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Whom should a leader imitate in multiple competitor settings? A contingency perspective

Dmitry Sharapov
Imperial College Business School
Department of Innovation and Entrepreneurship
dmitrysharapov1@googlemail.com

Jan-Michael Ross
Imperial College Business School
Department of Management
jan.ross@imperial.ac.uk

Abstract

Can a leader's imitation of rival competitors lead to superior performance in multiple-competitor settings, and, if so, which rival should the leader's imitative efforts be focused on? Building on prior work on the performance consequences of imitation strategies from competitive dynamics and neo-computational scholars, this paper examines the effectiveness of different imitation strategies pursued by a leader in a multiple-competitor setting subject to exogenous environmental shocks. Findings from an NK simulation model of a three-competitor setting suggest that a leader's imitation of either the rival closest to her in terms of performance to date (her challenger) or of the rival closest to her in terms of position on the landscape (her neighbor) can outperform an independent search strategy in all environments apart from those in which large changes occur frequently. This is because an imitative leader may benefit from ratcheting dynamics that occur as a result of their focal rival being forced into distant search by the leader's imitative behavior, leaving the leader with the opportunity to make productive minor changes to their rival's configuration. The effectiveness of the challenger-imitation strategy relative to one of neighbor-imitation is found to decrease with increasing magnitude of environmental changes, and to increase with their increasing frequency. We proceed to evaluate the external validity of these findings using fine-grained data on multiple-competitor (fleet) sailing races from the America's Cup World Series 2011-2013, and find support for the propositions emerging from the simulation results.

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Keywords: Competitive dynamics; Imitation; NK simulation; Environmental shocks

INTRODUCTION

Imitative behavior is an important part of the competitive process (Lieberman and Asaba, 2006), and scholars in the fields of strategy and organization have sought to understand the performance consequences of imitation decisions (e.g., Ferrier, Smith, and Grimm, 1999; Siggelkow and Rivkin, 2009; Csaszar and Siggelkow, 2010). It is commonly assumed that laggard firms use imitation strategies to catch up with the market leader (e.g., Kirzner, 1973; Nelson and Winter, 1982; Mezias and Lant, 1994; Rivkin, 2000). However, recent work has suggested that imitation of knowledge possessed by the laggard group (Posen, Lee, and Yi, 2013) or of a follower's tactical and strategic actions in a two-competitor setting can also be an effective means of avoiding dethronement for a leader (Ross and Sharapov, in press), and that even firms that make poor organizational choices can be targets for imitation (Siggelkow and Rivkin, 2009). The potential effectiveness of strategies in which a leader imitates poorer-performing competitors raises the questions of whether an imitation strategy can be beneficial for a leader in a setting with multiple competitors, and, if so, of which rival the leader's imitative efforts should be focused on.

A leader may decide to rely on her own capabilities and compete without considering the actions of competitors (Teece, Pisano, and Shuen, 1997). Alternatively, she may decide to search for better competitive positions by imitating others. Perhaps the most intuitive target of imitation for the leader is a competitor who is most similar to her. Competitors are likely to imitate each other when organizational characteristics are similar and when they operate in similar environments (Greve, 1998, 2005). Deviating from group norms (Chen and Hambrick, 1995) and leaving well-known contexts (Barnett and Pontikes, 2008) can yield inferior performance. Facing multiple rivals provides benefits from self-reinforcing, reciprocal effects of adaptive learning among organizations that are driven by incentives to improve performance to meet escalating aspiration levels (Barnett and Hansen, 1996). Because performance improvements can be achieved by imitating others (Mezias and Lant, 1994; Derfus et al., 2008) and imitating competitors tend to search for organizational changes that only slightly alter the status quo, these insights suggest that a leader may choose a similar rival as target of imitation if the rival shows superior short-term performance.

An alternative strategy could be to imitate a challenger who is a competitive threat despite being dissimilar to the leader. Focusing on similar rivals can lead to opportunities that have been discovered by more dissimilar others being overlooked (McNamara, Luce, and Tompson, 2002; Posen, Lee, and Yi, 2013). In particular, uncertain environments provide high-variance opportunities that can enable entrepreneurial firms to catch up with a market leader (e.g., Katila and Chen, 2008; Chen et al., 2010). In competition where being near the top in terms of performance matters, low performing competitors favor strategies of increasing performance variability over strategies of improving average performance, and, as a consequence, force a leader to do likewise (March, 1991). Because imitating the actions of distant rivals destroys their opportunities to catch up, these insights suggest that a leader who faces uncertain environmental conditions could benefit from imitating the actions of dissimilar rivals whose short-term performance poses a threat to the leader's dominance.

In seeking to answer the research questions, we address a number of unresolved issues in prior work on the performance outcomes of imitation strategies. First, the theory that underlies the process of competition and learning through imitation is incomplete. Seminal work on competition and learning in Red Queen settings excluded exogenous forces that upset the competitive equilibrium (Barnett and Hansen, 1996). However, as outlined above, environmental uncertainty provides temporary opportunities that allow entrepreneurial rivals to disequilibrate the market process (Roberts and Eisenhardt, 2003; Smith and Cao, 2007). Imitating the entrepreneurial rival's disequilibrating actions may be a competitive response of the leader aimed at achieving an improved competitive position. Hence, under some conditions, actions of others may trigger imitation even when own performance is above aspiration levels. As a consequence, assuming that the industry leader is the target of imitation and ignoring the role of competitive actions under varying exogenous environmental conditions draws an incomplete picture for predicting performance outcomes.

Second, the theory that underlies the relationship between environmental conditions and imitative search in dynamic competitive landscapes is incomplete. While comprehensive prior empirical work has emphasized the importance of environmental variations for imitation decisions (e.g., Haunschild and Miner, 1997; Anand, Mesquita, and Vassolo, 2009; Gaba and Terlaak, 2013), theory that could explain performance outcomes of imitative search processes with multiple competitors in one single, changing, competitive domain is lacking. Further, dichotomizing environmental conditions by using two performance landscapes, one stable and one unstable (Katila, Chen, and Piezunka, 2012), limits our ability to identify non-linear relationships between different kinds of environmental variations, search strategies, and performance outcomes (Miller, Ogilvie, and Glick, 2006; Davis, Eisenhardt, and Bingham, 2009). As a result, prior work provides little theoretical and practical guidance for a leading competitor on the effective use of imitation strategies in changing environments. For example, the magnitude and frequency of environmental change may have different effects on the relationship between imitation strategies and performance.

Third, efforts to develop and test theories that predict outcomes of imitation in multiple competitor settings have been constrained by methodological issues, limiting our understanding of competitive dynamics in multiple-competitor settings. In particular, pairwise considerations in competitive dynamics research (Chen, 1996; Chen and Miller, 2012), such as focusing on the interactions between the market leader and the second-place challenger, narrow the breadth of the competitive process being observed. Consequently, the lack of empirical evidence on the imitation-performance relationship might be the consequence of most empirical settings consisting of more than two competitors (Smith et al., 1991; Ferrier, Smith, and Grimm, 1999). Similarly, studies that separated competitors into groups (e.g., Ethiraj, Levinthal, and Roy, 2008; Katila, Chen, and Piezunka, 2012; Posen, Lee, and Yi, 2013) provide limited insights for a leader who is challenged by similar followers, because the underlying theoretical reasoning does not allow for differentiation between the industry leader and other rivals within the 'leading group'. As a result, current theory is imprecise in predicting performance outcomes of a leader's imitation strategy towards different types of followers in multiple competitor settings.

Overall, these unresolved issues suggest that our understanding of the link between imitation, performance and exogenous environmental variations, in general, and the imitation behavior of a leader in multiple-competitor situations, in particular, can be improved. Because leaders suffer more in short-term performance from rival actions than laggards (Derfus et al., 2008) and as imitative response lowers the durability of first-mover advantages of attacking rivals (Boyd and Bresser, 2008; Lee, Smith, Grimm, and Schomburg, 2000), research on how imitation strategies can be used to defend leadership is important. Extant conceptual and empirical work has emphasized asymmetries between leaders and followers (Khanna, 1995; Chen, 1996; Lerner, 1997; Shankar, 2006), indicating the need for leader-focused theoretical mechanisms that can explain the effectiveness of imitation strategies in various industries. In other words, while prior work has largely contributed to our understanding on how followers follow, we know less about how leaders lead.

