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EROSION, TIME COMPRESSION, AND SELF-DISPLACEMENT OF LEADERS IN HYPERCOMPETITIVE ENVIRONMENTS

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This article examines how leader firms should respond to the erosion of competitive advantages caused by rapid imitation and innovation in hypercompetitive environments. On the one hand, shorter-lived advantages induce leaders to develop new advantages faster. On the other hand, hypercompetition also erodes the expected returns from new advantages—reducing leaders' incentives to accelerate investments. Since investing faster also raises costs, this article shows that leaders often prefer to renew competitive advantages more slowly in more hypercompetitive industries—thereby increasing the probability of being displaced by competitors. This phenomenon is dubbed self-displacement. Firms' decision to self-displace themselves from industry leadership with greater probability is deliberate and rational—not a result of leaders' inability to respond to competitive threats, as previously assumed in the literature. This article also shows that leaders' rule of thumb in more hypercompetitive environments should be to accelerate the development of advantages with high competitive value but low market value. This study is based on a theoretical model and numerical analysis grounded on stylized empirical facts that govern industry competitive macrodynamics and firm investment microdynamics in most industries. Because the model builds on empirically observable constructs, its theoretical propositions are amenable to large sample testing.

INTRODUCTION

Strategy scholars have long been interested in the temporal forces governing the creation and erosion of competitive advantage. Two prominent research streams have directly contributed to our understanding of this phenomenon. The literature on hypercompetition, high-velocity markets, and turbulence has extensively studied the *macro* antecedents of temporary advantages at the industry level (D'Aveni, 1994; Waring, 1996; Eisenhardt and Brown, 1998; Ferrier, Smith, and Grimm, 1999; Wiggins and Ruefli, 2002, 2005; Thomas and D'Aveni, 2009). In contrast, the literature on time-based competition, time compression, and time-consuming resource accumulation has examined the *micro*-foundations of speed-to-market at the firm level (Scherer, 1967; Mansfield, 1971; Dierickx and Cool, 1989; Stalk and Hout, 1990; Eisenhardt and Tabrizi, 1995; Pacheco-de-Almeida and Zemsky, 2007). Although complementary, these two literatures have seldom been integrated in a formal analysis of competitive advantage.

This article fills the gap by examining the effect of industry competitive macrodynamics on firm investment microdynamics in the context of

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a theoretical model and a numerical simulation. This approach explicitly formalizes and extends D'Aveni's (1994) arguments on hypercompetition. The dual analysis of external competition and internal firm time compression allows a series of novel strategy problems to be addressed. Should leader firms always build new advantages faster in hypercompetitive industries to retain leadership? What is the optimal timing to develop new product market positions? And how does it depend on the type of industry hypercompetition—or on whether imitation or innovation is the dominant threat to sustainable advantages? Finally, when should leader firms cannibalize old advantages to preempt rivals?

The general contribution of this research is to show that leader firms may *not* want to sustain industry leadership when exposed to hypercompetition. The rapid concatenation of short-lived advantages required to maintain leadership is optimal only in some fast-moving industries; in others, this strategy may actually erode profits and shareholder value. Two opposing effects explain this result. On the one hand, hypercompetition quickly renders obsolete any given competitive advantage, which encourages leader firms to develop new advantages faster (D'Aveni, 1994). On the other hand, hypercompetition erodes the expected returns from new advantages, which reduces leaders' incentives to accelerate investments. Since investing faster also typically raises costs, leader firms often prefer to renew competitive advantages *more slowly* in hypercompetitive industries—thereby deliberately increasing the probability of being displaced by a competitor. I dub this phenomenon *self-displacement*.

The concept of self-displacement is a new explanation for why industry leaders fail to stay at the top of their industries. It is distinct from prior theories of leadership displacement such as organizational inertia, punctuated equilibria, and disruptive innovation, where leaders are said to be displaced because they cannot respond to competitive threats or are not aware of these threats (Hannan and Freeman, 1984; Tushman and Anderson, 1986; Christensen, 1997). In this article, industry leaders are aware of and have the means to respond to competitive threats, but simply have fewer economic incentives to remain industry leaders. In other words, investing in sustained competitive advantage is sometimes not profit maximizing. This finding also suggests that firms remain long-term leaders of hypercompetitive industries only by destroying shareholder value. Thus, temporary advantages should reign.

Finally, this research develops the bedrock principles of time compression under hypercompetition. I show that whether (or not) hypercompetition leads to time compression depends on moderating factors such as the market value of leaders' advantages, the effectiveness of preemptive strategies, and the type of industry hypercompetition.

In this article, the strategy dynamics literature is reviewed next, followed by a typology of hypercompetitive environments. Then, the theoretical model is presented. I proceed by characterizing the basic principles of time compression in stable environments before turning to the effect of hypercompetition on the microdynamics of firm investment. The conclusion section discusses the results.

STRATEGY DYNAMICS: LITERATURE REVIEW

I extensively reviewed the strategy dynamics and competitive advantage literatures from 1975 to 2007 to identify the main (1) stylized empirical facts and (2) theoretical predictions of how the macrodynamics of industry competition affect the microdynamics of firm investment. The stylized empirical facts were used to ground the assumptions of the theoretical model. This approach lent empirical validity to the theory while reducing unnecessary complexity not supported by existing phenomenological evidence. As a result, the model is largely consistent with prior econometric studies on the persistence of abnormal returns, which allows the calibration of its parameters using empirical estimates. The main theoretical predictions in the extant literature were, in turn, used to assess how exactly this article—and its results—advance our understanding of strategy dynamics.[1]

[1] This exercise also proved a useful way to audit the logic of prior verbal theories. This research methodology has increasingly been credited as valuable to generate new strategy theory. 'Mathematical models are particularly important in the study of dynamics, because dynamic phenomena are typically characterized by nonlinear feedbacks, often acting with various time lags. Informal verbal models may be adequate for generating predictions in cases where assumed mechanisms act in a linear and additive fashion (as in trend extrapolation), but they can be very

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The field of strategy dynamics has recently experienced burgeoning attention from scholars in strategy and economics, with published and unpublished work increasing exponentially in the past two decades by more than one order of magnitude. The two most influential literatures in publications and impact—also outside academia, as measured by the number of non-scholarly articles and Web impact—have been the work on hypercompetition and firm speed, which constitute the focus of this article. Hypercompetition and firm speed accounted for 21 and 32 percent of all articles published on strategy dynamics in business journals in the period 1975–2007. The next two subsections detail the results of the survey.[2]

Stylized empirical facts

All major articles in the survey were perused to identify empirical regularities governing the temporal dynamics of competitive advantage—its creation and erosion over time. Five main stylized empirical facts have been consistently shown in prior literature to hold across most industries. Stylized Facts 1 to 3 report the effect of industry competitive *macrodynamics* on the persistence of abnormal economic performance. Stylized Facts 4 and 5 characterize the *microdynamics* of time compression—the basic laws of capital investment when firms accelerate the creation of new advantages.[3] The facts are first listed and then documented.

Stylized Fact 1: Any abnormal firm-specific returns associated with a given competitive advantage eventually regress to the industry mean.

Stylized Fact 2: The pace of regression to the mean of firm-specific returns has accelerated over time in most industries.

Stylized Fact 3: The pace of regression to the mean of firm-specific returns differs across industries due to variation in the intensity of rival imitation and innovation.

Stylized Facts 1 to 3 have been established by a number of different empirical literatures—first and foremost, by prior work on hypercompetition and the persistence of intra-industry rents (Geroski and Jacquemin, 1988; Jacobsen, 1988; Schohl, 1990; Droucopoulos and Lianos, 1993; D'Aveni, 1994; Goddard and Wilson, 1996; Waring, 1996; Wiggins and Ruefli, 2002, 2005; Bou and Satorra, 2007; Thomas and D'Aveni, 2009). These studies have shown that competition erodes rents and have used autoregressive and stratification techniques to measure the rates of convergence of firm profitability to the industry mean and the time frames of sustained advantage. Second, the literature on industry life cycle dynamics has also provided systematic evidence consistent with Stylized Facts 1 to 3. Specifically, this research stream has showed that the time interval between the commercial introduction of a new product and rival imitation has substantially decreased over the last century (Gort and Klepper, 1982; Gort and Konakayama, 1982; Gort and Wall, 1986; Klepper and Graddy, 1990; Agarwal and Gort, 1996, 2001, 2002; Klepper and Thompson, 2006). Competition has created a race to take on new market opportunities swiftly and achieve economies of scale early in the industry life cycle, while prices are still relatively high (Jovanovic and MacDonald, 1994).

Third, the literature on first mover advantages has widely documented the conditions under which pioneering advantages are eroded over time in

misleading when we deal with a system characterized by nonlinearities and lags' (Ghemawat and Cassiman, 2007: 530). Recent examples of articles that have also contributed to the formal foundations of strategy include Makadok and Barney (2001), Adner and Zemsky (2006), Brandenburger and Stuart (2007), and Lenox, Rockart, and Lewin (2007).

[2] The survey was conducted in five main search engines: ProQuest, Google Scholar, Google News Archive Search, Google Web, and Google Books. Data for 2008 proved to be unreliable and preliminary in some of the search engines and, thus, is not reported in this article. I surveyed the literature post-1975 because the first noticeable boom in strategy research reportedly occurred during that period (Ghemawat, 2002) and work on strategy dynamics is unlikely to have started before the mid-1970s, as 'dynamic thinking (...) has [only] absorbed the bulk of academic strategists' attention in the last fifteen-plus years' (Ghemawat, 2002: 70). While accounting for every single paper and book in the field of strategy dynamics is an unfeasible task, the survey results should be representative of the aggregate publication trends in the academic literature from 1975 to 2007. The details of the survey are available from the author upon request.

[3] All search results classified as industry macrodynamics refer to literature mostly examining the timing of erosion of competitive advantage. This is work on factors that typically lie outside the control of any specific firm—external mechanisms at the industry level that determine the pace at which competitors copy or innovate around existing advantages. In contrast, search results on firm microdynamics represent research on the timing of creation of new advantages. This work analyzed internal firm investment decisions or drivers of competitive advantage that are directly controlled by individual firms.

different industries (Lieberman and Montgomery, 1988; Mitchell, 1991; Golder and Tellis, 1993; Lieberman and Montgomery, 1998; Suarez and Lanzolla, 2007; Franco *et al.*, 2009). Recent work on market entry order has also measured the average period of calendar time during which first mover firms enjoy abnormal returns (e.g., Boulding and Christen, 2003). Finally, Stylized Facts 1 to 3 are also supported by the literatures on Red Queen evolution (Barnett and Hansen, 1996; Barnett and Pontikes, 2008) and high-velocity markets (Eisenhardt, 1989; Brown and Eisenhardt, 1998). This line of research has found evidence that, as organizations struggle to cope with increasing competitive pressures, their fitness levels improve—raising the baseline against which competitive advantage is measured. Next, I turn to the microdynamics of time compression.

Stylized Fact 4: Project acceleration raises investment costs at an increasing rate.

Stylized Fact 5: The acceleration-cost trade-off varies with the extent of diminishing returns to effort, the degree of project complexity, and the level of firm speed capabilities.

The microdynamics of firm investment governing the timing of creation of new advantages are characterized by a well-documented temporal force: *time compression diseconomies* (Stylized Fact 4). The literature on firm speed has argued that the rate at which firms develop new products and technologies intrinsically depends on their internal pace of resource accumulation. Strategic projects that support privileged market positions require the commitment and deployment of valuable and rare firm-specific resources to product markets (Barney, 1991; Ghemawat, 1991). These firm-specific resources cannot be instantaneously purchased on strategic factor markets. Instead, they must be internally accumulated by firms over time through a series of investments (Barney, 1986; Dierickx and Cool, 1989). Firms' internal pace of resource accumulation is generally subject to time compression diseconomies: reducing project duration often raises costs, and more severe compressions are purchased at increasingly higher costs (Scherer, 1967, 1984; Dierickx and Cool, 1989).

