus on how competition impacts learning and imitation. Our model includes only the process of imitation and excludes experimentation by individual firms: firms in our model do not independently change to practice *j* unless they observe some other firm using practice *j*. Note, however, that in the context of this model it makes sense, at least initially, to copy the practices of other firms with superior instead of experimenting with random changes in practices. Suppose an inferior firm has a performance of 10 out of 100. Suppose there is a superior firm with a performance of 25 out of 100 (implying it has 25 out of 100 practices correct). By copying one practice of the superior firm, expected performance will increase with 0.25-0.1 = 0.15. If the inferior firms randomly change one practice, however, the expected change in performance is (1/k) –current performance, which will be negative if the current performance is large.

Moreover, we have assumed that if a firm *i* copies another firm and the performance of firm *i* falls, then firm *i* nevertheless sticks with the new practice. If it is costless to change back, this does not make sense: the firm should revert back to its old set of practice. However, if it is costly to change, changing back may not be worth it. Note also that it is quite unlikely that performance falls as a result imitation efforts, especially initially. Finally, we assumed that firms consider only the practices of the superior firm(s) when imitating practices of others. In reality, firms may use information about the practices and performances of a range of firms to identify the drivers of performance. Indeed, relying on information from both successful and unsuccessful firms may be crucial to understand whether a practice contribute to high performance or simply is risky (Denrell, 2003). Nevertheless, information about successful firms is often more easily available and managers and the managerial press tends to focus on successful firms (Strang and Macy, 2001; Denrell, 2003). Experiments also show that when given the choice, people prefer to get information about and imitate successful others even if information about failures is also available (Offerman and Schotter, 2009). Moreover, information is seldom freely available: firms have to invest resources to acquire information about the practices of other firms. In the context of this model, if only a firm can only get information about the practices of one firm, it is optimal to focus on the firm with the highest level of performance when $k > 2$. The reason is that in this case there are many incorrect alternatives, and thus many ways to be wrong, but only one correct alternative on each dimension. In such a setting, failure is less informative than success is.[1] Given the psychological bias towards successful others, it is then perhaps not unrealistic to assume that firms mainly consider successful others when imitating.

3.2 Results: How does the presence of a superior firm impact the performance of the industry? Specifically, we are interested in whether the average performance of all firms in an industry improves when one firm is initially superior to others. Intuitively, it would seem that if there is a superior firm, then other firms would be able to improve by copying this superior firm.

To examine the impact of an initially superior firm, consider the case when the number of dimensions is $m = 100$ and the number of firms is $n = 100$. Suppose the number of options on each dimension is $k = 10$. The expected initial level of performance is then 100*(1/10) = 10. Some firm will obviously have higher initial performance than this expected value. Simulations

[1] If you observe the practices of a firm with zero performance, you will know to avoid those practices. However, this will likely not improve your performance much because there are many ways to be incorrect. Specifically, the probability that you have the same practice as the zero performance firm on dimension j is, initially, (1/k)(1/k).

show that, on average, the expected *maximum initial* performance among 100 firms is about 18. Finally, we assume that the probability of copying is $p = 0.05$. Thus, on average, firms copy 5 dimensions of the superior firm(s) in each period.

Figure 1 shows how the average industry performance of all 100 firms after 500 periods varies with the initial performance of firm 1. After 500 periods all simulations have converged to an equilibrium where no firm can change because they all have the same performance.

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Insert Figure 1 about here

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Figure 1 shows that average industry performance is not much impacted by the initial performance of firm 1 when the initial performance of firm 1 is below 20. The reason is that firm 1 is then unlikely to be the superior firm initially (since the average maximum initial performance among 100 firms is about 18). If the initial performance of firm 1 is set to a value higher than 20, however, average industry performance *declines*. The decline continues until the initial performance of firm 1 is set to a value of about 35. After this, average industry performance increases in the initial performance of firm 1. Average industry performance only reaches the same level as when the initial performance of firm 1 was 15 when the initial performance of firm 1 is 50, which is five times as large as the expected initial performance of other firms.

3.3 Mechanism: What explains this dip in average industry performance as a result of the initial performance of firm 1? It is easy to understand why average industry performance is high when the initial performance of firm 1 is set to a very high level. After all, if the initial performance of firm 1 was m = 100 (the maximum level of performance), then firm 1 would never copy any other firm and all other firms would copy firm 1 until they reach the same level of performance. This explains why average industry performance is increasing in the initial performance of firm 1 for high level of the initial performance of firm 1.