We seek to fill this gap by examining the combined effect of three factors on competitive process performance outcomes: the number of competitors, the type of the imitation strategy (if any) pursued by the leader, and the kinds of variations of the exogenous environment in which competition takes place. In order to address the complexity of unfolding interactions between multiple rivals in varying environmental conditions over time, we follow a stepwise procedure of developing theory (Davis, Eisenhardt, and Bingham, 2007), by first using a simulation method and then empirically validating the results. In particular, building on the neo-computational literature (e.g., Rivkin, 2000; Csaszar and Siggelkow, 2010), we use existing insights on basic processes of competition and imitation to construct a simulation model. Simulation methods allow us to tackle non-linear effects in changing environment, which is an essential component in the theoretical foundations of disequilibriating forces in competitive dynamics (Roberts and Eisenhardt, 2003), and to disentangle competitive actions as responses to rivals' moves from simultaneous but independent responses to exogenous events, which are typical challenges when studying imitation behavior (Lieberman and Asaba, 2006; Chen and Miller, 2012). We compare the results with propositions on simple theory, run robustness tests that build on alternative ways of operationalization, extend simple theory by experimenting with the conditions of the simulation (i.e., varying values that were held constant, varying assumptions, and breaking environmental factors into two types of environmental variations), and finally validate the simulation results with empirical data.

We empirically test the insights from our simulations by making use of detailed data from multi-competitor (fleet) races from the America's Cup World Series 2011-2013 (ACWS). This context provides a controlled setting with identically equipped competitors who make decisions in the absence of cooperation behavior, reputational benefits and social pressures, which typically provide alternative explanations for imitation behavior and its outcomes, and offers us fine-grained data on competitor moves and environmental conditions that change exogenously and significantly impact race outcomes. We thus provide empirical validation for propositions regarding the performance effects of different imitation strategies in exogenously changing environments emerging from an NK simulation using fine-grained data from an empirical context that provides a good match for the simulation assumptions, making this, to our knowledge, the first paper that follows the recommendation of validating empirically the results of NK simulation models in order to provide evidence of their external validity (Davis, Eisenhardt, and Bingham, 2007).

IMITATION STRATEGY AND ENVIRONMENTAL CONDITIONS

Coevolving Competition in Volatile Environments

The outcomes of competitive interactions in coevolving competitions have been subject to extant study in the strategy literature. One stream of literature has used evolutionary theory to explain the origins of competitive actions and has improved our understanding on how laggards can become leaders (Smith, Ferrier, and Ndofor, 2001). The integrated view of competitive dynamics and evolutionary theory focuses on the role of sequences of actions and reactions in changing performance landscapes. For instance, empirical studies have supported the insight that rivals don't search in isolation by showing that rivals' actions determine how a focal firm, which can for instance be a high or low performer, searches in fluctuating performance landscapes (Katila and Chen, 2008; Chen et al., 2010). Recent work has emphasized that entrepreneurial firms have a chance to dethrone the market leader by taking advantage of unpredictable performance landscapes and leveraging temporary advantages (Katila, Chen, and Piezunka, 2012). However, this stream of research lacks insights on how a leader can benefit from the search efforts of rivals operating on the same performance landscape under varying environmental conditions. In order to extend existing work combining competition and evolutionary theory, research has to go beyond dichotomies of high- versus low-performing competitors or large versus entrepreneurial firms by focusing on the interactions between the market leader and different types of followers.

A second stream of research adopted the "Austrian School of Strategy" (Jacobson, 1992) to explain the relationship between disequilibrating actions of rivals and focal firm performance (Young, Smith, and Grimm, 1996; Ferrier, Smith, and Grimm, 1999; Ferrier, 2001). The Austrian School defines the competitive process as movements towards and away from equilibrium. In this process, disequilibrium states provide limited temporal windows for exploiting opportunities. Particularly unpredictable environments offer temporary advantages (Chen, Lin, and Mitchel, 2010; D'Aveni, Dagnino, and Smith, 2010), and the first competitor who senses and seizes an opportunity under uncertainty will be able to capture the benefits (Kirzner, 1973). As imitation equilibrates the disrupting actions of the innovator, recent work has suggested that an imitation strategy can be an effective means for a leader to destroy advantages created by a rival trying to catch up (Ross and Sharapov, in press). Because a leader may face multiple followers, a theory of imitative search will have to provide answers on whether and how to respond to different rivals who seek to overturn the status quo.

The role disequilibrium in competitive interactions has also been topic of studies examining the relationship between racing behaviors in coevolving competition and firm performance (e.g., Barnett and McKendrick, 2004; Derfus et al., 2008). This area of research has found that competitive success is driven by self-reinforcing, reciprocal effects of learning between organizations, which react to competitive pressures once a shortfall in performance occurs, and has defined competition as an endogenous force that continuously upsets the equilibrium among competing organizations. However, this view disregards the role of exogenous changes to the environment as a force that upsets the equilibrium (Barnett and Hansen, 1996). An exogenous shock that affects all competitors can change the relative position of rivals on a landscape (Van de Ven, Ganco, and Hinings, 2013) and create a threat to a leader because a follower could asymmetrically benefit from environment-induced variation. Proactive imitation may resolve the misfit with the environment by lowering the likelihood of performance variations that allow a follower to surpass the leader (Katila and Chen, 2008). Current theory is incomplete in determining which follower (if any) the leader should imitate in multiple competitor settings and what environmental contingencies favor alternative imitation strategies.

Leader's Imitative Search in Exogenously Changing Performance Landscapes

Studying imitation as search is particularly appropriate to enhance the understanding of imitation in competitive environments. Competitive moves are part of a problem-solving search in a landscape when firms search for a better competitive position (Chen et al., 2010). Imitative search can be defined as "…the process in which a firm attempts to replace a subset of its attributes" (Posen, Lee, and Yi, 2013: 151) with those of another firm, generally assumed to be high performing. Because imitative search is not always simple, and search for superior performance is limited by bounded rationality and path dependent, researchers have used simulation methods to better understand imitation strategies (e.g., Rivkin, 2000; Csaszar and Siggelkow, 2010). Those methods are appropriate when relationships are non-linear, processual and longitudinal, and when data are challenging to obtain. NK fitness landscapes are particularly helpful when studying incremental moves and long jumps (Davis, Eisenhardt, and Bingham, 2007).

Because our research problem is distinct from problems studied in prior work, we diverge from assumption of prior studies in several ways. First, neo-computational research on imitation strategies has focused on the market leader as target of imitation. Building on recent findings on imitation strategies (Posen, Lee, and Yi, 2013; Ross and Sharapov, in press), we relax this assumption in our model and suggest that the target of imitation can be a follower. The strategic group literature suggests that in the case of environmental changes competitors tend to develop group identities (Peteraf and Shanley, 1997) that provide a reference point for strategy decisions (Fiegenbaum and Thomas, 1995). Competitor's starting positions determine the choice of problem-solving moves in different landscapes (Chen et al., 2010). Since a leader faces multiple followers at the start of competitive interactions, and high-ranked competitors are more likely to learn from each other in competitive interactions (Derfus et al., 2008), we distinguish between different imitation strategies depending on the type of follower taken as a reference point by the leader. In particular, we focus on mechanisms that distinguish between imitating the second-placed challenger and imitating the rival closest to the leader in terms of attributes. This allows us to study within group differences and to address the possibility of leaders reacting to challengers who are successful in searching for superior performance in distant areas on the performance landscape.

Second, we relax assumptions of prior computational research that assumed the environment to be stable. Extant studies have emphasized that exogenous sources of environmental changes, such as changes in customer preferences, macroeconomic conditions, input cost, political changes are relevant for strategic decision making (e.g., Tushman and Anderson, 1986; Sutcliffe and Zaheer, 1998; Henisz and Delios, 2001; Baum and Wally, 2003; Gaba and Terlaak, 2013; Garcia-Sanchez, Mesquita, and Vassolo, 2014). We follow earlier work that suggested that the dimension of environmental dynamism be unpacked in studies of performance outcomes of strategic decisions (Miller, Ogilvie, and Glick, 2006; Davis, Eisenhardt, and Bingham, 2009) by focusing on two facets of environmental variation: frequency and magnitude of environmental changes. Studying imitation strategies in the face of different kinds of environmental conditions will provide a better understanding of the effectiveness of imitation strategies in different environments.