Empirical estimates of the acceleration-cost trade-off abound in the strategy, economics, and operations literatures (see Graves, 1989, for a review). Cost increases may be substantial—up to 7.4 percent for a 1 percent reduction in project duration. For example, Mansfield's (1988) elasticity estimate of time compression diseconomies in the electrical and instruments industry of 4.3 percent imply that a two-week schedule compression of Intel's 386 microprocessor development would have resulted in a \$8.6 million increase in costs (Casadesus-Masanell, Yoffie, and Mattu, 2005). Stylized Fact 4 has been incorporated in theoretical work on time compression (Pacheco-de-Almeida and Zemsky, 2007, 2009) and technology adoption (Reinganum, 1981; Fudenberg and Tirole, 1985; Riordan, 1992).

Several factors have been reported to affect the magnitude of time compression diseconomies (Stylized Fact 5). Speeding up a project usually involves crash investments, where more resources are deployed to the project at each point in time. The law of diminishing returns (where one input, viz. time, is held constant) typically limits overall productivity and drives up investment costs. In addition, time compression diseconomies tend to increase in project complexity, or the number of development steps of a project. Indeed, investment acceleration often requires parallel processing of previously sequential development steps, which reduces internal information flows across stages of the development process, increasing mistakes, rework, and costs. Finally, the acceleration-cost trade-off is also directly dependent on firms' capabilities. With superior capabilities, firms may be able to develop new competitive advantages faster or incur fewer investment costs. This same idea has been the hallmark of prior work on time-based competition (Stalk, 1988; Stalk and Hout, 1990).

Theoretical predictions

Prior literature has done more than just empirically document the macrodynamics of erosion and the microdynamics of creation of competitive advantage: it also verbally theorized how the former might affect the latter. The survey identified three main theoretical predictions in past research about the hypothesized effect of industry competition on firm time compression. This series of predictions summarizing the received knowledge sets the standard against which to assess whether the results of this article advance our understanding of strategy dynamics.

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One of the focal points of debate in the strategy dynamics literature has been how leader firms can enjoy persistent superior performance in hypercompetitive industries when abnormal returns quickly regress to the industry mean. This question lies at the heart of most literatures on strategy dynamics, including prior work on hypercompetition and Schumpeterian competition (D'Aveni, 1994; Nault and Vandenbosch, 1996; Wiggins and Ruefli, 2002, 2005), high-velocity markets (Eisenhardt, 1989; Eisenhardt and Tabrizi, 1995; Brown and Eisenhardt, 1998; Eisenhardt and Brown, 1998), time-based competition (Stalk, 1988; Stalk and Hout, 1990), Red Queen evolution (Barnett and Hansen, 1996; Barnett and Pontikes, 2008), dynamic capabilities (Teece, Pisano, and Shuen, 1997; Helfat *et al.*, 2007; Teece, 2007), and firm speed (Nayyar and Bantel, 1994; Siggelkow and Rivkin, 2005; Pacheco-de-Almeida, Hawk, and Yeung, 2010). In a nutshell, the idea put forward in these literatures is that, when any given advantage decays rapidly due to intense competition, leader firms can sustain superior performance only by concatenating a series of (short-lived) advantages. This implies that leaders must accelerate their investments in new products and technologies and launch them sooner—the relentless self-cannibalization of existing market positions being a prerequisite to retain industry leadership.

Prediction 1: In industries with faster regression to the mean of firm-specific returns, a leader firm should accelerate the development of new competitive advantages.

Prediction 2: In industries with faster regression to the mean of firm-specific returns, a leader firm should cannibalize more its existing competitive advantage.

Prediction 3: In industries with faster regression to the mean of firm-specific returns, a leader firm that accelerates the development of new competitive advantages is more likely to maintain industry leadership and sustain abnormal returns.

The verbal theorizing leading to normative Predictions 1 to 3 is based on evidence reported in Stylized Facts 1 to 3, which essentially advocate the value of being fast to market. However, these normative conclusions have largely ignored Stylized Facts 4 and 5: that acceleration comes at a cost. In other words, most past studies on hypercompetition have been one-sided views of speed, focusing exclusively on its benefits. In contrast, this article offers an integrated formal analysis of the project acceleration decision problem. By weighing the opportunity costs of entering a market too late against the costs of speed, this research can determine the optimal level of time compression in firms' activities in turbulent industries. This approach is used to revisit Predictions 1 to 3.

A TYPOLOGY OF HYPERCOMPETITION

Stylized Facts 1 to 3 on industry competitive macrodynamics create a simple typology of hypercompetitive environments that structures the analysis throughout this article. *Hypercompetition is measured by the pace of erosion, or regression to the mean, of abnormal returns*, such that more hypercompetitive industries are characterized by faster convergence of firm profits to the industry mean. The pace of regression to the mean of abnormal returns is set by the intensity of rivals' (1) innovation and (2) imitation in the industry (Stylized Fact 3). These two competitive forces have been unequivocally identified in the literature as the two main threats to the sustainability of competitive advantage of industry leader firms (e.g., Barney, 1991; D'Aveni, 1994). The pace at which competitors innovate in an industry has been referred to in the literature as *industry innovation clockspeed* (Fine, 1998; Mendelson and Pillai, 1999; Mendelson, 2000). I use this same terminology in this article to denote the average number of new products, processes, or technologies launched in an industry per period of time. In contrast, the speed of rivals' imitation of a given competitive advantage is determined by the average time that competitors take to accumulate resources in an industry, as advocated in the resource-based view (see, for e.g., Dierickx and Cool, 1989; Cohen *et al.*, 2002; Pacheco-de-Almeida, Henderson, and Cool, 2008). I refer to these imitation lags as *industry imitation clockspeed*.

Figure 1 defines the typology of hypercompetitive environments adopted in this research. Hypercompetition depends on the strength of the two main threats to sustainable competitive advantage:

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industry innovation clockspeed and industry imitation clockspeed. Industries with slow innovation and imitation clockspeed are *stable*, or non-hypercompetitive, environments. These are industries with highly persistent profitability differences between firms. Industries with slow innovation clockspeed but fast imitation clockspeed are characterized by *imitative* hypercompetition. Conversely, *innovative* hypercompetition prevails in industries with fast innovation clockspeed and slow imitation clockspeed. Finally, in environments with dual hypercompetition, both types of industry clockspeed are fast. 'This creates an environment (...) in which advantages are rapidly created and eroded' (D'Aveni, 1994: 2), akin to Red Queen competition (Barnett and Hansen, 1996; Barnett and Pontikes, 2008) since 'it takes all the running you can do to stay in the same place' (Carroll, 1904: 47).

The four cells in Figure 1 may represent different industries or, alternatively, different stages of one same industry life cycle. For example, innovation clockspeed is likely to slow down as industries decline. Several empirical estimates of hypercompetition and industry innovation and imitation clockspeed can be found in the literature. The results systematically document a wide variation in clockspeed across different industries: imitation lags range from as little as 10 months in footwear up to 46 months in the aircraft manufacturing industry, whereas innovation occurs in infra-annual cycles in the PC industry but takes up to 40 years in steel products (Fine, 1998; Mendelson and Pillai, 1999; Koeva, 2000; Cohen *et al*., 2002).

Most evidence also supports the view that both innovation and imitation clockspeed have recently been accelerating economy wide. This pattern is entirely consistent with Stylized Facts 1 to 3 and suggests a general convergence of most industries to the bottom-right cell in Figure 1—in which dual hypercompetition dominates. In this context, stable industries are increasingly rare. According to Waring (1996), the U.S. automobile industry was a stable industry in the 1970s, with persistent profit differences between the Big Three automakers. However, the early lead enjoyed by General Motors was rapidly eroded in subsequent periods. The three types of hypercompetition in Figure 1 (imitative, innovative, and dual) are analyzed in the model.

MODEL SPECIFICATION

The model examines the problem of an industry leader firm that has to decide on the development time T_i of its next competitive advantage in stable versus hypercompetitive environments (i indexes environment types). The firm maximizes the present value of expected product market revenues net of the development costs of the new advantage for a given discount rate (or cost of capital) r, $\Pi_i(T_i) = R_i(T_i) - C(T_i)$. The model is in continuous time denoted by $t \geq 0$. The revenue $R_i(T_i)$ and cost $C(T_i)$ functions are defined below. All proofs can be found in the Appendix.

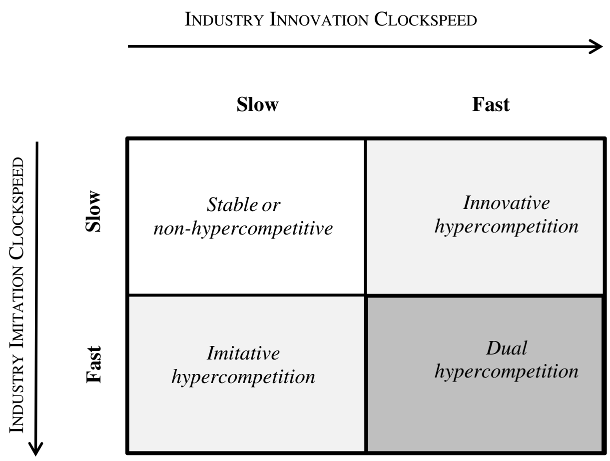

Figure 1. A typology of environmental hypercompetition (N.B.: darker shades indicate higher levels of hypercompetition)

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Competitive macrodynamics

Product market revenues are defined as follows: At the beginning of the period of analysis ($0 \leq t \leq T_i$), the leader firm has an initial competitive advantage with instantaneous revenue flows of $\pi_0(t, \delta) \geq 0$, whereas all its competitors earn the long-term industry average equilibrium profits (normalized to 0, without loss of generality). At time T_i, the leader firm creates a new competitive advantage and deploys it to the product market, and its instantaneous revenue flows increase to $\pi_1(t, \delta) \geq 0$. Note that $\pi_j(t, \delta)$ measures the intrinsic market value of each competitive advantage j ($j = 0,1$). Uncertainty about the market value of the new advantage is not considered because it does not qualitatively change our results and complicates the analysis. By default, it is assumed that the new competitive advantage of the leader replaces, or substitutes, the initial one—the case of sequential new product or technology generations. However, in a model extension, this assumption is relaxed to allow for additive competitive advantages in the context of (geographic or product market) diversification strategies.

Consistent with Stylized Facts 1 to 3 and the earlier section on the typology of hypercompetition, the sustainability of any given competitive advantage of the leader firm is dependent on two main competitive threats: imitation and innovation. *Imitation*, or the *intensity of imitation*, determines the rate of erosion or decay $\delta \geq 0$ of the leader's abnormal revenues to the industry mean over time. In the model, I consider exponential revenue decay $\pi_j(t, \delta) = \pi_j e^{-\delta(t - jT_i)}$ ($j = 0,1$), which is a continuous time approximation to the standard discrete time autoregressive models used in most empirical work to estimate the rate of persistence of abnormal returns (Geroski and Jacquemin, 1988; Jacobsen, 1988; Schohl, 1990; Droucopoulos and Lianos, 1993; Goddard and Wilson, 1996; Waring, 1996; Bou and Satorra, 2007).[4] *Innovation*, or the pace at which industry rivals introduce new products or business models, may render the leader firm's advantages obsolete. I assume that competitive innovation that displaces leader firms in a certain industry has a Poisson distribution with average frequency $\lambda > 0$ per period of time. Therefore, the length of the time interval between rivals' innovations over which the leader firm is able to sustain its competitive advantages has an exponential distribution. Specifically, the probability that the incumbent firm remains the leader at time t is given by $p(t, \lambda) = e^{-\lambda t}$, where $\lambda \geq 0$.[5] When competitors innovate, the leader firm is instantaneously displaced and earns the long-term industry average equilibrium profits of 0. In a model extension, I also examine the case in which the leader's new competitive advantage can deter future innovation by rivals. There, the leader is never displaced if it launches its next advantage before rivals innovate.