But why does average industry performance decline as a result of increasing the initial performance of firm 1 from 20 to 30? The mechanism is that having a superior firm initially reduces diversity and the scope for recombination. Figure 2 illustrates this mechanism. It plots the number of correct choices in the population. This is the number of dimensions in which at least one firm in the population of firms has the correct choice for (Posen et al, 2013). Figure 2 shows that the number of correct choices initially declines more rapidly when firm 1 is superior, i.e. when firm 1 has initial performance of 30 or 50 compared to when it has initial performance of 20. The reason is that when there is an initially much superior firm, then all firms will imitate this firm and the population will become more homogenous. Many imitation attempts will increase the performance of the imitating firm. But because imitating firms may imitate incorrect dimensions of a superior firm, it is possible that imitation will change a correct choice to an incorrect choice. Thus, as a result of such a process of "hitchhiking", incorrect choices can replace correct choices (Fang et al, 2010; Posen et al, 2013).

Insert Figure 2 about here

If there were initially only a few firms that had the correct choice on a given dimension and all of them imitate the best firm and exchange a correct for an incorrect choice, no firm in the population may have the correct choice on this dimension. The impact of such loss of knowledge in the population is that the scope for recombination, to create firm superior to the currently highest performer, is reduced. Suppose, for example, that the firm with the highest performance has correct choices on the first 30 dimensions and incorrect elsewhere. Suppose that most other firms have a performance at around 10, thus have 10 correct choices. These inferior firms could achieve a performance higher than the current leader if they i) had some of the last 70 dimensions correct and ii) copied only the first 30 correct dimensions of the current leader. Because they do not know on which dimensions of leader is correct, however, the laggards may decide to copy most of the choices of the leader. By doing so, they will very likely increase their performance but their correct choices on dimensions other than the 30 first will get lost.

Figure 2 shows that when the performance of firm 1 is initially high (30 and 50) there is a more rapid loss of correct choices in the population than if the initial performance of firm 1 is lower (at 20). When the initial performance of firm 1 is 30, this more rapid loss of knowledge leads to a lower level of long-run average industry performance than when the initial performance of firm 1 is 20. When the initial performance of firm 1 is 50 (five times the average), the long-run industry performance is slightly above that when the initial performance of firm 1 is 20. In this case, the rapid loss of knowledge is compensated by the increased chance of copying a correct dimension that having a superior firm leads to.

Why does having a superior firm initially lead to more rapid loss of knowledge? The reason is that a) having a superior firm initially implies that the same firm will lead (have the highest performance) for many periods initially and b) having the same unique leader increases the chances of loss of knowledge compared to having a diverse and changing set of leaders.

The first part, that having a superior firm initially implies that the same firm will lead during many initial periods, is easy to understand. If one firm is much superior to others initially, it will have superior performance for many periods because it will take several periods before others catch up and surpass firm 1 (or achieve the same level of performance).

The second part, that having the same unique leader increases the chances of loss of knowledge compared to having a diverse and changing set of leaders, requires a bit more explanation. The key idea is that correct choices that few firms have, and hence are “extinction-prone”, are more likely to diffuse widely, and thus be less likely to go extinct, if the leader(s) are diverse in the set of correct choices they have.

To explain this, suppose there are few firms initially that have the correct choice on dimension 100. Suppose now that firm 1 has initial performance equal to 30 and has all the 30 first dimensions correct. Firm 1 is then almost guaranteed to have the highest level of performance among all 100 firms. All other firms will then copy firm 1. Because firms only copy a few dimensions, firm 1 will remain a leader for several periods. During these periods, all other firms will imitate firm 1. As a result, the correct and incorrect choices of firm 1 will spread in the population. When the firms with a correct choice on dimension 100 copy firm 1, they are likely to replace their correct choice on dimension 100 with the incorrect choice by firm 1. As a result, the correct choice on dimension 100 may disappear from the population.

Suppose instead that firm 1 has initial performance equal to 20. This level of performance is close to the average maximum performance among the 99 other firms. In other words, firm 1 will be one of the better performing firms but not necessarily the best. Moreover, the best firms initially will have initial performances close to each other. The consequence of this is that the leadership, the identity of the firm with the highest level of performance, will shift between periods. It is also much more likely that more than one firm will have the highest level of performance. Both changing leaders and having several firms with the highest level of performance increases the chances that extinction prone correct choices will survive in the population. The reason is that if a new firm becomes the leader a new set of correct and incorrect choices will be imitated.