SIMULATION

To investigate the effectiveness of different leader-follower imitation strategies in a changing environment, we use an adapted version of an NK simulation model (see, e.g., Levinthal, 1997; Rivkin, 2000; Csaszar and Sigglekow, 2010). In such models, agents (commonly taken to represent firms) use boundedly-rational search heuristics to traverse a fitness landscape. The landscape represents payoffs to configurations of N binary choices, each of which is interdependent with K other decisions (drawn randomly). Increasing the number of interdependent decisions (K) increases the "ruggedness" of the landscape, with a smooth (K=0) landscape having only a single peak, while rugged landscapes have numerous performance peaks and valleys, making it less likely that boundedly-rational agents can search their way to the global optimum.

For our purposes, we use a standard, moderately rugged, NK model with N=12 and K=6 to reflect a competitive landscape featuring important interdependencies between competitor choices. This results in a landscape of 4,096 different possible configurations. The payoff to any given configuration is the average of the payoffs to all of the choices it contains, and these are drawn at random from a uniform distribution. As K=6, the payoff to any given choice is redrawn when either the choice itself or one of the 6 choices that it is interdependent with is altered.

In order to introduce environmental uncertainty into our simulation, we alter the landscape at regular intervals by changing the fitness values associated with each configuration. We do this by randomly generating another landscape using the same N and K parameters, and defining the fitness values of the landscape at period t+1 as the weighted average of the fitness values at time t and those of the newly-generated landscape. Thus, the weight w used in this updating reflects the magnitude of environmental changes, while the frequency f of changes corresponds to the length of intervals between periods in which the landscape is altered. The agents in our simulation are affected by these environmental changes but have no foresight regarding future changes to their environment, making these changes exogenous and unpredictable from their perspective.

Search strategies

We evaluate the effectiveness of three alternative strategies in settings of competition between two or three competitors on changing performance landscapes. A strategy is effective to the extent that it results in the leader's cumulative performance advantage over her rival(s) being maintained or extended throughout the course of the competition. More precisely, in the case of competition between three rivals, we take the minimum of the difference in cumulative performance between the leader and both of her rivals as our measure of strategy effectiveness. By doing so, we account for the possibility of a leader's advantage being threatened by any one of their competitors.

The first of these strategies, and the baseline, is one of independent greedy local search. In this strategy, the competitors, who are initially randomly placed on the landscape, pay no attention to one another and simply try to optimize their performance by considering the performance of all locations on the landscape that are within their immediate neighborhood, i.e. those locations that can be reached by changing only one of their 12 choices. Competitors then move to the neighborhood location with the highest performance, provided that its fitness is superior to that of their current configuration, and being the search again.

The second strategy we consider takes the leader's challenger, i.e. the rival closest to her in terms of cumulative performance to date, as the target of imitation. In this case, in every period, the leader takes the challenger's prior period configuration as a reference point in a distant search process. To capture the increasing difficulty of imitating more dissimilar competitors (e.g., Baum, Li, and Usher, 2000), the number of points in the neighborhood of the follower that the leader can choose from decreases with the number of choices that the leader must alter in order to move to the follower's configuration. Thus, a leader aiming to imitate a challenger whose configuration differs by only one choice will be able to choose among 12 points in the challengers immediate neighborhood (including the challenger's chosen configuration), while a leader imitating a challenger whose configuration differs by 11 choices will only be able to choose among two points in the challenger's immediate neighborhood. The leader proceeds to move to the best performing of these configurations, even if its performance is inferior to the leader's current one. Such behavior is reasonable if the leader is concerned about remaining ahead in an uncertain environment, because failing to imitate the challenger would leave open the possibility of the challenger benefiting from an environmental change that increases her performance while reducing that of the leader, resulting in a reduction in the extent of the lead and, potentially, dethronement. The assumption that only better-performing agents can be a target of imitation has also been relaxed in prior neo-computational work (Siggelkow and Rivkin, 2009; Posen, Lee, and Yi, 2013).

The final strategy we explore is that of the leader imitating the rival that's closest to her on the landscape, i.e. her neighbor, the follower that is most similar to the leader in terms of their configuration. The prior period configuration of this follower is then taken as the leader's reference point for a process of distant search proceeding in the same manner as described above.[1]

While the leader always aims to imitate the follower in the imitation strategies described above, followers perform greedy local search as long as their configuration is different to that of the leader. They do not aim to imitate the leader because imitating the leader's configuration guarantees that the lead will be maintained and that dethronement will not occur. However, if the configurations of the leader and a follower are the same, the follower tries to jump away from the leader, as otherwise there is no chance of the leader being dethroned. This is operationalized by having the follower perform an undirected distant search, in which a random point on the landscape is chosen as a reference configuration. This distant search process

[1] In the two-competitor case the challenger imitation and neighbor imitation strategies are identical.

proceeds in a manner similar to the leader's search process described above, with the difference that the follower chooses to move only if the best-performing of the distant configurations "visible" to her has a higher performance value than their current configuration.

Implementation

Our simulations run for 50 periods, and we perform 100 runs of each simulation.[2] Alongside the three competitive behaviors described above, we also vary the number of competitors between 2 and 3, as well as varying the frequency (f = 2, 5, or 10, corresponding to the landscape changing every f periods) and magnitude (w = 0.9, 0.5, and 0.1, corresponding to the weight given to the newly-generated performance landscape, with 1-w being the weight assigned to the previous one) of environmental changes. To evaluate the effectiveness of the alternative search strategies, we calculate the minimum difference in cumulative performance between the leader and its rivals in every period of the simulation, averaged over the 100 runs of the simulation that we perform for every combination of number of competitors, f, and w.

ANALYSIS

Competition between Two Rivals

In results available on request from the authors, we find that, in the case of competition between two rivals, an imitation strategy can outperform an independent search strategy. After 50 simulation rounds, the margin by which the cumulative performance (averaged over the 100 runs of the simulation) of an initial leader remains superior to her rival's is greater for a leader pursuing an imitation strategy (as opposed to a leader searching independently) when environmental changes are frequent (the landscape changing every f = 2 or 5 periods) and of high magnitude (new performance landscape weight w = 0.9 or 0.5).

[2] The results produced are preliminary. As we develop the paper further, we aim to increase both the number of periods we simulate and the number of runs of each simulation in order to improve our ability to evaluate the statistical significance of the simulation results.

The mechanism behind this finding is the result of imitative actions of the leader forcing their rival into distant search before all productive local search possibilities have been exhausted, which allows the leader to benefit from such local improvements while having the rival search for more attractive distant neighborhoods. Such dynamics become more beneficial for the leader as the environment becomes less stable.

More specifically, consider first the case of independent search strategies: In a landscape that changes little, the superior initial performance of the leader will generally be maintained as both leader and challenger move towards their respective local peaks. In such a situation there is little to be gained by the leader from giving up their initially superior position on the landscape and moving into the neighborhood of the challenger.

When competition takes place on a landscape subject to frequent and significant changes, however, an initially advantageous position on the landscape is far less likely to persist, and the risk of a change in the environment favoring the challenger is much greater. This risk is neutralized if the leader imitates the challenger by moving to the same point on the landscape, at the cost of the foregone superior performance that the leader could have enjoyed from remaining in her initially superior neighborhood. Such imitation then forces the challenger to look for superior positions on more distant parts of the landscape. Interestingly, this distant search by the challenger can come at the expense of productive local search, allowing the leader to extend their lead by moving closer to the local maximum while the challenger performs distant search. If this happens, the configurations of leader and challenger are no longer the same, and the challenger resumes searching locally, often moving to the leader's location as a result, and triggering another round of distant search. Due to these ratcheting dynamics, an imitation strategy can result in the extent of the leader's initial advantage increasing over the course of the competition, provided that environmental changes are frequent and significant enough to sufficiently reduce the long-term value of the leader's initially superior position on the landscape. If the challenger is successful in finding a superior location on a distant part of the landscape, the performance gained over the leader as a result is small as the leader will quickly imitate the challenger's new position.