The industry rate of regression to the mean of firm-specific returns due to imitation δ and

[4] For example, Waring's (1996) pooled OLS model to estimate the persistence of firm-specific rents over time for 68 different manufacturing industries from 1970 to 1989 was $f_{j,t} = a_j + b(f_{j,t-1}) + e_{j,t}$, where $f_{j,t}$ is firm j^{th}-specific rent component at time t and $b \in (0, 1]$ is 'the percentage of a firm's rent in any period before period t that systematically remains in period t' (Waring, 1996: 1255). This model is equivalent to $f_{j,t} = a_j \frac{1 - b^t}{1 - b} + b^t f_{j,0}$, which is identical to my specification with $a_j = 0$, $f_{j,0} = \pi_j(0, \delta) = \pi_j$, and $\delta = \ln \frac{1}{b}$ is the continuous time inverse of Waring's persistence measure (i.e.,

$$b^t = \lim_{n \to \infty} \left(\frac{1}{\left(1 + \frac{\delta}{n}\right)^n} \right)^t = e^{-\delta t},$$

where $\delta \in [0, +\infty)$ since $b \in (0, 1]$. Note that continuous time decay models similar to the one developed in this article have found multiple applications in economics, finance, and physics (e.g., to model radioactive decay).

[5] The exponential distribution has a density given by $f(t, \lambda) = \lambda e^{-\lambda t}$, with a constant positive hazard rate over time ($\lambda > 0$). Thus, the probability that the leader is not displaced (i.e., that competitors do not innovate) is $p(t, \lambda) = 1 - \int \lambda e^{-\lambda t} dt = e^{-\lambda t}$. Note that I define the probability distribution also for the case where $\lambda = 0$ for convenience of notation, as it allows for a more parsimonious description of the environmental typology studied in the article. Specifically, when $\lambda = 0$, there is no competitive innovation and the focal firm remains the industry leader with probability 1. The scale parameter λ is exogenously given in the model by the average frequency of innovation in an industry, or the industry innovation clockspeed (see the earlier section on typology of hypercompetition). In industries where process innovation is the leading driver of change, then λ should measure the industry process innovation clockspeed. Finally, while the assumption that rivals' innovation follows a Poisson distribution is the standard probabilistic representation of a count variable of focal events per period of time (e.g., Mood, Graybill, and Boes, 1974), it also ensures the analytical tractability of the model. Specifically, the exponential distribution denoting the length of time between rivals' innovation is identical in functional form to the exponential revenue decay from imitation. This fact makes it possible to derive closed-form expressions for some of the variables of interest and to carry out the analysis of comparative statics that support much of the results. The qualitative findings in the model should be generally robust to alternative specifications of rival innovation distribution probability because innovation always undermines the leader's future returns from investing in new competitive advantages.

innovation λ provide a bidimensional characterization of the environmental typology studied in this article. As in the section on the typology of hypercompetition, four main types of competitive environments i are considered: (1) stable, or non-hypercompetitive, environments (denoted by $i = S$), where $\delta = \lambda = 0$; (2) environments with imitative hypercompetition ($i = Im$), where $\delta > 0$, $\lambda = 0$; (3) environments with innovative hypercompetition ($i = In$), where $\lambda > 0$, $\delta = 0$; and (4) environments with dual hypercompetition ($i = D$), where δ, $\lambda > 0$. Note that δ and γ jointly measure the intensity of market hypercompetition, such that increasing δ and λ 'creates an environment (...) in which advantages are rapidly created and eroded' (D'Aveni, 1994: 2). Let the set of hypercompetitive, or unstable, environments be generally denoted by $H = \{Im, In, D\}$. Define $\Delta = \pi_1(0, \delta) - \pi_0(0, \delta) > 0$ as the increase in revenue flows for the leader from developing the next competitive advantage, which is a constant across the four types of environments ($\Delta = \pi_1 - \pi_0$, the increase in revenue flows from launching the new advantage in stable environments). Thus, the revenue function in the baseline model is given by

$$R_i(T_i) = \int_0^{T_i} p(t, \lambda)\pi_0(t, \delta)e^{-rt}dt + \int_{T_i}^{\infty} p(t, \lambda)\pi_1(t, \delta)e^{-rt}dt$$

Cannibalization is defined as the total expected revenues from the leader's existing competitive advantage that are forgone due to the development of a new competitive advantage, $F_i = \int_{T_i}^{\infty} p(t, \lambda)\pi_0(t, \delta)e^{-rt}dt$ (where $i = S, H$). It is straightforward to see that the leader firm cannibalizes its initial competitive advantage only when advantages are sequential (i.e., when the new advantage replaces the previous one). In the case of geographic or product market diversification, advantages are additive and, thus, no cannibalization occurs. Leadership transition frequency is the probability that the leader firm is displaced by a competitor through innovation, $L_i = 1 - e^{-\lambda T_i}$ (where $\lambda > 0$, $i = S, H$).

Figure 2 is an example of how the model represents the erosion and convergence to the mean of expected firm-specific returns in the auto industry during the 1970s. The parameters δ and λ were calibrated using estimates of autoregressive discrete time model coefficients in prior empirical work on the persistence of superior economic performance of car manufacturers. Waring reports that 'an industry with highly persistent profitability differences is the American automobile industry in the 1970s (...)—with convergence rates (...) [of] almost zero' (Waring, 1996: 1253). Hence, during the period of analysis, the U.S. auto industry *de facto* qualified as a stable industry with $\delta_{US} = \lambda_{US} = 0$. In contrast, Geroski and Jacquemin (1988) estimated the persistence of

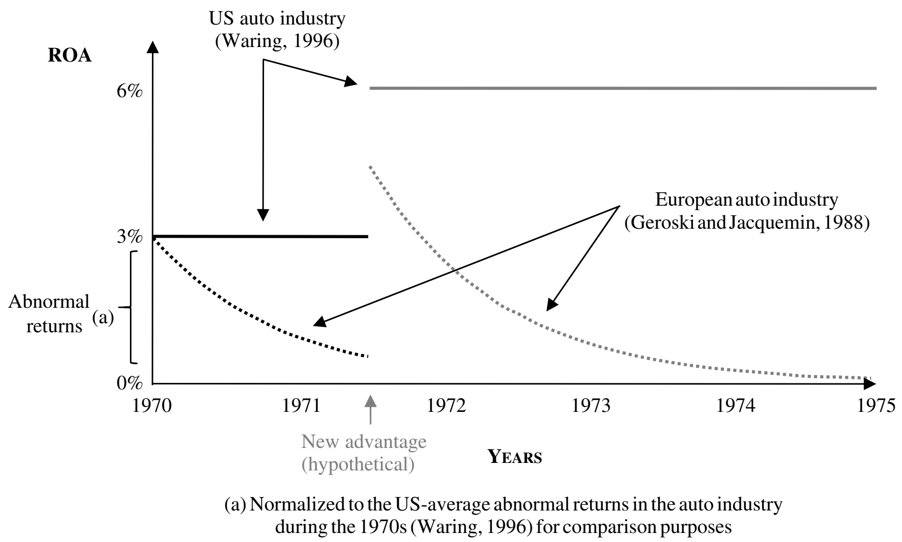

Figure 2. Example of how expected firm-specific returns regress to the industry mean in the model (N.B.: parameters calibrated using the continuous time inverse of persistent measures for the 1970s' auto industry)

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firm-specific returns in the European auto industry in the 1970s to be considerably higher, at approximately 0.328, which is equivalent to a continuous time rate of regression to the mean of $(\delta_{EU} + \lambda_{EU}) = 1.1147$ (see Footnote **4**). For illustration purposes, Figure 2 also shows the effect of a hypothetical new advantage (arbitrarily assumed to be developed in 1971) on the stream of rents earned by an industry leader.

Investment microdynamics

In the model, the development of new product market positions requires the internal accumulation of nontraded resources. As in Stylized Fact 4, I assume that the time-consuming asset stock accumulation process is subject to time compression diseconomies such that faster development of the new competitive advantage by the leader results in higher investment costs (Dierickx and Cool, 1989; Graves, 1989). This time-cost trade-off is given by the cost function $C(T_i) = \frac{(1-d)^2 K^2 r}{e^{rT_i} - 1}$, which was originally derived by Pacheco-de-Almeida and Zemsky (2007) for a similar micromodel of asset stock accumulation with diminishing returns to effort. The reason to use Pacheco-de-Almeida and Zemsky (2007)'s functional form for $C(T_i)$ is threefold: first, the function is not an *ad hoc* assumption but endogenously derived from the microdynamics of resource accumulation. Second, it gives tractability to the model.[6] Third, the cost function is consistent with Stylized Fact 5. The costs of developing the new advantage increase in K, the underlying complexity of the advantage (e.g., the technical sophistication of the new product to be launched). Development costs decrease in the level of speed, or time compression, capabilities d—firms' intrinsic ability to quickly accumulate the resources. With higher levels of speed capabilities, the leader either develops the new advantage more quickly (for a fixed level of investment) or has less costs (for a given development time). The leader firm incurs the development costs at the beginning of the period of analysis. Note that I restrict the analysis to parameter values for which the leader firm always has incentives to develop the next advantage.

Figure 3 illustrates the cost function using parameter values estimated for refinery plant construction from 1996 to 2005 in Pacheco-de-Almeida *et al.* (2010). On average, an oil refinery took 30 months and \$230 million to expand. Efforts to accelerate refinery construction increase costs, as in Stylized Fact 4. The magnitude of time compression diseconomies is reduced when firms possess superior speed capabilities (Stylized Fact 5).

THE EFFECT OF HYPER-COMPETITION ON INDUSTRY LEADERSHIP

The erosion of firm-specific returns has accelerated over time in most industries (Stylized Fact 2). This increase in hypercompetition has been credited as one of the main reasons for the widespread displacement of industry leaders in recent years. Yet, this explanation for why leader companies fail raises the important follow-up question of why leaders haven't accelerated the development of new competitive advantages in response to the increasing pace of competition, as advocated by most management scholars (Prediction 1).

The baseline case: stable environments

To understand the effect of hypercompetition on industry leadership, we first need to study the creation of new advantages by leader firms in controlled, or non-hypercompetitive, environments. The basic laws of investment acceleration in stable industries set the foundations for the subsequent analysis of environmental hypercompetition. The fundamentals of this baseline case were originally solved by Pacheco-de-Almeida and Zemsky

[6] Pacheco-de-Almeida and Zemsky (2007) solved the following investment problem. A firm makes investments at time t, $z_t \geq 0$, to accumulate the stock of resources required to develop the new competitive advantage, where there are diminishing returns to investment $(z_t)^\alpha$ for some $\alpha \in (0, 1)$. It is assumed that the stock of resources required to develop the new advantage is increasing in the underlying complexity of the next advantage K and decreasing in the firm's general ability to develop the advantage d, $(1-d)K$. For a given time T_i, the investment profile must be such that $\int_0^{T_i} (z_t)^\alpha dt = (1-d)K$, which assures that the firm accumulates the resource stock by time T_i. The cost-minimizing investment profile is shown to be $z_t^*(T_i) = e^{rt/(1-\alpha)} \left(\frac{\alpha}{1-\alpha} \frac{r(1-d)K}{e^{rT_i\alpha/(1-\alpha)} - 1} \right)^{1/\alpha}$. Therefore, the resulting cost function is $C(T_i) = \int_0^{T_i} z_t^*(T_i) e^{-rt} dt$ or $C(T_i) = (1-d)^{1/\alpha} K^{1/\alpha} \left(\frac{\alpha}{1-\alpha} \frac{r}{e^{rT_i\alpha/(1-\alpha)} - 1} \right)^{(1-\alpha)/\alpha}$. In this article, I assume quadratic cost of progress ($\alpha = 1/2$), which simplifies the cost function to $C(T_i) = \frac{(1-d)^2 K^2 r}{e^{-rT_i} - 1}$ and gives tractability to the model.