To illustrate this argument, suppose there are 5 dimensions and the leader initially is firm 1 with 2 correct choices: 1,1,3,7,5 (remember 1 is the correct choice). Other firms will copy both the correct and incorrect choices of firm 1. If this process continues for some time, the incorrect choices on the last 3 dimensions will spread in the population and crowd out the correct choices on these dimensions. Suppose, however, there is a change in leadership and the new leader has 3 correct choices: 1,3,3,1,1. Other firms will imitate the new leader and the number of firms with correct choices on the last two dimensions will increase. The same argument holds if there are multiple leaders. For example, suppose there are two firms with the highest performance and they each have 2 correct choices but they differ in what choices are correct (such as 1,1,3,7,5 and 1,4,8,1,6). Because other firms randomly pick one of these leaders to imitate, the chances that all firms will end up with incorrect choices on some particular dimension (such as the 4^{th}) is lower than if there is only one leader.

To verify that having a superior initial performer leads to a more diverse set of leaders Figure 3 plots the average number of leaders (the number of firms who share the highest level of performance) and the number of new leaders (a leader is new if a firm has the highest performance in period t but was not among the firms with the highest performance in period *t-1*) over time when firm 1 has initial performance equal to 20, 30 and 50.

The upper panel of Figure 3 shows that when firm 1 has initial performance equal to 50 there is a single leader (firm 1) during the first 30 periods. When firm 1 has initial performance equal to 30 there is a single leader (firm 1) during the first 10 periods. If firm 1 has initial performance equal to 20, however, the average number of leaders starts increasing immediately and reaches 2 (shared leadership) after only 5 periods. Note that eventually all firms will have the same level of performance, thus eventually the number of leaders will increase to n = 100 which occurs when the process has reached equilibrium. This explains the eventual rise in the number of leaders and why it rises more rapidly when initial performance of firm 1 is 50 (in this case many other firms imitate the choices of firm 1 and many firms converge to having similar choices and thus similar performance).

Insert Figure 3 about here

The lower panel in Figure 3 shows that when firm 1 has initial performance equal to 20 there are initially many more new leaders than when firm 1 has higher initial performance. Note that the number of new leaders eventually decrease because all firms converge to the same level of performance implying that there can be no new leader.

Finally, to illustrate that close competition, resulting in change in leadership, reduces loss of knowledge, Figure 4 shows the effect of introducing two initially superior firms instead of only one. Specifically, Figure 4 plots how the number of correct choices in the population changes over time when there is one superior firm (firm 1) with an initial performance of 30 and when there are two initially superior firms where firm 1 has initial performance of 30 while firm 2 has initial performance of 28. As shown, providing firm 1 with a close competitor, who can quickly catch up with or surpass firm 1, substantially reduces the loss of correct choices in the population. As a result, eventual average industry performance is now as high as it was when the initial performance of firm 1 was 20.

Insert Figure 4 about here

3.4 Robustness: The u shaped impact of the initial performance of firm 1 disappears if firms can quickly copy the leader. For example, suppose the probability that firm i copies the choice of firm j along dimension r with probability $p = 0.30$ (rather than 0.05). Then average industry performance is then *increasing* in the initial performance of firm 1. The reason is that when other firms can quickly copy the leading firm, they will quickly catch up. Asa a result, there is no long period during which all other firms copy a single leader, reducing the diversity of practices within the industry. Only the positive effect of having an industry leader with high initial performance remains: the fact that other firms can copy the superior practices of this leading firm. The implication is that an even initial playing field matters more in settings when it is not easy to catch up with leaders. This scope condition also applies to other accounts, focusing on the motivation to invest to catch a leader. For example, an uneven initial starting point does not impact incentives much if the laggard in a patent race knows that it can quickly catch up with the leader. The loss of motivation occurs only when it is difficult to catch up with a leader.

The u-shaped impact of the initial performance of firm 1 is occurs over a broader set of initial performance if the number of alternative choices on each dimension, *k*, is smaller. Figure 5 shows how the average industry performance of all 100 firms after 500 periods varies with the initial performance of firm 1 when $k = 5$ instead of 10. Average performance is about the same when the initial performance of firm 1 is between zero and 30, then starts to decline and only reaches the same level again when the initial performance of firm 1 is about 65. This effect occurs simply because when the number of choice alternatives are few all firms will have a higher expected initial level of performance. The dip is thus shifted to the right (towards 100) on the x-axis.

Insert Figure 5 about here

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4. Discussion

4.1 Learning instead of motivation: The results show that uneven competition can impact the process of learning as well as motivation. Prior work on the impact of competition has often emphasized the impact of motivation. Competition by a strong rival and lead to poor performance which in turn can trigger search for improvements (Barnett, 2008). Economic models of patent races have suggested the opposite mechanism: a laggard may give up and stop investing in innovation if another firm has a sizeable lead (Fudenberg, Gilbert, Stiglitz and Tirole

1983; Anderson and Cabral, 2007). The prediction from these models is that a “level” playing field, where contestants have similar abilities, will provide stronger incentives to innovative and improve (Stein, 2002, Baik 1994), an outcome also observe in some empirical studies (Brown, 2011; Gross, 2020). Our model shows that even if the presence of other firms does not impact the incentives to improve or innovate, a “level” playing field, where contestants have similar abilities, can still be beneficial for progress. The mechanism is about learning instead of motivation: a “level” playing field leads to s shifting set of leaders which generates more diversity in the set of practices adopted by firms and such diversity promotes recombination that can lead to identification of superior combinations of practices.