Interestingly, we also find strong support for the idea that an imitation strategy can be an effective way of avoiding dethronement in head-to-head competition (Ross and Sharapov, in press). The simulation results show that leadership status after 50 simulation periods is more frequently retained by a leader who imitates than one who doesn't across all combinations of environmental change (i.e., frequency and magnitude). The difference is lowest in environments with the highest frequency and magnitude of changes – in such challenging settings an imitative leader retains the lead after 50 periods in 52% of simulation runs, versus in 46% of runs for an independent leader. The difference is highest when frequency and magnitude of changes are both moderate, with an imitative leader retaining the lead in 77% of simulation runs, versus 52% for an independent leader.

Competition between Three Rivals

In the three-rival case, an independent search strategy outperforms both challenger and neighbor imitation strategies only when environmental changes are both very frequent ($f = 2$) and of high magnitude ($w = 0.9$) at the same time. This is also the only environment in which the proportion of simulation runs in which leadership was retained by the initial leader pursuing an independent search strategy is higher, at 49%, than those of leaders pursuing either challenger or neighbor imitation, both 39%. In all other cases, either challenger or neighbor imitation strategies, or both, lead to a higher average minimum extent of the lead at the end of the simulation's 50 periods than does the independent search strategy. In these cases, leadership is also more frequently retained by an imitative initial leader than by an independent one.

In light of the two-rival results discussed above, in which an imitation strategy was found to be superior to an independent one in environments subject to frequent and significant changes, this finding is rather unexpected. The explanation is likely to be that such highly variable environments lead to frequent changes in the competitor being imitated by the leader, regardless of whether the leader seeks to imitate her challenger or her neighbor. A frequently changing focus of imitation reduces the possibilities the leader has to benefit from the ratcheting dynamics described in the two-rival case, and instead results in the leader frequently jumping between different neighborhoods while being further away from their local maxima than are the competitors that she is trying to imitate.

The average differences in the performance of the challenger- and neighbor-imitation strategies under different magnitudes of environmental change, holding the frequency of changes fixed, are presented in Figure 1.[3] When environmental changes are relatively infrequent ($f = 10$), a challenger-imitation strategy is more effective than a neighbor-imitation strategy when the magnitude of environmental changes is low ($w = 0.1$), but less effective when the magnitude of environmental changes is moderate or large ($w = 0.5$ or 0.9). In environments that change with moderate frequency ($f = 0.5$), a challenger-imitation strategy is more effective when the magnitude of changes is either low or high ($w = 0.1$ or 0.9), and somewhat less effective than a neighbor-imitation strategy when the magnitude of environmental changes is moderate ($w = 0.5$). In fast-changing environments, a neighbor-imitation strategy appears to be more effective regardless of the magnitude of environmental changes. Overall, unless environmental changes are very frequent, an increase in the magnitude of environmental changes appears to decrease the effectiveness of a challenger-imitation strategy relative to one of neighbor imitation, with the exception of an increase from moderate to high magnitude of changes in environments subject to changes of moderate frequency.

Figure 1 about here

Figure 2 shows the average differences in the performance of the challenger- and neighbor-imitation strategies under different frequencies of environmental change, holding the magnitude of changes fixed. When the magnitude of environmental changes is low ($w = 0.1$),

[3] The results for f =2, and $w = 0.9$ are not shown as in this case both imitation strategies are inferior to an independent search strategy.

challenger imitation is more effective than neighbor imitation in environments changing with low or moderate frequency (f = 10 or 5), and is less effective than neighbor imitation in frequently changing environments (f = 2). In environments subject to changes of moderate magnitude (w = 0.5), challenger imitation always appears to be less effective than neighbor imitation, but by very little when the frequency of environmental changes is moderate (f = 5). Finally, when the magnitude of environmental changes is high (w = 0.9), a challenger-imitation strategy outperforms a neighbor-imitation strategy when the frequency of environmental changes is moderate (f = 5), but not when the environment changes only infrequently (f = 10). Overall, an increase in the frequency with which the environment changes appears to increase the effectiveness of a challenger imitation strategy relative to one of neighbor imitation, with the exceptions of an increase to a very high frequency when the magnitude of environmental changes is low or moderate.

Figure 2 about here

The above findings can be explained by considering the key trade-off between the two imitation strategies: A challenger-imitation strategy results in the leader always focusing her imitation efforts on the rival closest to her in terms of cumulative performance to date. This means that the leader is less likely to lose ground to a distant competitor who benefits from a change in the environment, as the leader's imitation focus will change to this competitor as soon as she moves up to second place in the cumulative performance ranking. However, imitation of a more distant competitor means that the leader has a reduced choice of points in the competitor's neighborhood to move to, increasing the average number of periods that it takes the leader to reach the same location on the landscape as that of its target competitor, and thus reducing the extent to which the leader can benefit from the advantageous ratcheting dynamics described in the two competitor case above.

Pursuit of a neighbor-imitation strategy, on the other hand, means that the leader will be quicker to successfully imitate her most similar competitor, resulting in an increased likelihood of the ratcheting dynamics described in the two competitor case playing out. However, the risk of this strategy is that any performance gains achieved through this process will be wiped out by an environmental change which benefits a more distant rival, leading to a reduction in the extent of the lead.

With the above trade-off in mind, an increase in the magnitude of environmental changes can be thought of as increasing both the benefits for the leader of the ratcheting dynamics described in the two competitor case (as the local maximum is more likely to change), as well as the likelihood of a change in the ranking of the leader's two competitors (which would force the leader to change focus to more distant rivals more frequently), both of which decrease the effectiveness of the challenger imitation strategy relative to the neighbor imitation one.

An increase in the frequency of environmental changes, on the other hand, increases the chances of a distant search process of an imitated rival being successful, thus reducing the average duration of situations in which ratcheting dynamics favorable to the leader are in play. The key advantage of a neighbor imitation strategy over one of challenger imitation is then negated, leading to an increase in the relative effectiveness of the latter.

Overall, unless the competitive environments are subjects of high frequency changes of high magnitude, the simulation results and their analysis suggest two propositions:

Proposition 1: An increase in the magnitude of changes to the competitive environment will reduce the effectiveness of a challenger imitation strategy relative to a neighbor imitation strategy.

Proposition 2: An increase in the frequency of changes to the competitive environment will increase the effectiveness of a challenger imitation strategy relative to a neighbor imitation strategy.

EMPIRICAL VALIDATION

Study Context

In order to provide external validation for the insights drawn from the simulation model, we require a setting that involves multiple competitors in a race-like competition with exogenous changes to the environment that have a material impact on the competition's outcome, and in which imitation behavior by the leader can be observed over the course of the competition. Ideally, the context should also be such as to minimize the influence of possible alternative explanations of imitation behavior and its performance outcomes, such as social pressures, reputational benefits, and differences in tangible resource endowments. We therefore empirically test the propositions drawn from the simulation model by making use of data from multiple-competitor (fleet) sailing boat races during the America's Cup World Series (ACWS) 2011-2012 and 2012-2013. Sailing has been used to study a leader's incentives to imitate the follower in competitive environments (Dixit and Nalebuff, 1991: 10; Ross and Sharapov, in press) and as an analogy to explain theoretical insights of empirical studies in strategic management (Boumgarden, Nickerson, and Zenger, 2012).

The ACWS is a series of regattas taking place at seven different international venues, which consist of multiple sailing teams competing on one-design 45-foot long catamarans in both match (head-to-head) and fleet races. As the competitors in the ACWS sail on one-design boats, the professional sailing circuit offers a setting where performance differences are based primarily on the team's ability to handle their boats, which requires coordinated action between the members of the team responsible for different sails and other boat systems, and on the decisions made during the race by the boat's helmsman. The interdependent nature of strategic decisions taken during a race and the multiple coordinated physical actions required to successfully execute them can be thought of as moderately coupled decisions, making this setting a reasonable one in which to test propositions resulting from a simulation of imitative search on moderately rugged landscapes. In this setting, changes in wind direction, which are exogenous, can have a major effect on race outcomes, as the effective distance that the boats have to sail in order to reach each mark that they must sail through in order to complete the race is dependent on wind direction.