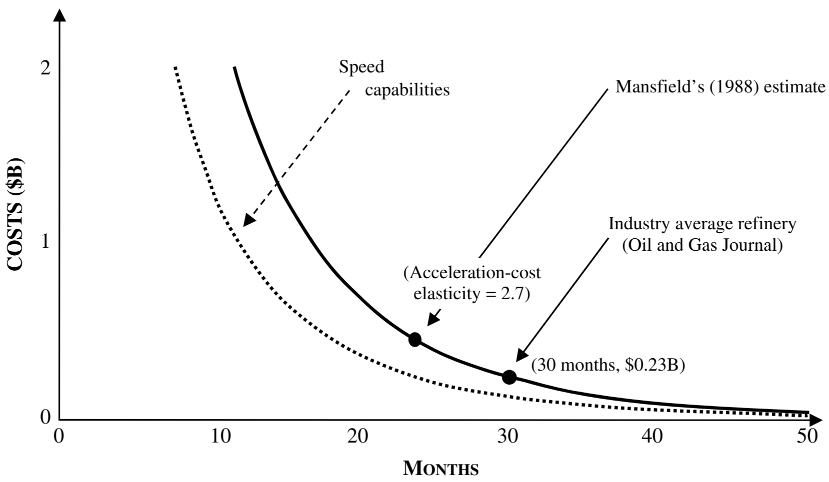

Figure 3. Example of how costs increase with investment acceleration in the model (N.B.: parameters calibrated using estimates for refinery construction from 1996 to 2005 in Pacheco-de-Almeida *et. al.*, 2010)

(2007). In this subsection, I restate the main results of that paper for later comparison purposes, but also extend the analysis.

In noncompetitive settings, advantages are perfectly sustainable because rivals' imitation and innovation are either inexistent or inconsequential ($\delta = 0$ and $\lambda = 0$). Note that stable environments include, but are *not* limited to, situations of pure monopoly in non-contestable markets. A case in point is the U.S. auto industry in the 1970s, which reportedly exhibited persistent differences in profitability between firms despite considerable imitation and innovation efforts by competitors over time (Waring, 1996). The electric utilities industry is a more standard example of a non-hypercompetitive environment: up until recently, large regional monopolies controlled the entire supply chain from power generation to retail supply. Industry innovation and imitation clockspeed for electric utilities is very slow—product and process innovations occur only in cycles of 50 to 100 years (Fine, 1998). Industry imitation clockspeed, or the pace at which rivals accumulate resources to enter the market or pursue imitation strategies, is also slow. For example, utility firms take, on average, more than seven years to amass the assets required to bring new production facilities online. This contrasts with the majority of other industries studied by Koeva (2000), where the average time-to-build of new plants is two years.

Figure 4 illustrates the revenue-cost trade-off that leader firms face when deciding how fast to develop new advantages. On the one hand, the development of a new competitive advantage is expected to increase firm revenues. Thus, delays in introducing this advantage to the product market result in revenue losses: later launch times move further into the future the new stream of rents, which become more heavily discounted. These potential forgone revenues (represented in Figure 4 by the downward-sloping revenue curve) give leader firms incentives to accelerate the development of new advantages. But is faster development always better? On the other hand, acceleration raises investment costs at an increasing rate due to time compression diseconomies (represented in Figure 4 by the convexity of the cost curve). Given this investment problem, a leader firm's optimal new competitive advantage development time is such that any marginal acceleration in project development would equally increase revenues and costs. This optimal time also maximizes profits, or the difference between revenues and costs in Figure 4.

Any variable that induces parametric shifts in the revenue or cost curves in Figure 4 affects the optimal level of acceleration of new advantages. For example, when the leader possesses superior speed capabilities or its advantages are less complex, the cost curve is less convex (see Figure 3) and faster development is optimal. Leader firms also prefer to accelerate investments the higher the market value of the new advantage is relative to the existing advantage—a situation that shifts upward the revenue curve in Figure 4. In contrast, with

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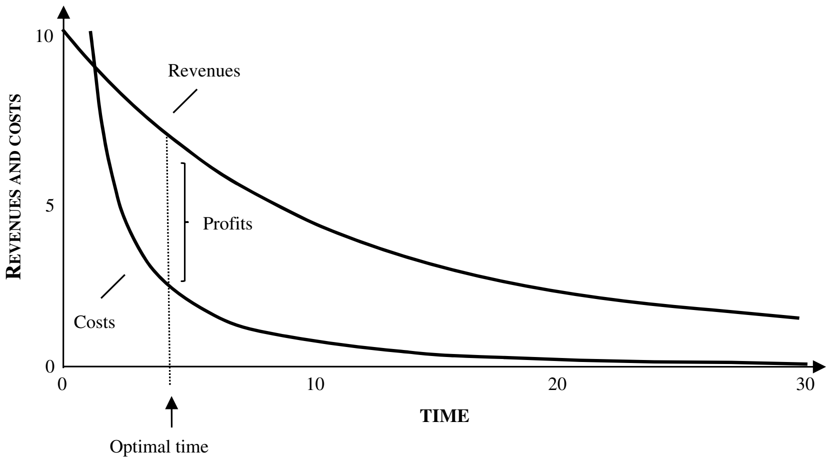

Figure 4. Optimal development time of new advantages for $\pi_1 = 1$, $\pi_1/\pi_2 = 10$, $d = 0.1$, $K = 4$, $r = 0.1$, and $\delta = \lambda = 0$.

higher cost of capital, long-term revenues are more heavily discounted than shorter-term development costs and leaders decelerate investments. Lemmas 1 and 2 summarize these results (where I assume that $\sqrt{\Delta} > r(1-d)K$ so that leaders always have incentives to develop the next advantage).

Lemma 1: In stable industries, a leader firm should accelerate the development of a new competitive advantage if it has higher market value and is less complex, the existing advantage is less valuable, the cost of capital is lower, and the leader firm has superior speed capabilities.

Lemma 2: In stable industries, any factor that accelerates the leader firm's optimal development time of a new competitive advantage also increases (1) the leader's profits and (2) the cannibalization of sufficiently valuable existing advantages.

Even in stable environments with no competitive pressure (imitation or innovation), a leader firm may have incentives to cannibalize its initial advantage. A leader accelerates the development of its next advantage when it results in higher profits. Industry leaders may also prefer to increase the cannibalization of advantages that have higher market value, which is counterintuitive. Increasing the value of an existing advantage raises the forgone revenues of replacing it with a new one. Thus, cannibalization is reduced only if the leader substantially slows down the adoption of the new advantage. This occurs if the returns from both advantages are nearly identical. Otherwise, the firm will still be willing to cannibalize its initial advantage—even if at a greater cost—to achieve the new superior positioning.

Imitative hypercompetition

In imitative environments, any given competitive advantage is imperfectly sustainable. The technological and managerial knowledge associated with superior strategies of leader firms eventually leaks out to competitors after a period of time. The diffusion of advantages process is intrinsically dependent on the industry rate of imitation, or industry imitation clockspeed. The model is unspecific about whether imitation comes from within or outside the focal industry. Investments by new entrants and existing rivals are treated as equivalent because they lead to the same final outcome from the perspective of the leader firm: the inevitable decline of its abnormal returns to the long-term industry average equilibrium profits. In settings with imitative competition, it is also assumed that rivals do not engage in innovation or that their innovation is negligible, nonradical, or nondisruptive and does not displace the leader ($\lambda = 0$).

An example of imitative hypercompetition is the online dating industry, which is one of the most important subscription-based businesses on the Internet (with \$214 million in revenues and 40 million e-visitors in 2003, according to comScore, Inc.). The industry was started by Match.com in the mid-1990s. Since then, several firms

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have rapidly imitated Match.com's strategy and launched similar online dating services. Examples include nationally advertised sites like Matchmaker.com, eHarmony, and Yahoo!Singles as well as more specialized companies such as JDate.com, BlackSingleConnection.com, or ChristianSingles.com (Hitsch, Hortaçsu, and Ariely, 2009). Imitation in the online dating industry is relatively easy and quick, as firms need little more than a Web site—and no major backstage logistics—to enter the industry. Therefore, the industry has a fast imitation clockspeed. At the same time, there has been little (if any) radical innovation throughout the history of the industry. The industry pioneer (Match.com) has not been displaced since the industry's inception. Although improvements in online dating services have occurred throughout the years, they have mostly been marginal in nature (Hitsch *et al*., 2009). Thus, the industry innovation clockspeed is very slow.

In the model, I consider two distinct imitation regimes. First, I analyze the case of continuous regression to the mean, where the leader's returns exponentially decay at a certain rate $\delta > 0$ to the industry average. A scenario with continuous exponential decay of revenues is perhaps more likely in a highly fragmented industry with heterogeneous competitors that choose to imitate at different points in time. This approach follows most prior empirical work on the persistence of intra-industry performance heterogeneity (e.g., Geroski and Jacquemin, 1988; Jacobsen, 1988; Schohl, 1990; Droucopoulos and Lianos, 1993; Waring, 1996; Bou and Satorra, 2007).

Second, I examine an alternative competitive regime with imitation lags. In environments with imitation lags, the leader's advantage is not replicated for some period of time, after which rivals imitate and the abnormal returns from the superior product market position are instantaneously competed away (i.e., $\delta = 0$ for $T_0 < t < T_0 + \theta$ and $\delta \to \infty$ for $t \geq T_0 + \theta$, where θ is the imitation lag period and T_0 denotes the moment of deployment of an advantage to the market). Cohen *et. al*. (2002) have empirically estimated imitation lags for (un)patented products and processes in the U.S. and Japan in the mid-1990s. The mean imitation lag for an unpatented product in the U.S. was reportedly 2.8 years, whereas competitors took substantially longer to replicate an unpatented process—3.37 years, on average. In an earlier study, Mansfield (1985) estimated that information concerning new technology development decisions generally leaks out to competitors after 12 to 18 months. These average times to imitation constitute the most direct measure of industry imitation clockspeed. Note also that this second imitation regime is consistent with Wiggins and Ruefli (2005), who empirically studied the time frames (as opposed to the rate of decay or erosion) of persistent superior performance. A scenario with imitation lags is perhaps characteristic of a more consolidated industry with fewer and more homogeneous competitors (e.g., an oligopoly). In such settings, one expects a time period with perfect sustainability of the leader's advantage, after which the rest of the industry catches up.

The results on imitative competition with exponential decay are presented first and the results on competition with imitation lags follow. The first two lemmas summarize the conventional strategy views on the impact of imitation on leaders' incentives to develop new advantages.

Lemma 3: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive imitation, a leader firm should accelerate the development of a new competitive advantage when imitation erodes its existing advantage but not its new one.

Lemma 4: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive imitation, a leader firm should decelerate the development of a new competitive advantage when imitation erodes its new advantage but not its existing one.

Lemma 3 describes a number of different real world business situations. For example, it can represent a case where the leader's patent on its current product expired and competitors are entering the market. Consistent with prior literature on hypercompetition (e.g., D'Aveni, 1994; Wiggins and Ruefli, 2005), the leader will have incentives to accelerate the development of its next competitive advantage. The relative benefits from creating a new advantage are greater for the leader because the existing advantage yields lower returns due to imitation.

Lemma 4 describes the opposite situation, where the current business of the leader is stable, but its next advantage is sufficiently more profitable to warrant development despite the fact that rivals

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will likely imitate. In this case, imitation lowers the future stream of rents associated with the next advantage and the leader has fewer incentives to deploy the advantage to the market than in more stable conditions. As a result, the leader typically decelerates its investments. This result echoes the long-standing idea in the R&D literature that the incentives to innovate decrease if a firm expects its new products or technologies to be quickly imitated (e.g., Cohen, Nelson, and Walsh, 2000).