Because the mechanisms differ, it is possible to empirically distinguish these alternative accounts of the impact of a “level” playing field. The motivational account focuses on how competition changes the propensity to invest or search. The learning account focuses on the cumulative effects of imitation attempts. The prediction of the learning account is that a level playing field will generate i) a shifting set of leaders and that ii) a shifting set of leaders will preserve a diverse set of practices and, finally, iii) that long-run technological progress is higher in populations with a diverse set of practices. To examine these predictions empirically, researchers need to look at the population rather than the firm level consequences of competition. Preservation of a diverse set of practices, as a result of a shifting set of leaders, may not have a positive short-run impact on most firms. In the long-run, however, it can have a positive impact on progress in the industry because such diversity makes it possible for some firm to identify a superior set of practices which then can diffuse, via imitation, to many other firms. Practically, this means that empirical study designs need to consider the impact of competition at the industry level and in the long-run. Because the learning accounts operates at the industry level, while the motivational account operates at the firm level, it is also possible that an even playing field has a negative motivational effect (because, say, if most firms are doing equally well, they all are above their aspiration level), while it has a positive learning effect (because it leads to a shifting set of leaders that preserves diversity).

4.2 Implications for positioning: Understanding the impact of competition also has normative consequences. Traditionally, firms have been advised to avoid competition (Porter, 1980). Realizing that competition is an essential spur to technological progress, however, some strategists have changed their mind and recommended that firms become exposed to competition (Barnett, 2008; Porter, 1990). The recommendation to firms to expose themselves to competition is largely based on the motivational impacts of competition: competition can spur firms to innovate in a way that can be difficult to induce by other means. The learning account developed here, however, has a different normative implication. In our model, we assumed that firms were motivated to search for improvements. Competition was not necessary to enhance motivation. If this is the case, then exposure to competition may not be an individually rational course of action.

To explain this, note that our model shows that industry progress is greater if there is an even playing field. Consider, however, what this implies for a leading firm. Is the leading firm better off if the other firms initially have a performance closer to the leading firm? That is, will the leading firm be more profitable, over time, if competing firms initially had a performance closer to the leading firm? The answer to this question depends on how much profitability varies with industry progress. Specifically, is demand for the product much influenced by technological progress? Suppose, first, this is not the case. That is, there is a more or less fixed demand for the products produced by the industry and demand will not increase much if the price falls as a result of technological progress within the industry. In this case, the leading firm is likely to profit more if the performance (cost effectiveness, say) of competing firms is lower. If the leading firms is much superior to competing firms, and have much lower costs, the leading firm can profit substantially. Thus, from the perspective of the leading firm, uneven competition is recommended. Such uneven competition may lead to lower industry progress: the average performance of firms will be lower than if competition was more even. This may not impact the profitability of the leading firm: it may only be the difference in performance between firms that matter, not the average level.

The recommendation for positioning changes if demand for the product produced by the industry can expand substantially if technological progress reduces prices. In this case, even a leading firm can benefit from industry progress: the average level of performance (which impact prices) and not only the difference in performance may matter to the leading firm. Increased progress, stimulated by more even competition, can lead to more technological progress in the industry. To the extent that the leading firm will benefit from this (the leading firm may, for example, be likely to be one of the leaders even after some time) then a leading firm may in fact benefit from stronger competitors. Examining these implications in a computational model of profitability is an interesting avenue for future research.

4.3 Diversity and rational inference: Our model is behavioral and assumes that firms more or less mindlessly copy superior others. The firms do not try to figure out whether the choice on a particular dimension contributes to performance or not. A related mechanism holds, however, even if firms did try to figure out the choices that contribute to high performance. Specifically, having a diverse set of firms, which engages in different practices, makes it easier to figure out the choices that contribute to high performance.