This sports context offers the benefits of a controlled 'living laboratory' with pre-defined rules and boundary conditions. In particular, it allows us to study the effectiveness of a leader's imitation strategy in a multiple competitor setting. Detailed positional data allow us to observe the pattern of multiple competitive moves of the leader and followers over time. Detailed wind data allow us to observe changes in wind direction and volatility which can influence the decisions made by the competitors and their performance outcomes.

Data and Variables

The data we use come from fleet races which are part of a regatta. For each race the teams collect points (e.g., 10 point for the first, 9 points for the second, 8 points for the third, and so forth). The team with the maximum amount of points wins the regatta. The winner of the overall ACWS is that team which has the maximized the number of points over all 6 regattas in the season 2011-2012 and all 3 regattas in the season 2012-2013.

As illustrated in prior work by Ross and Sharapov (in press), a single race works as follows: Once the boats have started, they sail a short sprint to a first mark before the up- and downwind legs begin. They have to sail around the marks in order, but can choose their way between marks. The leeward mark and the windward mark (cf., Figure 3) both take the form of a gate between two buoys so that the boats can sail left or right once entering the gate. Sailing boats cannot sail into the direction from which the wind is blowing. Because the windward mark (the mark on the top of Figure 3) is positioned in line with direction from which the wind is blowing, the boats have to sail a zig-zag pattern to get from leeward to windward mark (i.e., the upwind leg). The sailed trajectory of a boat is influenced by the positioning, timing, and frequency of tacking maneuvers. Similar to other sports, the sailing boats have to remain within the boundaries of the course at all times during a race.

Figure 3 about here

Our data are supplied by the America's Cup Race Management in a publically accessible format and are constructed from three types of information: GPS data on the position of the sailing boats and the boundaries that define the course; information about the direction and the speed of the wind (both this and GPS data are recorded 5 times per second); and "chatter" files that offer information on the race start timing, the competing boats, the mark-rounding order and time, and the umpire decisions. The unit of analysis is the upwind leg. Over a total of 9 events, complete data is available on 62 fleet races, consisting of 138 upwind legs. Missing data on wind direction force us to exclude five of these upwind legs, resulting in a sample of 133 upwinds. While the races were contested by 8 to 11 participating teams, for the purposes of our empirical analysis, we consider only the three competitors that were ahead of the rest of the pack at the start of each upwind.

Dependent Variable. Our dependent variable captures the **minimum change in the lead** of the leader over her rivals over the upwind leg, which is the minimum difference between the lead (in seconds) of the leader at the start of the upwind leg and her lead at the leg's end, relative to competitors who were second and third at the start of the upwind. If d_{12} and d_{13} are the changes in the extent of the leader's advantage relative to rivals who started the upwind in second and third place, respectively, then our dependent variable is calculated as $\min(d_{12}, d_{13})$. This variable takes on positive values if the extent of the leader's advantage over both of her rivals was increased over the course of the upwind, and negative values if at least one of the rivals reduced the gap to the leader.

Independent Variables. We operationalize the leader's imitation strategy by considering the extent to which the leader imitates her challenger (second boat around the mark at the start of the leg, boat C in Figure 3) relative to her neighbor (the boat that is closest to her in terms of position relative to the sides of the course, boat B in Figure 3) over the course of the upwind leg. Specifically, we follow prior work by measuring both the extent to which the leader's actions during the upwind are correlated to those taken a second earlier by her rivals using lagged correlations between the compass headings of the boats, and the similarity of the boats' positions relative to the sides of the course (Ross and Sharapov, in press).

While correlations between compass headings and similarity in positioning relative to the sides of the course have been shown to correspond to two different but complementary kinds of imitation (Ross and Sharapov, in press), for the purposes of this paper we combine both in one measure of the leader's extent of imitation of each of her 2nd- and 3rd-placed rivals. This measure is the normalized correlation in headings ranging from zero (correlation between headings is equal to -1 over the course of the upwind) to one (correlation between headings is equal to 1 over the course of the upwind) weighted by the normalized distance between the average positions of boats relative to the sides of the course over the upwind, ranging from zero if the average lateral distance between the boats in question is the maximum observed during the race day to one if the average lateral distance between the boats is zero. The variable capturing the extent of imitation therefore takes on a value of 0 if the leader imitated neither the actions nor the positioning of a given competitor over the course of the upwind, and a value of 1 if both actions and positioning of a given competitor were fully imitated.

If the leader's extent of imitation of the challenger is higher than or equal to the leader's imitation of her neighbor, we consider the leader to be using a challenger imitation strategy, and the **challenger imitation** binary variable takes on a value of 1. If the converse is true, we consider the leader to be using a neighbor imitation strategy, and the challenger imitation binary variable takes on a value of 0. To control for the extent to which the leader imitates either her challenger or her neighbor, we include an **extent of imitation** variable that takes on the maximum value of the leader's imitation of her 2nd- or 3rd-placed rival, thus corresponding to the extent to which the leader imitated the competitor who was the focus of her imitation efforts during the upwind.

In order to measure the frequency and magnitude of changes to wind direction during the course of the upwind, corresponding to changes to the competitive environment in the simulation, we follow prior work on measuring environmental variations (Miller, Ogilvie, and Glick, 2006). Specifically, we use detailed data on wind direction during the upwind to calculate the **frequency** of environmental changes as the number of wind shifts - reversals of changes in wind direction of at least 2 degrees over 15 seconds - over the upwind normalized by the upwind's duration. To measure the **magnitude** of environmental changes we take the average extent (in degrees) of wind shifts over the course of the upwind.

Control Variables. To rule out competing explanations, we include a number of relevant control variables in our econometric model. We control for the **leader's initial advantage** over her second- and third-placed rivals by including a variable capturing the number of seconds that the leader was ahead of her respective competitors at the start of the upwind leg, and for any **penalty** suffered by rivals during the course of the upwind.

To capture longer-term differences in capabilities between the leader and her rivals, we control for **difference in performance to date** between the leader and her competitors, measured as the difference between the proportion of available fleet race points prior to the current race gained by the leader and those gained by her rivals. This variable is positive if the leader's performance to date is superior to that of a given competitor, and negative otherwise. Additionally, we control for **difference in America's Cup experience** between the helmsman of the leading boat and those of her rivals. This variable takes on a value of 1 if the helmsman of the leading boat has participated in a prior America's Cup competition while the helmsman of the rival boat has not, a value of -1 if the converse is true, and a value of 0 if both helmsmen have the same experience of participating (or not) in prior America's Cup competition.

As competitive behaviors in the final part of a series of competitive interactions might differ significantly from those observed in the rest of the series (e.g., Lehman, Hahn, Ramanujam, and Alge, 2011), we control for whether or not an upwind is the **final upwind** of a race using a binary variable equal to 1 if this is the case and zero otherwise. Finally, we control for possible effects of short- and long-term learning from observing the racing strategies used by other teams by including variable capturing the **race number** of the focal race (its position in that day's racing order), and the **event number** (the position of the event in the series order).

Empirical Results

The descriptive statistics of the variables used in our empirical analysis are presented in Table 1. On average, the leading boat appears to extend its advantage over its rivals over the course of the upwind, and the leader's imitation efforts are focused on the challenger (2^{nd}-placed boat at start of upwind) in close to two-thirds of the upwind legs in our sample. The magnitude of observed environmental changes is small to moderate on average. While the mean magnitude of wind shift of close to 5 degrees and the maximum value of 32 degrees represent important changes to the wind direction, they are far below the theoretical maximum of 180 degree wind shifts. In terms, of frequency, this ranges from 0 to nearly 4 wind shifts per minute of the upwind, with an average value of around 1.6. Our sample thus contains both upwinds in which significant changes to wind direction were absent as well as those in which such changes took place nearly every 15 seconds on average. Again, we do not observed extremely high values of environmental change frequency, as theoretically a wind shift could occur in every second of the upwind.

Table 1 about here

The pairwise correlations between our variables can be seen in Table 2. These do not suggest any cause for concerns regarding multicollinearity, as the only high correlations are between variables measuring the same constructs for leader-2nd-placed and leader-3rd-placed dyads, which are never included in the same model, as we explain in a discussion of our econometric approach below.