These preliminary findings set the stage for the full-fledged analysis of imitative hypercompetition. In most industries, imitation pressures will likely erode *both* the existing and future competitive advantages of a leader firm. This is the underlying assumption behind *all* of the remaining results presented later in this article and corresponds to the default setup of the model. The first two propositions summarize the main conclusions of this section.

Definition 1: The leader's new competitive advantage has high (low) relative market value if it is sufficiently more (less) valuable than the leader's existing competitive advantage.

Proposition 1: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive imitation, a leader firm should accelerate (decelerate) the development of a new competitive advantage that has low (high) relative market value.

Proposition 2: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive imitation, a leader firm cannibalizes more (less) of its existing competitive advantage when its new advantage has low (high) relative market value.

Propositions 1 and 2 are counterintuitive for two main reasons. First, they revisit the two most important beliefs in the field of strategy dynamics about industry hypercompetition—as summarized in Predictions 1 and 2. When the sustainability of any given competitive advantage is shorter, leader firms may not always have incentives to accelerate the development of new advantages and cannibalize their existing product market positions. Faster imitation cycles in an industry undermine not only the current market position of the leader, but also the returns from investing in future competitive advantages. Therefore, with time compression diseconomies, it is often not worthwhile to accelerate, or even develop, a new advantage. In this case, cannibalization of an existing advantage is also reduced.

Second, the conditions described in Propositions 1 and 2 under which acceleration and deceleration likely occur are surprising. Unexpectedly, leader firms slow down valuable advantages while accelerating low-value ones. This result is in apparent contradiction with Lemma 1 in stable environments, whereby leader firms should accelerate the development of valuable advantages. So what explains these findings? When imitation erodes both existing and future advantages, the leader firm experiences two opposite incentives: on the one hand, the decay of its current market position induces the leader to develop a new privileged position (as in Lemma 3). On the other hand, the anticipated lower returns from future advantages due to competitive replication demotivate the leader (as in Lemma 4). Whether (or not) the former effect dominates the latter depends on the *relative* market value of the new advantage vis-à-vis the leader's existing advantage. If the new advantage is highly valuable compared to the current one, the negative consequences of imitation are mostly felt on the returns from future advantages—and the leader decelerates investments. If the new advantage is of poor value relative to the existing advantage, imitation mostly dampens the returns from the current product market strategies and the leader is better off speeding up its new advantage. Propositions 1 and 2 break with the intuition in Lemma 1 because there I am *not* varying the pace of imitation but only the value of the new advantage. In other words, Lemma 1 is valid when all else is equal (i.e., *ceteris paribus*)—namely, when the speed of regression to the mean of firm-specific returns is constant, which is not the case in Propositions 1 and 2.

Figure 5 is a graphical illustration of the conditions in Lemmas 3 and 4 and Propositions 1 and 2 under which a leader firm accelerates and decelerates the development of a new advantage for a set of parameter values. I graph only the results for low levels of regression to the mean of firm-specific returns (0.2 continuous time decay, or 0.81 discrete time persistence, of firm rents) because, in this example, the leader stops having incentives to develop the new advantage for higher levels of competitive imitation.

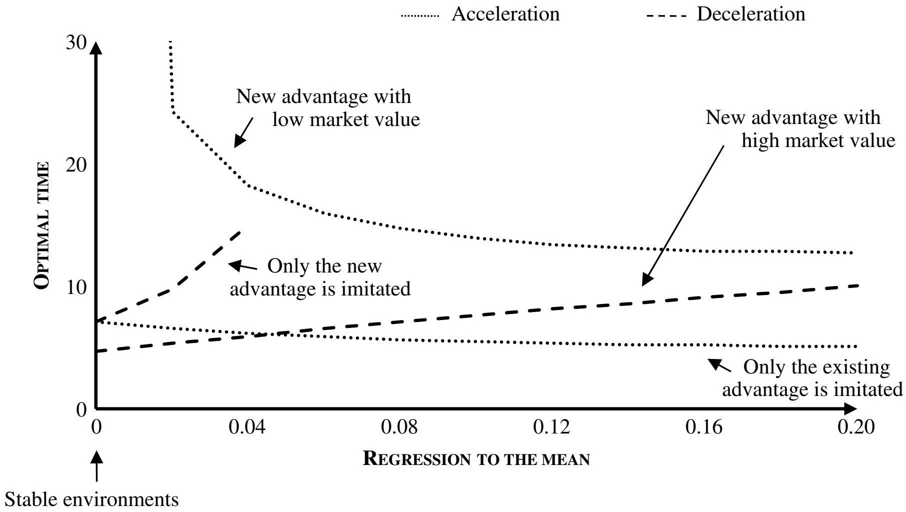

Figure 5. The effect of regression to the mean on optimal development time of new advantages in imitative environments for $\pi_1 = 1$, $\pi_1/\pi_2 = 2$, $d = 0.1$, $K = 4$, $r = 0.1$, and $\lambda = 0$ (and $\pi_1/\pi_2 = 10$, $\pi_1/\pi_2 = 0.91$ for a new advantage with high and low market value, respectively)

Consider now the second imitation regime where both competitive advantages of the leader are replicated by rivals only after an exogenous imitation lag that starts at the time the leader deploys an advantage to the product market, $\theta \in (0, T_S)$. After the imitation lag, the leader's revenues instantaneously decay to the long-term industry average equilibrium profits of 0. This means that $\delta = 0$ when $0 < t < \theta$ and $\delta \to \infty$ when $t \geq \theta$ for the first advantage; and $\delta = 0$ when $T_{lm} < t < T_{lm} + \theta$, $\delta \to \infty$ when $t \geq T_{lm} + \theta$ for the second advantage.

Proposition 3: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive imitation, a leader firm should decelerate the development of a new competitive advantage when its advantages are replicated only after an imitation lag.

Proposition 4: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive imitation, a leader firm cannibalizes less its existing advantage when its advantages are replicated only after an imitation lag.

With imitation lags, competitors erode the existing advantage of the leader only if they are able to replicate the leader's existing positioning before it develops a new advantage. In other words, the imitation lag has to be shorter than the leader's optimal development time of a new advantage for the current advantage to decay due to imitation. I proceed on this assumption and, thus, the leader firm necessarily earns the industry average equilibrium profits for a temporary period of time—until its new advantage is deployed to the product market. Also as a result, any variation in the length of the imitation lag impacts only the returns from the leader's new advantage. Specifically, shorter imitation lags always reduce the revenues from creating new products or technologies, thereby slowing down the leader and reducing cannibalization.[7]

I now turn to the simpler situation where the advantages of the leader are not sequential, but can be simultaneously pursued (i.e., they do not replace each other). This is the case of independent investment opportunities such as unrelated geographic or product diversification. As such, Corollary 1 is perhaps more relevant to corporate strategy decisions.

Corollary 1: In industries with faster regression to the mean of firm-specific returns due to

[7] Note that the above mentioned propositions on imitation lags do not hold if the reason for a sudden erosion of the leader's advantages is exogenous to the imitation process. For example, if government deregulation of the leader's industry will cause instantaneous entry, then the leader's time compression decisions should be independent of the expected date of deregulation. The reason for this result is that the leader firm's *marginal* increment in revenues from acceleration does not vary with the date of rivals' entry into the industry.

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hypercompetitive imitation, a leader firm should decelerate the development of a new competitive advantage when its advantages are additive.

When advantages are additive, leader firms never cannibalize their existing advantage. The leader's decision to accelerate the deployment of its next advantage to the product market should not be affected by its current market positioning. Thus, imitation has only one consequence: it erodes the leader's stream of rents from the new advantage, thereby slowing down its development. Corollary 1 is valid for both types of imitation regimes discussed earlier—continuous time decay of abnormal returns and imitation lags. It suggests that international business diversification is slowed down by an increase in hypercompetition in global markets.

Innovative hypercompetition

In innovative environments, competitive advantages are unsustainable because rival firms launch new products that displace industry incumbents ($\lambda > 0$). The average rate of industry innovation is dependent on multiple factors, such as market structure, technological complexity, and the strength of the legal system that protects intellectual property rights. The model abstracts away from the reasons behind the average pace of innovation in a certain industry. In other words, industry innovation clockspeed is an exogenous variable in the analysis. The model is also unspecific about whether innovation comes from within or outside the focal industry. In my reduced form treatment of product market competition, innovation from new entrants and existing rivals has an identical dampening effect on the leader's profits. This article focuses on radical and disruptive innovation.

In this stylized setting with innovative competition, it is assumed that rivals do not engage in any sort of imitative behavior, or that imitation is negligible, inconsequential, or too time-consuming to erode the leader's returns ($\delta = 0$).

The cosmetics industry is an example of an environment with innovative hypercompetition. According to Fine (1998), the cosmetics industry has a fast industry innovation clockspeed, with an estimated time lag between innovations of approximately two to three years. This rapid introduction of competing new products is due to the existence of a high number of industry players, ranging from large, highly diversified pharmaceutical corporations to numerous small laboratories. These firms continuously compete on innovation by making substantial investments in concurrent R&D projects. In contrast, imitation of high-end cosmetics—the most profitable industry segment—is typically slow and difficult. As with branded-drug pharmaceuticals, high-end cosmetics are generally protected by stringent patents, which allow cosmetic companies to recoup the high R&D investment costs. In addition, the development of new high-end cosmetics tends to be a time-consuming, complex, and increasingly regulated process involving extensive laboratory work and clinical testing. Thus, the cosmetic industry has slow imitation clockspeed.

I consider two different innovation regimes in the analysis of innovative hypercompetition. First, I examine the optimal investment patterns of a leader firm whose advantages have no preemption value. In this case, the leader will not be able to deter or render obsolete future innovations by rivals by innovating faster. Thus, rivals eventually launch an innovation that will displace the incumbent firm. This is equivalent to assuming that the leader does not have the ability to predict or match the radical or disruptive innovation of its rivals or that the leader is not technologically at par with its competitors. As discussed earlier, this has been the conventional view in most strategy literature examining the displacement of industry leaders.

Second, I consider the opposite scenario, where the next competitive advantage of the leader does have the potential to preempt rivals. However, the leader also runs the risk of being preempted by competitors if it is late to market. This is perhaps the most interesting case to analyze in environments with innovative hypercompetition. The leader and its competitors are in a situation of pure competitive parity regarding the potential of their next generation of advantages. Since the extent of firm heterogeneity in the industry is reduced, the model becomes a pure timing game, which is closer in nature to the idea of hypercompetition. In this context, the frequency of industry leadership transition can be examined.[8] I start by defining the

[8] Allowing for the possibility of preemption brings this section close to a number of important literatures in strategy and economics. The issue of entry timing in competitive innovation has been extensively studied in prior work on first mover advantages

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two innovation regimes studied in this article and then present the main findings.

Definition 2: The leader's new competitive advantage has high (low) competitive value if it does (not) deter or render obsolete future innovation by competitors.

Proposition 5: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive innovation, a leader firm should decelerate the development of a new competitive advantage that has low competitive value.

Proposition 6: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive innovation, a leader firm should accelerate the development of a new competitive advantage that has high competitive value and sufficiently low cost of capital.

Proposition 7: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive innovation, a leader firm cannibalizes its existing competitive advantage less.[9]

Proposition 8: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive innovation, a leader firm that optimally accelerates the development of a new competitive advantage is less likely to maintain industry leadership and sustain abnormal returns.[10]

Innovation and imitation efforts by rivals have a similar impact on the profits of leader firms: they erode the expected returns from competitive advantages. As such, one could expect leaders to respond in identical ways to both innovative and imitative hypercompetition. However, this is not the case: the optimal investment strategies described in Propositions 1 and 2 differ from those reported in Propositions 5, 6, and 7. This asymmetry in optimal investment strategies to fight distinct threats to sustainable competitive advantage constitutes the first interesting observation from this set of propositions. But it also raises the question of why leader firms respond differently to innovative and imitative hypercompetition.