To explain why, suppose there are three dimensions and you observe the choices of a firm with a performance of 2 out of 3. This firm thus got 2 out of 3 choices correct. Suppose the choices observed are 1, 4, 1 (remember that we assumed that a choice of 1 is correct, on each dimension). The first and the third dimension are correct choices, but suppose you do not know that. If you only know that this firm has 2 out of 3 choices correct, how can you figure out which choices that are correct? The answer is that you cannot. Each choice is correct with probability 2/3. Suppose, next, that you observe two firms, both with performance 2 out of 3. Suppose the choices observed are 1, 4, 1 for the first firm and 1, 4, 1 for the second firm. There is no advantage of an observing two firms here, if their choices are identical. You still cannot figure out which choices that contribute to high performance. An increased sample size (from one to two firms) is not beneficial here because the mapping between choices and performance is deterministic. Overall, in this scenario, if you copy 1 dimension the probability you will get this dimension correct is (2/3). If you copy two dimensions, the probability of getting both correct is 2/3*2/3 = 4/9.

Suppose, however, you observe two firms both with performance 2 out of 3, and their choices are not identical. This can enable you to figure out which choices that contribute to high performance. Suppose the choices observed are 1, 4, 1 for the first firm and 1, 1, 6 for the second firm. In this case you know that the first choice, which is one for both firms, has to be correct. Why? Say that the first choice is not correct. Consider the first firm, who has a performance of 2 out of 3. If the first choice is not correct, the last two must be correct (to achieve performance of 2). But this is also true for the second firm. However, both firms cannot both have made correct choices on the last two dimensions because these firms differ in their choices on the last two dimensions. It follows that their choice on the first dimension cannot be incorrect; it has to be correct. So, diversity in choices can improve the efficiency of the imitation process even for rational (or logical) firms. Overall, in this scenario, if you copy 1 dimension the probability you will get this dimension correct is one, because you should copy the first dimension. If you copy two dimensions, the probability of getting both correct is $1*0.5 = 0.5 > 4/9$.

Of course, if a firm is rational it should use information from all firms, not just from the superior firms. As mentioned above, however, when $k > 2$, and there are more ways to be incorrect than to be correct, information about the practices of firms that are performing well is more informative about correct practices than information about the practices that are doing poorly. Thus, obtaining information about the practices of high performing firms is more valuable than information about other firms. Presumably, information about high performing firms that engages in a diverse set of practices would be most valuable. This suggests that having diverse set of industry leaders (i.e., firms with high performance that differ in the practices they make use of) is beneficial for the accuracy of vicarious learning even if firms are rational. Developing this idea in more detail would be interesting.