Table 2 about here

To evaluate whether and to what extent a challenger imitation strategy is more effective than a neighbor imitation one while accounting for the multiple competitors present in our setting, we use a seemingly-unrelated regression (SUR) approach. Specifically, for each model we run two regressions, one with variables capturing differences between the leader and the rival in 2nd place at the start of the upwind, and one capturing differences between the leader and the rival in 3rd place at the start of the upwind. These models are labelled 2nd and 3rd in our regression tables. SUR takes correlations between the errors terms in these two models into account, thus producing more efficient estimates than would be the case were the models to be estimated separately using OLS. As our sample size is relatively small, we use small-sample t-statistics instead of z-values to evaluate the significance of coefficients. As a robustness check, we also estimate the regression models separately using OLS with heteroscedasticity-robust standard errors, as well as using an alternative, seemingly unrelated estimation (SUEST) approach to accounting for correlation between the error terms of the two models, which also allows the use of heteroscedasticity-robust standard errors.

The results the SUR estimation can be seen in Table 3. Model 1 is the baseline specification that includes only the control variables. Of these, the estimated coefficient on the last upwind of a race is significant and negative, suggesting that leaders lose around 10 to 11 seconds of their lead to at least one of their 2nd- or 3rd-placed rivals during final upwinds of races, while extent of imitation is significant and positive, suggesting that closer imitation of the rival chosen for imitation by the leader tends to be increase the extent of the lead during the course of the upwind.[4] Model 2 introduces the challenger imitation variable into the specification. In itself, this variable is not significant in most specifications, supporting the view that there is indeed no unconditional advantage to imitation being focused on a challenger rather than a neighbor, or vice versa. Model 3 adds the interaction between challenger imitation and the magnitude of environmental changes to the model in order to provide some empirical evidence on proposition 1. The proposition appears to be supported in this setting, as the coefficient on the interaction is negative and significant in all specifications, suggesting that challenger imitation is less effective than neighbor imitation when the environment is subject to shocks of higher magnitude. To test proposition 2, the interaction between challenger imitation and frequency of environmental changes is included in model 4. The estimated coefficient on this interaction is positive, and while it is not significant when included by itself, it is significant at a 5% level when included alongside the interaction between challenger imitation and magnitude in model 5. We thus also find support for proposition 2.

Table 3 about here

Table 4 presents the results of our robustness checks. Model 1 presents the full specification from Table 3 estimated using SUEST with heteroscedasticity-robust standard errors. While there are some differences in terms of the significance of a number of control variables, the estimated coefficients on the interactions between challenger imitation and magnitude, and challenger imitation and frequency are significant and of same sign as reported in Table 3. Models 2 and 3 present the results of separately estimating the models using variables for leader-2nd and leader-3rd dyads, respectively, by OLS with heteroscedasticity-robust standard errors. Again, the estimated coefficients on the interaction terms are significant and of the same sign as in Table 3.

[4] Interestingly, replacing our extent of imitation variable with separate ones for leader and 2nd-, and leader and 3rd-placed boats leads to estimates that show both of these variables to be insignificant across all specifications (results available on request from the authors). This suggests that findings of the extent to which the 2nd-placed rival was imitated by the leader having no significant effect on performance outcomes in a multiple-competitor setting (e.g., Ferrier, Smith, and Grimm, 1999) may be the result of the imitative activity of the leader being focused elsewhere (in some cases), and not of the ineffectiveness of imitation per se.

Table 4 about here

Comparing Simulation and Empirical Results

Taking into account the range of magnitude and frequency of environmental changes (wind shifts) observed in our data on upwinds during the ACWS 2011-2013, the empirical results presented above are consistent with the results from our simulation model. As both the magnitude and frequency of exogenous environmental changes observed in our data range from low to moderate, both simulation and empirical results suggest that in such settings, an increase in the magnitude of environmental changes will result in reduced effectiveness of a challenger-imitation strategy vis-à-vis a neighbor-imitation one, while an increase in the frequency of environmental changes will, conversely, result in the relative effectiveness of a challenger imitation strategy being increased.

Our empirical data provide a good fit for the simulation model, and allow us to evaluate empirically the external validity of the simulation results. Future work will have to use industry data to test our predictions in business contexts and further develop the underlying theory in order to account for the other factors affecting imitation-performance outcomes in such settings, such as legitimacy considerations. The competitive moves observed in our empirical setting are more analogous to market moves than to R&D moves, which can also disrupt the competitive status quo, though in a different manner (Katila, Chen, and Piezunka, 2012). Though the fine-grained data in our empirical setting allow us to construct detailed measures of our core constructs for the empirical analysis, we lack data on cognitive aspects of decision making during the competition or on factors that influence within-team processes. Another limitation is rooted in the small number of observations in the empirical setting. This limits the number of control variables that we can include in our econometric models, and prevents us from empirically investigating potentially interesting conjectures arising from the simulation results, such as three-ways interactions between imitation strategies and the two different dimensions of environmental change.

DISCUSSION

Our simulation model suggests that imitation of poorer-performing rivals can be beneficial for a leader in settings with multiple competitors, but that the relative effectiveness of different imitation strategies varies depending on the magnitude and frequency of exogenous shocks to the competitive environment. In particular, unless frequency and/or magnitude of environmental shocks are very high, an increase in the magnitude of environmental changes decreases the effectiveness of a challenger-imitation strategy relative to a strategy of neighbor-imitation, while an increase in the frequency with which changes to the environment occur increases the relative effectiveness of a challenger-imitation strategy. These propositions are supported by an empirical analysis of multiple-competitor (fleet) races during the America's Cup World Series (ACWS) 2011-2013.

Theoretical Contribution

These findings allow us to contribute to prior work on competitive dynamics that has examined the imitation-performance relationship by extending it to a multiple competitor setting. Using a neo-computational simulation model, we support prior work finding that imitating a follower can be an effective means for a leader to avoid dethronement in two-competitor settings (Ross and Sharapov, in press). We then proceed to show that imitation strategies can also be effective for the leader in multiple competitor settings, though under environmental conditions that are different to the two-competitor case.

Interestingly, our empirical findings show that insignificant results in prior work that only considered the competitive interactions between the first- and second-placed rivals in an industry (Ferrier, Smith, and Grimm, 1999) may be driven by the possibility of the leader focusing on another rival. This suggests that future research on sequences of actions and reactions in competitive dynamics should consider whether the outcomes of competitive interactions depend on the leader's choice of a focal rival towards whom competitive moves are directed.

Furthermore, we find that the effectiveness of a leader's imitation behavior is subject to important boundary conditions. By leveraging exogenous environmental shocks that materially influence the dynamics of competition in both our simulation and empirical analysis, we show that magnitude and frequency of environmental changes matter for the relative effectiveness of different imitation strategies. Both environmental conditions are important as they influence the trade-off between the leader being able to imitate and improve on a rival's configuration, a source of temporary advantages for the leader (D'Aveni et al., 2010), and the leader being able to respond to threats from dissimilar rivals.

We add to the contributions of recent studies on competitive dynamics and evolutionary theories that focused on the origins of sequences of competitive actions and reactions (Katila and Chen, 2008; Katila, Chen, and Piezunka, 2012; Chen et al., 2010), by providing answers to questions about how leaders maintain their leadership position depending on the type of competition (i.e., competitor- or multiple competitor setting), the environmental conditions, and the type of imitation strategy (if any) used. Prior work in this stream of literature has studied outcomes of coevolving competition by comparing insights from two different competitive domains with different environmental conditions. By contrast, this paper studies sequences of competitive interactions in one domain with varying environmental conditions, which allows us to identify non-linear effects of exogenous environmental changes on the imitation-performance relationship for different kinds of imitation strategies.

The insights from our study also extend prior work that has suggested that search for performance improvements can be triggered even when own performance is above aspiration levels (Smith and Cao, 2007). The Red Queen literature emphasized that aspiration levels are endogenous outcomes of competitive dynamics in which search is triggered once own performance falls below aspiration levels (e.g., Barnett and Hansen, 1996; Barnett and McKendrick, 2004; Derfus et al., 2008). Relaxing the assumption that only endogenous forces upset the competitive equilibrium, our theory suggests that proactive imitation by the leader can, under some conditions, be an effective strategy to limit opportunities to catch up with the leader. In competition as race-like contests, low performing competitors favor strategies of increasing performance variability over strategies of improving average performance, which force a leader to do likewise (March, 1991). Uncertainty rooted in rapidly changing environments provides opportunities for those performance variations. Proactive imitation resolves the leader's misfit with combined effect of competitors and the exogenous environmental conditions by lowering the likelihood of potential performance variations that allow a lower ranked rival to catch up.