There is, in fact, a subtle distinction between imitation and innovation. In the model, imitation starts eroding the leader's profits only *after* the leader has launched its new advantage in the market. I believe this is a reasonable assumption because, at that point in time, competitors are best able to observe the leader's strategy, reverse engineer its products, and start the imitation process.[11] In contrast, innovation—or the probability that rivals innovate—decays the leader's expected profits *even before* the leader has developed its next product market positioning. The longer a leader waits to introduce a new advantage, the lower the advantage's expected market value because of the increasing odds that competitors will have, meanwhile, innovated and displaced the leader. This fundamental difference between imitation and innovation has important consequences for firms' investments.

Since rivals' innovation risks unseating the leader, *both* of the leader's advantages decay simultaneously over time (even before the leader launches its new advantage in the market). Of the two advantages, however, it is the leader's new advantage that is more rapidly eroded because it is more valuable—and exponential erosion is proportional to value. This is referred to as the *simultaneous erosion effect*, and it reduces leaders' incentives to accelerate the development of new

(e.g., Lieberman and Montgomery, 1988, 1998; Boulding and Christen, 2003), strategic commitment (e.g., Ghemawat, 1991), and patent races (e.g., Langinier and Moschini, 2002). Nault and Vandenbosch (1996) perhaps constitute the most notable example of work explicitly analyzing the effect of preemption on the development times of leader firms. Unlike my article, however, Nault and Vandenbosch do not examine imitative hypercompetition: assumption 4 in their model 'captures the futility of following (...) ensur[ing] that after the first launch of the next generation there will not be a following launch of the same generation' (Nault and Vandenbosch, 1996; 353). In addition, Nault and Vandenbosch (1996) do not model competitors' innovation in probabilistic terms and, thus, their article is also silent about the likelihood of industry leadership displacement.

[9] Proposition 7 assumes that the cost of capital is sufficiently low.

[10] Proposition 8 assumes that the leader's new competitive advantages can deter or render obsolete future innovations by competitors (and that the cost of capital is sufficiently low). By definition, in the model, industry leadership transition always occurs with probability 1 if the leader's new advantages do not deter rivals' innovation. This trivial result is an artifact of the model's assumptions and, thus, is not explicitly analyzed in this section.

[11] Note that the qualitative results should still hold in a mixed imitation regime, where rivals would be able to start part of the imitation process before the leader launches its new advantage—as long as most of the imitation would still take place *after* the leader developed its next positioning.

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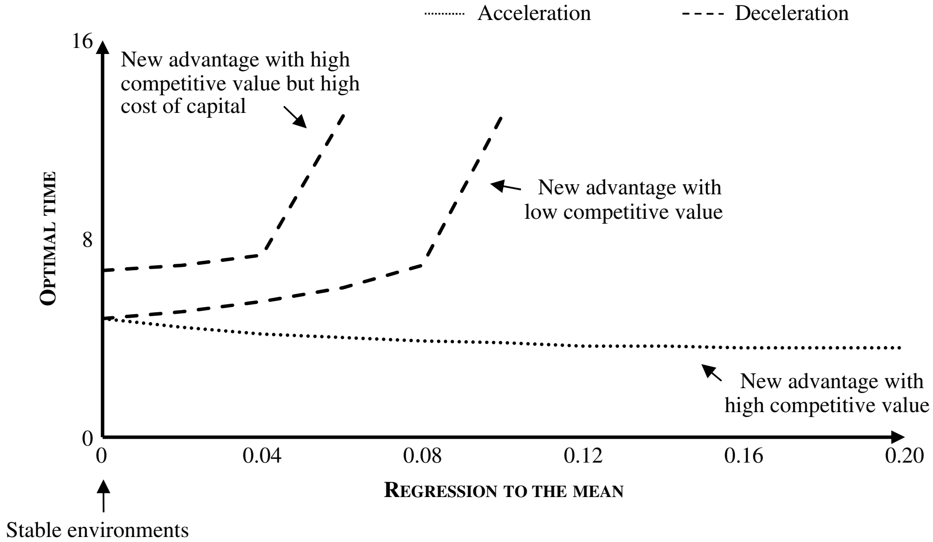

Figure 6. The effect of regression to the mean on optimal development time of new advantages in innovative environments for $\pi_1 = 1$, $\pi_1/\pi_2 = 10$, $d = 0.1$, $K = 4$, $r = 0.1$, and $\delta = 0$ ($r = 0.19$ for high cost of capital)

advantages. This is particularly the case when the new advantage of the leader does not deter rivals' innovation. In these circumstances, the leader prefers to slow down its investments, as described in Proposition 5.

The simultaneous erosion effect may be reversed only if the leader's new advantage has high competitive value. The prospect of preempting rivals' future innovation induces the leader to speed up. Acceleration increases the leader's odds of retaining industry leadership and receiving the long-term rents of its new advantage. These incentives offset the simultaneous erosion effect described in the previous paragraph only if the present value of these extra rents from acceleration is sufficiently high—which occurs when the discount rate (or cost of capital) is low. This explains the intuition behind Proposition 6, which is entirely consistent with the idea of *protection through preemption* described in prior literature (Nault and Vandenbosch, 1996). Figure 6 illustrates these results for a set of parameter values in the model.

With low cost of capital, the leader firm always reduces the cannibalization of its existing advantage for higher levels of rival innovation (Proposition 7). This is an intuitive outcome when the leader's new advantage has low competitive value because the leader decelerates its investments. When the new advantage has high competitive value, the leader speeds up with more innovative hypercompetition—but the residual value of its existing advantage decays at an even faster rate and cannibalization still ultimately decreases.

Proposition 8 established an important result: that the displacement of industry leaders is *always* more likely with higher innovative hypercompetition—even if leaders accelerate their investments. Figure 7 helps explain this finding. The curve *Industry innovation clockspeed* indicates the frequency of rival innovation that is required to obtain each given rate of regression to the mean of firm-specific returns represented in the horizontal axis. The most noticeable pattern in Figure 7 is the rapid convergence between the innovation speed of the leader firm and that of the rest of the industry. In other words, faster regression to the mean of firm-specific returns due to rivals' innovation may induce leaders to speed up, but only marginally compared to the pace of acceleration in industry innovation clockspeed. Because competitors close the innovation gap with the leader, the probability of industry leadership transition (or displacement) increases. The reason why the leader does not further accelerate the development of its new advantages is due to the simultaneous erosion effect described earlier. Note also how modest rates of regression to the mean of firm-specific returns may be enough to produce a high displacement probability of the industry leader.

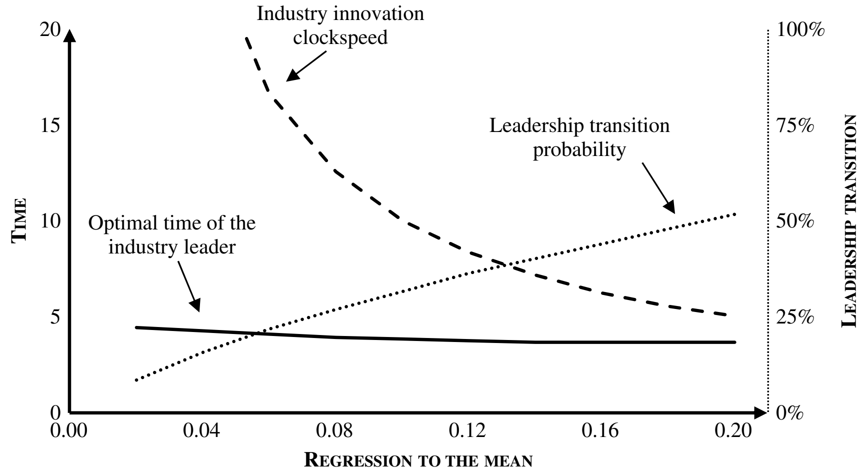

Figure 7. The effect of regression to the mean on industry leadership transition probability in innovative environments for a new advantage with high competitive value and $\pi_1 = 1$, $\pi_1/\pi_2 = 10$, $d = 0.1$, $K = 4$, $r = 0.1$, and $\delta = 0$.

Corollary 2: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive innovation, a leader firm should pursue the same investment strategies to develop a new competitive advantage with sequential and additive advantages (cf. Propositions 5 and 6).

The main results in this subsection hinge on the effect of rivals' innovation on the expected value of the leader's new advantage. Therefore, Propositions 5 to 8 should hold, irrespective of whether the leader's advantages are additive or sequential.

Dual hypercompetition

Dual hypercompetition generates the highest level of environmental turbulence. In these industries any advantage is eroded by rivals' continuous efforts to simultaneously imitate and innovate around the leader's product market positions (i.e., $\delta, \lambda > 0$).

The forces of innovation and imitation are at their peak in the PC microprocessor market. The innovation clockspeed is very fast, with new product innovation occurring every 18 months in accordance with the prediction of Moore's Law. Imitation has also played a major role in the unfolding of the competitive dynamics over the industry's evolution. In the pre-Pentium period, Advanced Micro Devices (AMD) usually waited until Intel released its processors and quickly copied and developed its own microprocessors based on Intel's specifications. For the first two generations, the 8086 and the 80 286, AMD benefited from high technological spillovers due to a cross-licensing agreement with Intel. The imitation lag for AMD to launch its version of the 80 286 in 1984 was two years. In the post-Pentium phase, Intel tried to reduce the threat of imitation. In 1985, Intel refused to license its designs of the 386. In response, AMD increased its *innovative* pressure over Intel by ramping up its own product development capabilities. More recently, AMD has, at times, succeeded in challenging Intel's role as the industry leader (*The Economist*, 1998; Shih and Ofek, 2007).

Since industries with dual hypercompetition consist of complex, mixed-regime environments where both imitation and innovation pressures are at play, one might expect the optimal investment strategies to be equally complex. Interestingly, however, these optimal strategies can be summarized in deceptively simple terms. Finding straightforward, hard-and-fast rules to guide strategy in highly turbulent environments has been hailed as critical in the recent literature (Eisenhardt and Sull, 2001). Propositions 9 and 10 lay down the *strategy as simple rules* that leader firms should follow when facing imitative and innovative hypercompetition.

Proposition 9: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive imitation and innovation, a leader firm should pursue the same investment strategies to develop a new competitive

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Market value(a)	Competitive value(b): Low	Competitive value(b): High
High	*Deceleration*	*Acceleration if innovative hypercompetition dominates* *Deceleration if imitative hypercompetition dominates*
Low	*Acceleration if imitative hypercompetition dominates* *Deceleration if innovative hypercompetition dominates*	*Acceleration*

(a) Market value of the new advantage relative to the existing advantage
(b) New advantage deters or renders obsolete future competitive innovation (assumes low cost of capital)

Figure 8. Optimal acceleration strategies in response to increased industry hypercompetition

advantage as with imitative hypercompetition (cf. Propositions 1 and 2 and Corollary 1) if imitation is a more powerful threat to the sustainability of the leader's advantages than innovation.

Proposition 10: In industries with faster regression to the mean of firm-specific returns due to hypercompetitive imitation and innovation, a leader firm should pursue the same investment strategies to develop a new competitive advantage as with innovative hypercompetition (cf. Propositions 6 to 8 and Corollary 2) if innovation is a sufficiently more powerful threat to the sustainability of the leader's advantages than imitation.