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Figures

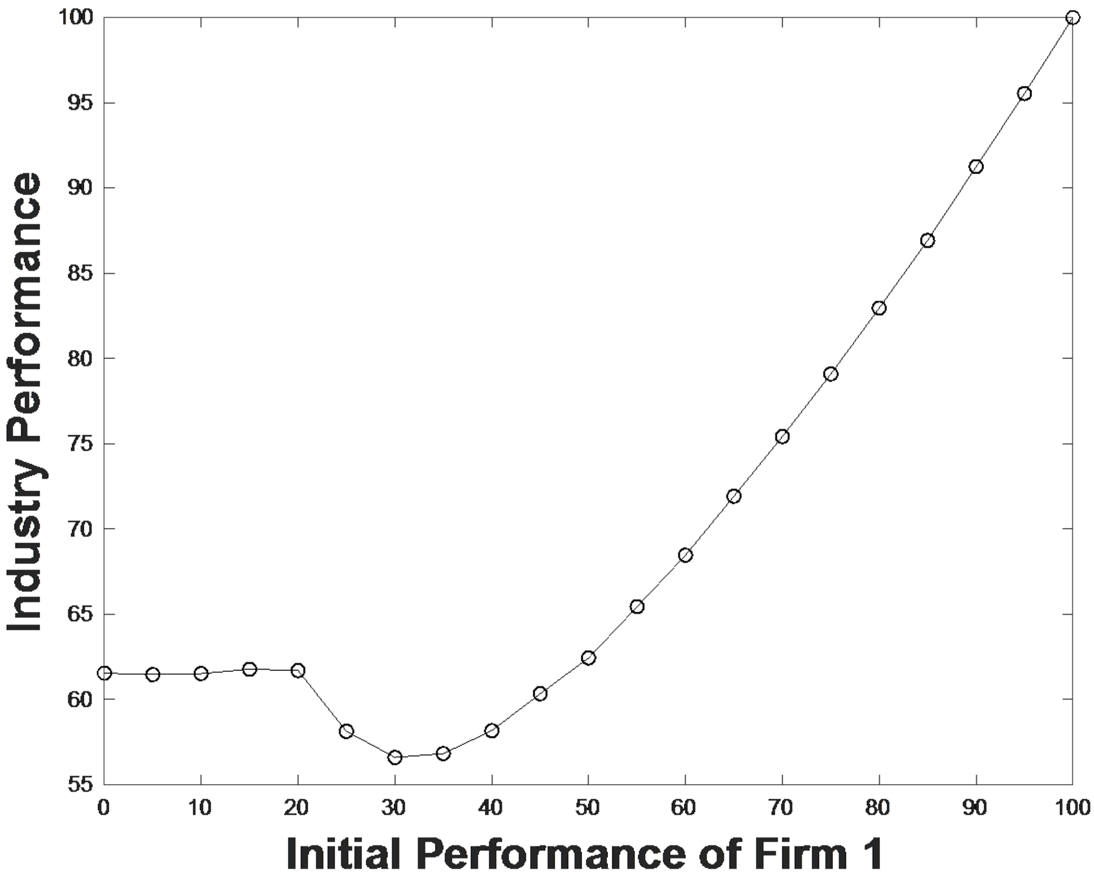

Figure 1: How average industry performance of all 100 firms after 500 periods varies with the initial performance of firm 1 (m = 100, n = 100, k = 10, p = 0.05). Based on 500 simulations.

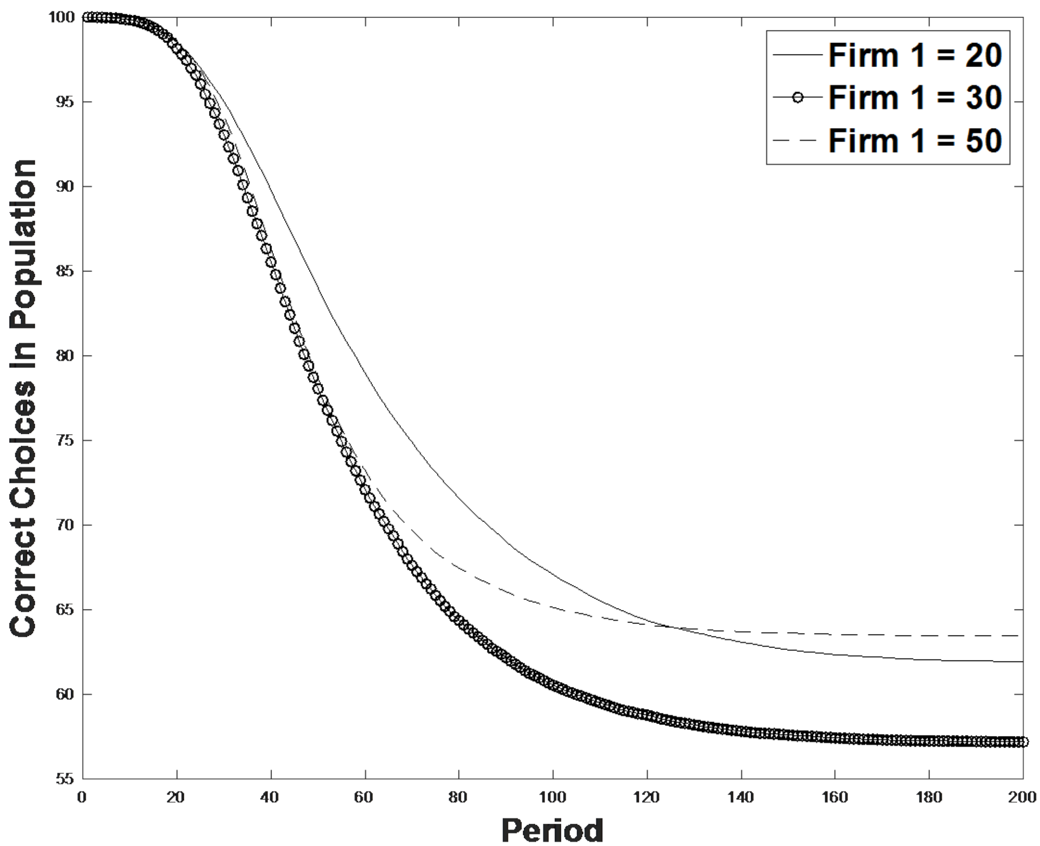

Figure 2: How the number of correct choices in the population changes over time when the firm 1 initially has 20, 30, or 50 correct choices (m = 100, n = 100, k = 10, p = 0.05). Based on 500 simulations.