Interestingly, our findings suggest that imitation strategies can be beneficial for a leader in multiple competitor settings as, in most environments, they allow a leader to improve her own long-term performance relative to rivals by making small improvements to the rival's configuration while allowing the rival to seek out better-performing distant alternatives. Since the leader's performance improvements change aspiration levels of lower performing rivals, it is likely that it will trigger rivals into search as a reaction to these shortfalls in relative performance. Hence, our insights suggest that in addition to problemistic search as a driver of Red Queen competition, such dynamics can also arise due to agents searching for new longer-term opportunities (as opposed to immediate performance improvements) in changing environments. In other words, dynamics that appear to result from efforts to improve performance to meet escalating aspiration levels may in fact be driven by the leader's attempts to prevent Red Queen dynamics through proactive imitation of rivals in multiple competitor settings, destroying their opportunities to catch up.

Finally, by relaxing some of the assumptions commonly used in neo-computational work considering the consequences of imitative search (e.g., Rivkin, 2000; Siggelkow and Rivkin, 2009; Csaszar and Siggelkow, 2010; Posen, Yee, and Li, 2013), we are able to demonstrate some important trade-offs between imitation strategies that result in different combinations of local and distant search behaviors under different environmental conditions. In particular, an imitative leader may benefit from ratcheting dynamics that occur as a result of their focal rival being forced into distant search by the leader's imitative behavior, leaving the leader with the opportunity to make productive minor changes to their rival's configuration, but their ability to do so is a function of both the focus of their imitation and of the magnitude and frequency of shocks to the landscape on which the rivals compete. Additionally, by providing empirical validation for propositions emerging from an NK simulation using fine-grained data from an empirical context that provides a good match for the simulation assumptions, this is, to our knowledge, the first paper that follows the recommendation of validating empirically the results of NK simulation models in order to provide evidence of their external validity (Davis, Eisenhardt, and Bingham, 2007).

Further Research

Our study opens important avenues for future research. Scholars may want to test our predictions and further the theory using different industry contexts. Since exogenous environmental conditions are important for our theory, industry settings that are affected by fluctuating oil-price movements, changes in foreign exchange rates, regulatory changes, and commodity-price movements could be potential areas of study. While conventional wisdom in business practice often leads to resistance towards using imitation strategies, industry studies could examine how imitation strategies (including the leader having a follower as target of imitation) influence the distribution of performance in the industry. Prior work has suggested that imitation behavior under environmental uncertainty can put industries at risk, with potentially costly effect for the society (Lieberman and Asaba, 2006). Since leaders are, under some conditions, actually improving their performance through imitation, future studies may use our insights to further develop answers on net effects of imitation strategies and on the origins of competitiveness. Finally, our study highlights the importance of endogenous and exogenous competitive conditions for the performance outcomes of competitive rivalry, thus contributing to the exploration of the recently raised potential of bridging micro and macro perspectives in competitive dynamics research (Chen and Miller, 2012).

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Table 1: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Minimum change in lead	133	9.795	25.620	-52.2	191.8
Challenger imitation	133	0.639	0.482	0	1
Magnitude	133	4.670	3.529	0	32.105
Frequency	133	1.634	0.864	0	3.75
Extent of imitation	133	0.472	0.231	0.000	0.960
Initial advantage$_{12}$	133	20.641	20.571	0.2	125.6
Initial advantage$_{13}$	133	36.535	26.890	5.6	147.2
Penalty$_{2}$	133	0.030	0.171	0	1
Penalty$_{3}$	133	0.045	0.208	0	1
Difference in perf. to date$_{12}$	133	0.041	0.193	-0.367	0.625
Difference in perf. to date$_{13}$	133	0.074	0.207	-0.444	0.718
Difference in AC experience$_{12}$	133	0.143	0.479	-1	1
Difference in AC experience$_{13}$	133	0.173	0.609	-1	1
Last upwind of race	133	0.444	0.499	0	1
Race number	133	1.594	0.708	1	3
Event number	133	4.827	2.627	1	9

Table 2: Correlations

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. Minimum change in lead	1														
2. Challenger imitation	-0.025	1													
3. Magnitude	0.093	0.085	1												
4. Frequency	0.169	-0.048	0.393	1											
5. Extent of imitation	0.170	0.147	-0.126	0.000	1										
6. Initial advantage$_{12}$	0.037	0.070	0.264	0.262	-0.017	1									
7. Initial advantage$_{13}$	0.199	0.057	0.318	0.253	-0.047	0.870	1								
8. Penalty$_{2}$	0.085	0.041	-0.086	-0.088	-0.089	-0.076	-0.114	1							
9. Penalty$_{3}$	0.112	0.013	0.006	0.076	0.070	-0.117	-0.154	0.174	1						
10. Difference in perf. to date$_{12}$	0.223	-0.031	0.127	0.158	0.041	0.085	0.076	-0.033	0.114	1					
11. Difference in perf. to date$_{13}$	0.066	0.123	0.154	0.142	0.154	0.098	0.042	-0.140	0.063	0.361	1				
12. Difference in AC experience$_{12}$	0.251	0.094	-0.030	-0.100	0.180	0.058	0.098	-0.053	0.087	0.178	0.091	1			
13. Difference in AC experience$_{13}$	0.085	0.111	-0.025	-0.036	0.141	0.086	0.042	-0.050	0.117	-0.003	0.435	0.304	1		
14. Last upwind of race	-0.193	0.041	-0.028	-0.051	0.044	0.380	0.354	-0.069	-0.048	-0.058	-0.092	-0.014	0.020	1	
15. Race number	-0.102	0.078	-0.123	0.044	0.135	-0.108	-0.113	-0.086	0.022	0.108	0.076	-0.006	0.094	0.042	1
16. Event number	-0.063	0.034	-0.241	-0.293	-0.048	-0.136	-0.171	0.113	0.070	-0.125	-0.165	0.146	-0.071	0.013	-0.254

Table 3: Regression results

DV: Minimum change in lead	(1) 2nd	(1) 3rd	(2) 2nd	(2) 3rd	(3) 2nd	(3) 3rd	(4) 2nd	(4) 3rd	(5) 2nd	(5) 3rd
Initial advantage	0.063	0.063	0.065	0.065	0.060	0.060	0.064	0.063	0.053	0.052
	(0.068)	(0.053)	(0.069)	(0.054)	(0.065)	(0.050)	(0.068)	(0.054)	(0.062)	(0.049)
Penalty	1.428	1.670	1.460	1.681	1.352	1.803	1.352	1.618	1.116	1.493
	(4.702)	(3.958)	(4.721)	(3.959)	(4.442)	(3.708)	(4.665)	(3.929)	(4.136)	(3.452)
Difference in perf. to date	1.756	0.316	1.729	0.330	0.873	-0.293	1.717	0.349	0.432	-0.444
	(4.528)	(4.711)	(4.547)	(4.737)	(4.368)	(4.418)	(4.488)	(4.685)	(4.086)	(4.119)
Difference in AC experience	1.475	0.465	1.498	0.479	1.171	0.410	1.517	0.474	1.044	0.429
	(1.814)	(1.550)	(1.817)	(1.551)	(1.719)	(1.448)	(1.794)	(1.542)	(1.599)	(1.352)
Last upwind of race	-10.564*	-10.875**	-10.535*	-10.845**	-10.815**	-11.107**	-10.234*	-10.552*	-10.074*	-10.327*
	(4.148)	(4.162)	(4.144)	(4.157)	(4.075)	(4.039)	(4.137)	(4.165)	(4.002)	(3.978)
Race number	-4.580	-4.509	-4.434	-4.366	-3.724	-3.669	-4.640	-4.558	-3.968	-3.929
	(2.989)	(3.010)	(3.001)	(3.021)	(2.969)	(2.951)	(2.997)	(3.024)	(2.916)	(2.903)
Event number	-0.346	-0.278	-0.317	-0.246	-0.311	-0.257	-0.368	-0.295	-0.452	-0.401
	(0.834)	(0.842)	(0.836)	(0.843)	(0.823)	(0.821)	(0.834)	(0.843)	(0.810)	(0.809)
Magnitude	0.156	0.122	0.203	0.167	4.639**	4.656**	0.116	0.088	6.467***	6.432***
	(0.638)	(0.647)	(0.645)	(0.654)	(1.778)	(1.770)	(0.649)	(0.658)	(1.888)	(1.884)
Frequency	3.959	3.886	3.845	3.773	2.447	2.357	1.001	1.130	-6.022	-5.899
	(2.591)	(2.606)	(2.599)	(2.614)	(2.612)	(2.596)	(3.872)	(3.894)	(4.248)	(4.219)
Extent of imitation	21.475*	21.892*	22.126*	22.539*	23.608**	23.969**	21.338*	21.819*	22.144*	22.498**
	(8.772)	(8.837)	(8.869)	(8.931)	(8.754)	(8.710)	(8.872)	(8.952)	(8.617)	(8.581)
Challenger imitation			-1.996	-1.982	18.497*	18.781*	-9.172	-9.727	7.239	6.759
			(4.231)	(4.263)	(8.723)	(8.694)	(8.972)	(8.871)	(9.749)	(9.772)
Challenger imitation x magnitude					-4.806**	-4.863**			-7.031***	-7.043***
					(1.799)	(1.788)			(1.967)	(1.976)
Challenger imitation x frequency							4.753	4.420	12.785*	13.082*
							(4.795)	(4.854)	(5.207)	(5.212)
Constant	4.489	3.397	4.999	3.888	-13.047	-14.222	10.964	9.444	-5.019	-6.179
	(10.249)	(10.390)	(10.292)	(10.431)	(12.190)	(12.126)	(11.880)	(12.081)	(12.385)	(12.361)
R^2	0.13	0.14	0.14	0.14	0.17	0.18	0.14	0.15	0.21	0.21
N	133	133	133	133	133	133	133	133	133	133