The main conclusion from Propositions 9 and 10 is that if one of the threats to the sustainability of competitive advantage dominates the industry, the leader should implement the investment strategies that directly target that threat. In other words, the leader should *de facto* behave as if it was operating in an industry where the dominant force of hypercompetition was the only threat to the sustainability of its advantage. This direct matching between dominant threats and strategies represents a major simplification of the course of action that leaders should follow in complex hypercompetitive industries. I dub this strategy of responding to the prevailing driver of industry hypercompetition *matching dominant threats*.[12]

Figures 8, 9, and 10 summarize the main results of this article for all types of hypercompetitive environments. The three figures are organized by topic—acceleration, cannibalization, and industry leadership transition—to match each of the three main theoretical predictions in prior literature on strategy dynamics. Predictions 1 to 3 represent the received knowledge on the expected effect of hypercompetition on time compression.

The contribution of this article becomes clear when one compares and contrasts Predictions 1 to 3 with Figures 8 to 10. Several conclusions can be drawn. First, contrary to the course of action typically endorsed by most prior literature,

[12] In the context of the model, imitation is a more powerful threat to the sustainability of competitive advantage than innovation when $\delta > \lambda$. In contrast, imitation is a sufficiently less powerful threat to the sustainability of competitive advantage than innovation when $\delta \ll \lambda$. I do not formally analyze the case in which imitation and innovation are exactly equal threats to sustainability for two reasons. (1) Theoretically, assuming $\delta = \lambda \neq 0$ reduces the analysis to a submodel that is not particularly tractable. Specifically, I am able to derive only partial comparative statics results on the effect of hypercompetition on acceleration. (2) Statistically, if I assume that δ and λ are continuous random variables distributed on $[0, \infty)$ with given probability density functions, $\delta = \lambda$ is a point with *ex ante* probability mass zero. In other words, the occurrence of an exact match between imitation and innovation is empirically unlikely. Most real world situations will, *de facto*, fall into one of the two cases characterized in Propositions 9 and 10. Therefore, the lack of formal results for $\delta = \lambda \neq 0$ is a reasonable simplification.

Market value[(a)] \ Competitive value[(b)]	Low	High
High	*Lower cannibalization*	*Lower cannibalization*
Low	*Higher cannibalization if imitative hypercompetition dominates* *Lower cannibalization if innovative hypercompetition dominates*	*Higher cannibalization if imitative hypercompetition dominates* *Lower cannibalization if innovative hypercompetition dominates*

(a) Market value of the new advantage relative to the existing advantage
(b) New advantage deters or renders obsolete future competitive innovation (assumes low cost of capital)

Figure 9. Optimal cannibalization strategies in response to increased industry hypercompetition

Market value[(a)] \ Competitive value[(b)]	Low	High
High	*n/a*[(c)]	*Higher leadership transition probability*
Low	*n/a*[(c)]	*Lower leadership transition probability if imitative hypercompetition dominates* *Higher leadership transition probability if innovative hypercompetition dominates*

(a) Market value of the new advantage relative to the existing advantage
(b) New advantage deters or renders obsolete future competitive innovation (assumes low cost of capital)
(c) By definition, in our model, leadership transition occurs with probability 1 if the new advantage has low competitive value

Figure 10. Changes in industry leadership with increased industry hypercompetition

leader firms should *not* always accelerate investments and cannibalize existing market positions when rivals innovate and imitate faster. The appropriate strategy to be followed depends on (1) the leader's type of advantage (its market and competitive value) and (2) the type of industry hypercompetition (imitative versus innovative). Second, an acceleration rule of thumb is that firms should speed up advantages that have low market value and high competitive value. Also, market (competitive) value should be the key decision criterion under imitative (innovative) hypercompetition. Third, there is not an obvious causal link between acceleration and cannibalization: it is possible to reduce cannibalization while speeding up investments.

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Finally, greater innovative hypercompetition always increases the probability of displacement of industry leaders, even when leaders respond to rivals' innovation by (optimally) accelerating the development of new advantages (Figure 10). Leader firms are able to stay at the top of innovative industries only if they suboptimally and excessively accelerate investments. The reason why it is not optimal for leaders to sufficiently accelerate investments to secure market dominance with increased innovative hypercompetition is that rival innovation erodes the leader's future advantage faster than its current one (see the simultaneous erosion effect). Thus, leaders have fewer incentives to bear the costs of speed to rapidly concatenate temporary advantages, thereby increasing the probability of displacement. Leadership displacement is also more likely with imitative hypercompetition, unless imitation provides leaders with exceptionally strong incentives to accelerate investments (which only happens when the next advantage of the leader has low relative market value).

These important results on leadership displacement are at odds with Prediction 3, in which it was assumed that acceleration (presumably optimal acceleration) would always make leaders more likely to maintain industry dominance. This finding helps explain the large incidence of industry leadership transition economy wide—without making use of conventional arguments hinging on the leader's inability to match rivals' disruptive or radical innovation. It also suggests that firms that remain leaders in hypercompetitive industries over long periods of time are likely destroying shareholder value. Regular industry leadership rotation may be a mutually beneficial arrangement for all firms operating in hypercompetitive markets—including industry leaders. In other words, temporary advantages by one firm should be the norm with competitive turbulence not only because followers want to reach market dominance, but also because leaders may want to step down from it—a phenomenon dubbed *leadership self-displacement*.

DISCUSSION AND CONCLUSIONS

This article showed that leader firms should not always accelerate the development of new advantages when competitors quickly innovate or imitate. Faster imitation and innovation cycles in an industry erode not only the current advantage of the leader, but also the returns from future advantages—making it harder to recoup the investments required to develop new market positions. Thus, leaders often have fewer incentives to bear the costs of speed to accelerate investments. These findings contrast with the accepted view in strategy that leader firms should rapidly concatenate short-lived advantages in hypercompetitive industries.

By choosing to renew competitive advantages more slowly (or not sufficiently fast) in more turbulent markets, leaders often make a deliberate and rational decision to accept a higher probability of being displaced by competitors—a phenomenon that is referred to as leadership *self-displacement*. Figure 11 summarizes leaders' recommended investment strategies (for the most interesting case of new advantages with high competitive value).

Note that in only one instance of higher hypercompetition should leaders increase self-cannibalization and significantly accelerate the concatenation of temporary advantages to increase the odds of renewing industry leadership (a strategy dubbed self-renewal). In the other three regimes, leaders should *milk* the old advantage and allow self-displacement. Specifically, self-displacement is always more likely as innovative hypercompetition increases, even when leaders partially counter rivals' innovation by (optimally) accelerating the development of new advantages. In other words, leader firms are able to stay at the top of innovative industries only if they suboptimally and excessively accelerate investments. This result helps explaining the large incidence of leadership transition in many industries—without relying on explanations such as leaders' inability to match rivals' disruptive or radical innovation, as assumed in prior literature. Profit-maximizing firms may sometimes choose not to invest in sustained competitive advantages precisely because they are profit maximizing. Thus, regular rotation in industry leadership may be a mutually beneficial arrangement to both follower and leader firms in hypercompetitive environments. For example, AMD's temporary success at challenging Intel's role as industry leader in recent semiconductor generations (such as the x86-based dual-core architecture) may also reflect Intel's incentives to momentarily self-displace itself from industry leadership. Specifically, the extra costs that Intel needed to incur to speed up the development of its

		Type of hypercompetition[b]	
		Imitative	**Innovative**
Market value[a]	**High**	*Self-displacement (deceleration)*	*Self-displacement (insufficient acceleration)*
	Low	*Self-renewal: concatenation of temporary advantages (acceleration, cannibalization)*	*Self-displacement (insufficient acceleration)*

(a) Market value of the new advantage relative to the existing advantage
(b) Also denotes the dominant type of hypercompetition when both types co-exist

Figure 11. Overview of leaders' optimal responses to increased industry hypercompetition (for a new advantage with high competitive value and low cost of capital)

Xeon processors and beat AMD's Opteron processors to market in 2005 likely exceeded the expected revenues from earlier commercialization of this technology—precisely because AMD was slated to quickly replicate the same technology (Hesseldahl, 2005).

In Figure 11, leaders should respond differently to different types of hypercompetition because there is a subtle, but important, distinction between competitive innovation and imitation. While imitation starts eroding new advantages only *after* they are launched in the market, innovation—or the probability that rivals will innovate—erodes expected profits *even before* leaders develop their next product market positioning. That is, the longer leaders wait to introduce a new advantage, the lower its expected market value because of the increasing odds that competitors will have, meanwhile, innovated and displaced the leader. Thus, hypercompetitive innovation never prompts leaders to sufficiently accelerate the development of new advantages—and competitors always displace leaders with greater probability. In contrast, leadership self-renewal may be more likely under hypercompetitive imitation: when leaders' new advantages are less valuable than existing ones, imitation mostly erodes the rents from current strategies, which induces leaders to speed up new advantages. Irrespective of the type of hypercompetition, a general rule of thumb for acceleration is that leaders should accelerate the development of new advantages that have high competitive value but low market value when industries become more turbulent.

Because the model in this article builds on empirically observable constructs, its main theoretical propositions are amenable to large sample testing. For example, in a cross-industry study of the timing of new technology development by leader firms, we should observe faster (slower) launches of incremental (drastic) technologies in industries with more rapid imitation. The opposite should be true in industries with higher levels of innovative hypercompetition.[13] Departures from these investment patterns are expected to dampen leader firms' profits. These hypotheses can be tested by merging data from multiple sources, including estimates of industry innovation and imitation clockspeed from the Carnegie Mellon University Survey with financial data from Compustat, and data on new technology development from industry publications.

This article aims at contributing to the literatures on hypercompetition, the persistence of firm-specific rents, and strategy dynamics. While the theoretical model was structured after the key stylized empirical facts documented in these literatures, its results departed from most standard predictions in this earlier work.

[13] Assuming drastic (incremental) innovation has high (low) market and competitive value (cf. Figure 8).)

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APPENDIX

Proof of Lemmas 1 and 2: (i) and (ii) follow Pacheco-de-Almeida and Zemsky (2007). (i) The profits of the leader in stable environments are $\Pi_S(T_S) = \frac{\pi_0}{r} + e^{-rT_S}\frac{\Delta}{r} - \frac{(1-d)^2K^2r}{e^{rT_S}-1}$ and the first-order condition (FOC) for the leader's optimization problem is $\Pi_S(T)' = -\Delta e^{-rT} + \frac{K^2r^2(1-d)^2}{(e^{Tr}-1)^2}e^{Tr} = 0$. Substituting $T = \frac{\ln x}{r}$ where $x > 1$ then $\frac{x}{x-1} = \frac{\sqrt{\Delta}}{Kr(1-d)}$, which solves for $T_S = \frac{1}{r}\ln\left(1 - \frac{r(1-d)K}{\sqrt{\Delta}}\right)^{-1} > 0$ because $\sqrt{\Delta} > r(1-d)K$ by assumption. This solution is unique because the LHS of the FOC is everywhere decreasing in x, whereas the RHS is a constant. Also, T_S is a global maximum where $\Pi_S(T_S) > 0$ since $\lim_{T\to 0^+}\Pi_S(T) = -\infty$ and $\lim_{T\to\infty}\Pi_S(T) = \frac{\pi_0}{r}$. Hence, the second-order condition (SOC) is satisfied. (ii) The comparative statics on T_S w.r.t. K, d, and Δ follow by inspection. The comparative statics w.r.t. r is $\frac{\partial T_S}{\partial r} = \left(-\frac{1}{r}\right)e^{rT_S}\frac{\partial e^{-rT_S}}{\partial r}$ and $\frac{\partial e^{-rT_S}}{\partial r} = -\frac{(1-d)K}{\sqrt{\Delta}} < 0$, which establishes that $\frac{\partial T_S}{\partial r} > 0$. (iii) The leader's profits can be rewritten as $\Pi_S(T_S) = \frac{\pi_0}{r} + \frac{1}{r}(\sqrt{\Delta} - r(1-d)K)^2$ and $\Delta = \pi_1 - \pi_0$. The comparative statics on the leader's profits w.r.t. π_1, d, and K follow by inspection. The comparative statics w.r.t. π_0 is $\frac{\partial \Pi_S(T_S)}{\partial \pi_0} = \frac{K(1-d)}{\sqrt{\Delta}} > 0$. The comparative statics w.r.t. r is $\frac{\partial \Pi_S(T_S)}{\partial r} = -\frac{1}{r^2}(\pi_1 - r^2(1-d)^2K^2) < 0$ because $\sqrt{\Delta} > r(1-d)K$ by assumption and $\pi_1 > \Delta$. (iv) The leader cannibalizes $F_S = \int_{T_S}^{\infty}\pi_0 e^{-rt}dt$, which is equivalent to $F_S = \frac{\pi_0}{r\sqrt{\Delta}}(\sqrt{\Delta} - r(1-d)K)$. The comparative statics on cannibalization w.r.t. π_1, d, K, and r follow by inspection, w.r.t. π_0 is $\partial F_S/\partial \pi_0 = \frac{1}{r} - (1-d)K(2\pi_1 - \pi_0)/(2(\pi_1 - \pi_0)\sqrt{\pi_1 - \pi_0})$. If $\pi_0 = 0$, $\partial F_S/\partial\pi_0 = 1/r - (1-d)K/\sqrt{\pi_1} > 0$ because $\sqrt{\pi_1} > r(1-d)K$. If $\lim_{\Pi_0\to\Pi_1^-} - (\partial F_S/\partial \pi_0) = -\infty$. Since $\partial^2 F_S/\partial(\pi_0)^2 = -(1-d)K \quad \frac{4\pi_1 - \pi_0}{4\sqrt{(\pi_1-\pi_0)^5}} < 0$, there exists a critical value $\overline{\pi}_0$ such that decreases in π_0 increase cannibalization if and only if. $\pi_0 > \overline{\pi_0}$. □