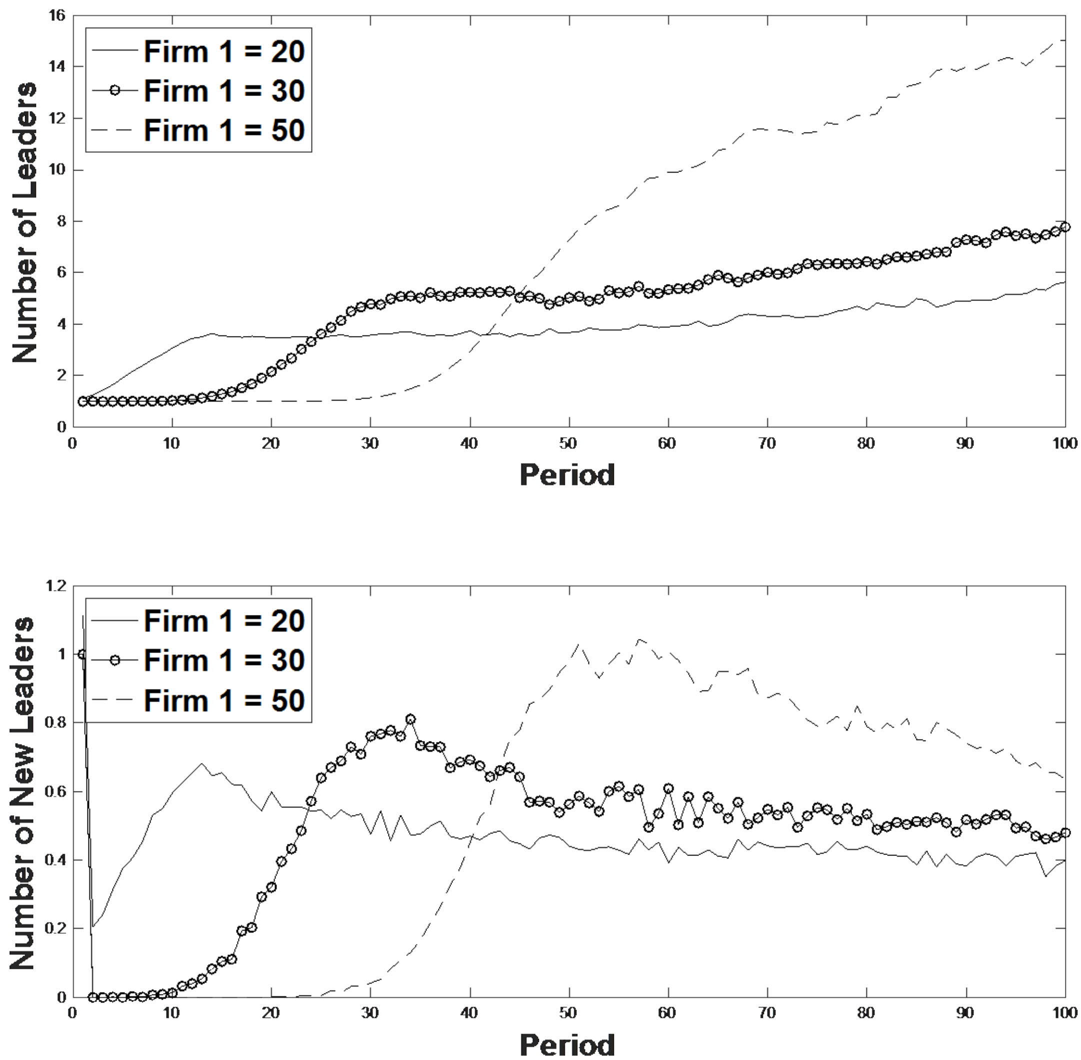

Figure 3: Upper Panel: How the number of leaders changes over time when the firm 1 initially has 20, 30, or 50 correct choices. Lower Panel: How the number of new leaders changes over time

when the firm 1 initially has 20, 30, or 50 correct choices. Based on 1000 simulations when m = 100, n = 100, k = 10, and p = 0.05.