SUR regression; + p<0.1; * p<0.05; ** p<0.01; *** p<0.001; small-sample-adjusted standard errors in parentheses.

Table 4: Robustness checks

DV: Minimum change in lead	(1) 2nd	(1) 3rd	(2)	(3)
Initial advantage	0.038	0.257*	0.038	0.257*
	(0.103)	(0.118)	(0.108)	(0.124)
Penalty	17.682***	16.471*	17.682***	16.471*
	(3.464)	(7.203)	(3.648)	(7.586)
Difference in perf. to date	12.387	-9.961	12.387	-9.961
	(8.962)	(8.349)	(9.439)	(8.793)
Difference in AC experience	10.740*	2.983	10.740*	2.983
	(4.914)	(2.829)	(5.175)	(2.979)
Last upwind of race	-8.927*	-14.632**	-8.927*	-14.632**
	(3.603)	(5.274)	(3.794)	(5.555)
Race number	-4.302	-3.008	-4.302	-3.008
	(3.112)	(2.557)	(3.278)	(2.693)
Event number	-0.734	-0.317	-0.734	-0.317
	(0.673)	(0.774)	(0.709)	(0.815)
Magnitude	5.267+	6.014*	5.267	6.014*
	(3.046)	(2.773)	(3.208)	(2.921)
Frequency	-4.390	-6.160	-4.390	-6.160
	(6.064)	(5.439)	(6.387)	(5.728)
Extent of imitation	18.977*	22.915*	18.977+	22.915+
	(9.299)	(11.112)	(9.793)	(11.704)
Challenger imitation	3.179	8.274	3.179	8.274
	(8.621)	(8.749)	(9.080)	(9.215)
Challenger imitation x magnitude	-5.772+	-6.837*	-5.772+	-6.837*
	(3.090)	(2.837)	(3.254)	(2.988)
Challenger imitation x frequency	11.562+	11.354*	11.562+	11.354+
	(6.600)	(5.719)	(6.951)	(6.023)
Constant	-1.406	-11.647	-1.406	-11.647
	(10.333)	(11.577)	(10.883)	(12.193)
R^2			0.26	0.26
Adjusted R^2			0.18	0.18
N	133	133	133	133

(1): SUEST regression with heteroscedasticity-robust standard errors; (2) and (3): OLS regression with heteroscedasticity-robust standard errors; + p<0.1; * p<0.05; ** p<0.01; *** p<0.001

Figure 1: Differences in the effectiveness of challenger and neighbor imitation strategies in environments subject to changes of different magnitudes (averages from 100 simulation runs)

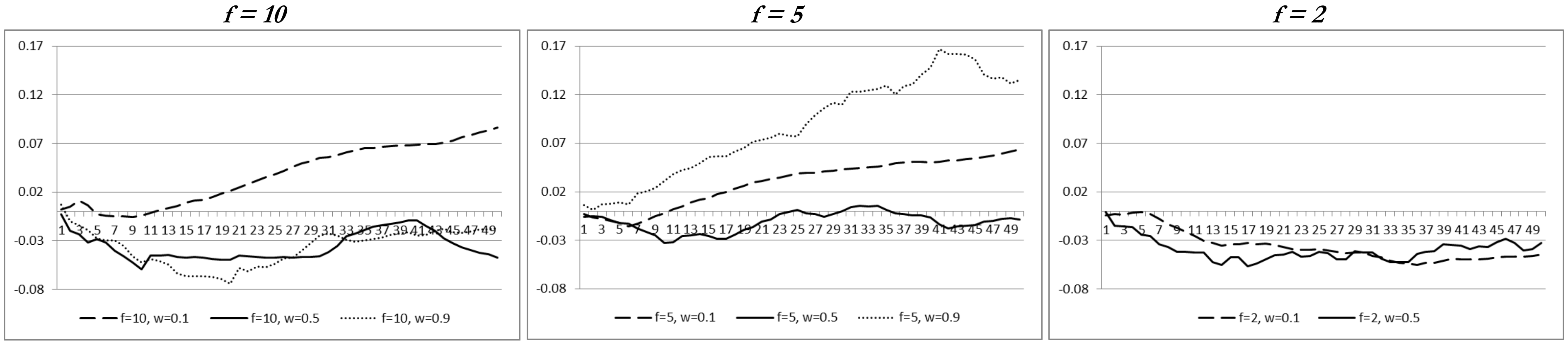

Figure 2: Differences in the effectiveness of challenger and neighbor imitation strategies in environments subject to changes of different frequencies (averages from 100 simulation runs)

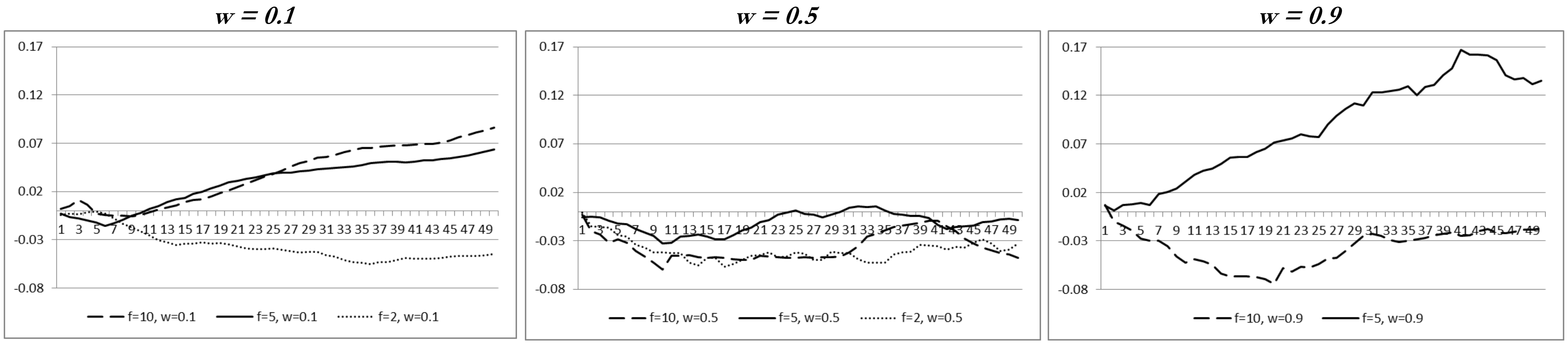

Figure 3: Race course, boundaries, and example trajectory of competitor B