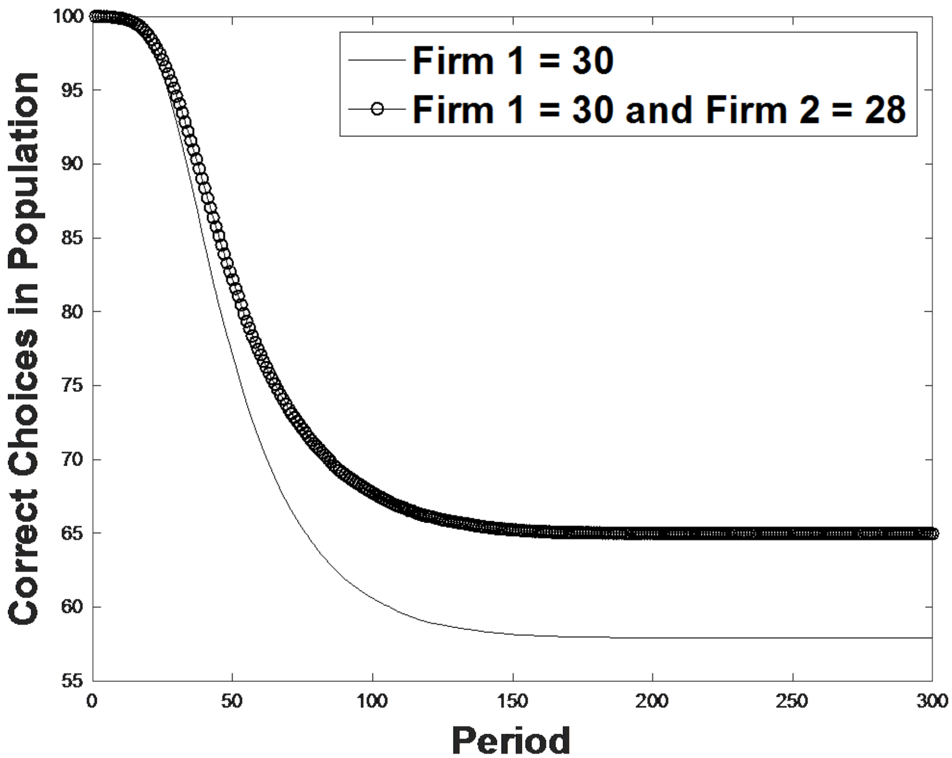

Figure 4: How the number of correct choices in the population changes over time when the firm 1 initially has 30 correct choices and when firm1 has 30 and firm 2 has 28 in initial performance. Based on 500 simulations where m = 100, n = 100, k = 10, and p = 0.05.

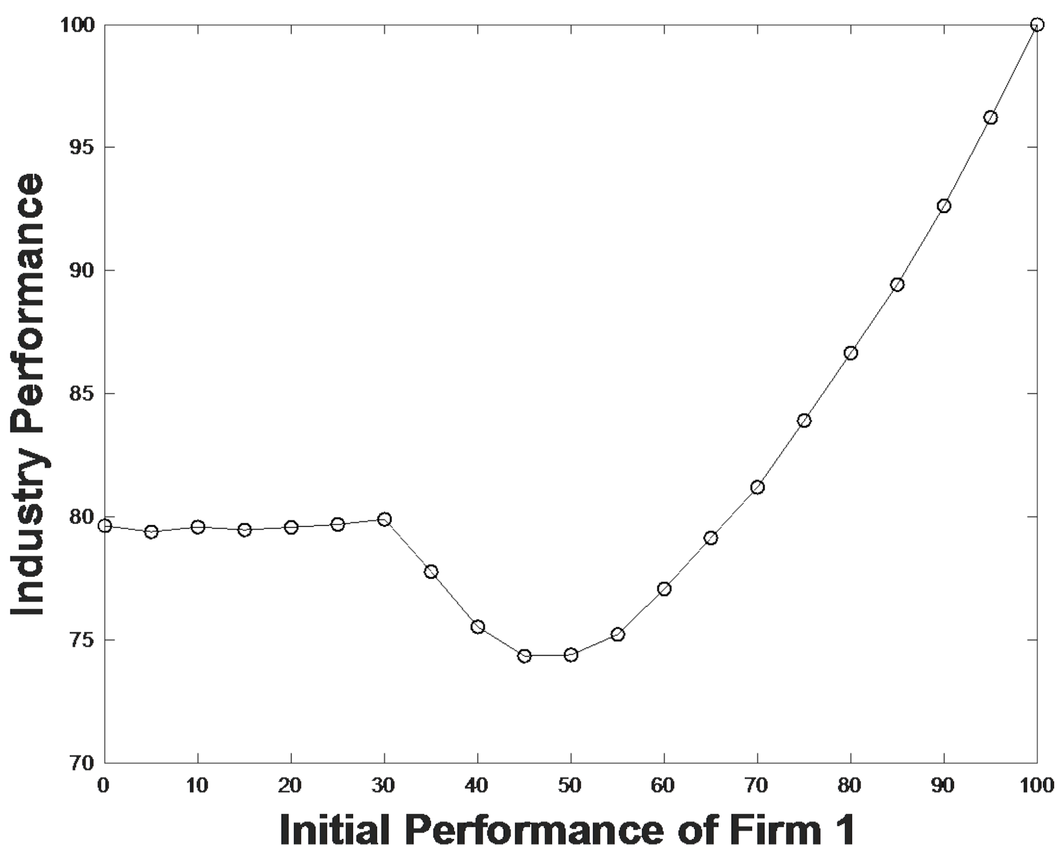

Figure 5: How average industry performance of all 100 firms after 500 periods varies with the initial performance of firm 1 (m = 100, n = 100, k = 5, p = 0.05). Based on 500 simulations.