Proof of Lemmas 3 and 4: (i) Assume that only the next advantage of the leader is imitated. The leader's profits are $\Pi_{Im}(T) = \frac{\pi_0}{r}(1 - e^{-rT}) + \frac{\pi_1}{\delta + r}e^{-rT} - \frac{(1-d)^2K^2r}{e^{rT}-1}$. The FOC is $\Pi_{Im}(T)' = \pi_0 e^{-rT} - \frac{r}{\delta + r}\pi_1 e^{-rT} + \frac{K^2r^2(1-d)^2}{(e^{rT}-1)^2}e^{rT} = 0$, which solves for $T_{Im} = \frac{1}{r}\ln\left(1 - \frac{r(1-d)K}{\sqrt{\frac{r}{\delta+r}\pi_1 - \pi_0}}\right)^{-1}$. For $T_{Im} > 0$, we assume that $r(1-d)K < \sqrt{\frac{r}{\delta+r}\pi_1 - \pi_0}$ and $\delta < r\pi_1/\pi_0 - r$. T_{Im} is unique because the LHS of the FOC is everywhere decreasing in x, whereas the RHS is a constant. Also, T_{Im} is a global maximum where $\Pi_{Im}(T_{Im}) > 0$ since $\lim_{T\to 0^+}\Pi_{Im}(T) = -\infty$ and $\lim_{T\to\infty}\Pi_{Im}(T) = \frac{\pi_0}{r}$. Hence, the SOC is satisfied. By inspection, $T_{Im} > T_S$ and $\partial T_{Im}/\partial\delta > 0$. (ii) Assume that only the existing advantage of the leader is imitated. Profits are $\Pi_{Im}(T) = \frac{\pi_0}{\delta + r}(1 - e^{-(\delta+r)T}) + \frac{\pi_1}{r}e^{-rT} - \frac{(1-d)^2K^2r}{e^{rT}-1}$ and the FOC is $\Pi_{Im}(T)' = \pi_0 e^{-(\delta+r)T} - \pi_1 e^{-rT} + \frac{K^2r^2(1-d)^2}{(e^{rT}-1)^2}e^{rT} = 0$. T_{Im} has no closed-form solution, but $\partial\Pi_{Im}(T)'/\partial\delta = -T\pi_0 e^{-(\delta+r)T} < 0$. Since $\Pi_{Im}(T_S)'\,|_{\delta=0} = \Pi_S(T_S)' = 0$, $\Pi_{Im}(T_S)' < 0\ \forall_{\delta>0}$. As $\lim_{T\to 0}\Pi_{Im}(T) = -\infty$, there is at least one maximum for $T < T_S$. The profit function $\Pi_{Im}(T)$ does not have any other maximum for $T \geq T_S$ because $\Pi_{Im}(T)' < \Pi_S(T)'\ \forall_T$ and $\partial^2 F/\partial\delta\partial T = \pi_0 e^{-(\delta+r)T}(T(\delta + r) - 1)$, which is first negative and then positive in T. Hence $T_{Im} < T_S$. The comparative statics on T_{Im} w.r.t. δ follow from the implicit function theorem since $\frac{\partial \Pi'_{Im}}{\partial\delta}, < 0\ \forall_T$ and T_{Im} is a maximum. □

Proof of Propositions 1 and 2: Assume that both advantages of the leader are imitated. (i) Profits are $\Pi_{Im}(T) = \frac{\pi_0}{\delta + r}(1 - e^{-(\delta+r)T}) + \frac{\pi_1}{\delta + r}e^{-rT} - \frac{(1-d)^2K^2r}{e^{rT}-1}$. The FOC is $\Pi_{Im}(T)' = \pi_0 e^{-(\delta+r)T} - \frac{r}{\delta + r}\pi_1 e^{-rT} + \frac{K^2r^2(1-d)^2}{(e^{rT}-1)^2}e^{rT} = 0$. T_{Im} has no closed-form solution, but $\partial\Pi_{Im}(T)'/\partial\delta = e^{-rT}\left(\pi_1 r/(\delta + r)^2 - \pi_0 Te^{-\delta T}\right)$, where $Te^{-\delta T} \in (0, 1/\delta e)$ has a unique maximum at $T = 1/\delta$ and $\lim_{T\to 0^+}(Te^{-\delta T}) = \lim_{T\to\infty}(Te^{-\delta T}) = 0$. (Also, $\partial^2(Te^{-\delta T})/\partial T^2 = \delta e^{-\delta T}(T\delta - 2)$ and the subfunction is concave (convex) for low (high) values of

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T.) At $T = T_S$, it follows that $\pi_0 T_S e^{-\delta T_S}$ is monotonically increasing in π_0 for π_0 sufficiently small since $\partial T_S / \partial \pi_0 > 0$. Thus, there is a critical value $\overline{\pi}_0$ such that for $\pi_0 < \overline{\pi}_0$ $\partial \Pi_{Im}(T)' / \partial \delta \,|_{T=T_S} > 0$ $\forall_\delta$. Note also that $\lim_{\delta \to 0} \Pi_{Im}(T)' = \Pi_S(T)'$ $\forall_T$. Hence, $\Pi_{Im}(T_S)' > \Pi_S(T_S)' = 0$ when $\pi_0 < \overline{\pi}_0$. Also, for π_0 sufficiently small, $\partial \Pi_{Im}(T)' / \partial \delta > 0$ $\forall_T$ and $\Pi_{Im}(T)$ does not have a stationary point when $T \leq T_S$ as $\Pi_S(T)' > 0$ for $T \leq T_S$. Because $\lim_{T \to 0} \Pi_{Im}(T) = -\infty$ and $\lim_{T \to \infty} \Pi_{Im}(T) = \pi_0/(\delta + r) > 0$, any finite maximum must be such that $T_{Im} > T_S$. The implicit function theorem yields the comparative statics on T_{Im} w.r.t. δ, $\partial T_{Im}/\partial \delta = -\frac{\partial \Pi_{Im}{}'}{\partial \delta} \Big/ \frac{\partial \Pi_{Im}{}'}{\partial T} \,|_{T=T_{Im}}$, which is positive since $\frac{\partial \Pi_{Im}(T)'}{\partial \delta} > 0$ $\forall_T$ for π_0 sufficiently small, or π_1/π_0 sufficiently large, and T_{Im} is a maximum. Finally, because $T_{Im} > T_S$ with π_0 small (π_1/π_0 high) and the potential forgone revenues from cannibalization at any time T are lower due to revenue decay with imitation, $F_{Im} < F_S$. An analogous reasoning establishes that $\partial F_{Im}/\partial \delta < 0$. (ii) If π_0 is sufficiently large, such that $\pi_0 > \pi_1 - r^2(1-d)^2 K^2$, then $T_S = \infty$ and it must be that $T_{Im} < T_S$ for T_{Im} finite. Also, for π_0 sufficiently large (i.e, π_1/π_0 small), $\partial \Pi_{Im}(T)' / \partial \delta < 0$ $\forall_T$ and $\partial T_{Im}/\partial \delta < 0$ because of the implicit function theorem. Since $T_S = \infty$, it must be that $F_{Im} > F_S = 0$ under the same conditions. The comparative statics on $F_{Im} = \frac{\pi_0}{r+\delta} e^{-(\delta+r)T_{Im}}$ w.r.t. δ is $\partial F_{Im}/\partial \delta = -\pi_0 e^{-(\delta+r)T_{Im}} \left(\frac{\delta T_{Im} + r T_{Im} + 1}{(\delta + r)^2} + \frac{\partial T_{Im}}{\partial \delta} \right)$, which is positive if $\frac{\partial T_{Im}}{\partial \delta}$ is sufficiently negative. Since $\partial \Pi'_{Im} / \partial T = -\delta \pi_0 e^{-(\delta+r)T} - r \Pi_{Im}(T)'$, $\partial T_{Im}/\partial \delta = -\frac{e^{-rT}\left(\pi_1 \frac{r}{(\delta+r)^2} - \pi_0 T e^{-\delta T}\right)}{-\delta \pi_0 e^{-(\delta+r)T}}$ as $\Pi_{Im}(T)' \,|_{T=T_{Im}} = 0$ (the FOC is satisfied). Note first that $\lim_{\pi_0 \to \infty} (\partial T_{Im}/\partial \delta) = -T/\delta$ and $\partial F_{Im}/\partial \delta > 0$ if δ is sufficiently small. For general δ, there are no closed-form expressions for T_{Im} and $\partial F_{Im}/\partial \delta$. However, numerical analysis showed that $\partial F_{Im}/\partial \delta > 0$ for π_1/π_0 sufficiently small in the (large) subset of parameter space studied. □

Proof of Propositions 3 and 4: Assume an imitation lag $\theta \in (0, T_S)$ such that, for the first advantage, $\delta = 0$ for $0 < t < \theta$ and $\delta \to \infty$ for $t \geq \theta$ and, for the second advantage, $\delta = 0$ for $T_{Im} < t < T_{Im} + \theta$ and $\delta \to \infty$ for $t \geq T_{Im} + \theta$. The leader's revenues are $R_{Im}(T) = \int_0^\theta \pi_0 e^{-rT} dt + \int_T^{T+\theta} \pi_1 e^{-rT} dt$ and profits are $\Pi_{Im}(T) = \frac{\pi_0}{r}(1 - e^{-r\theta}) + \frac{\pi_1}{r} e^{-rT}(1 - e^{-r\theta}) - \frac{(1-d)^2 K^2 r}{e^{rT} - 1}$. The FOC is $\Pi_{Im}(T)' = \pi_1 e^{-rT} e^{-r\theta} - \pi_1 e^{-rT} + \frac{K^2 r^2 (1-d)^2}{(e^{rT}-1)^2} e^{rT} = 0$, which solves for $T_{Im} = \frac{1}{r} \ln\left(1 - \frac{r(1-d)K}{\sqrt{\pi_1(1 - e^{-r\theta})}}\right)^{-1}$, assuming $\sqrt{\pi_1(1 - e^{-r\theta})} > r(1-d)K$. This solution is unique because the LHS of the FOC is everywhere decreasing in x, whereas the RHS is a constant. Also, T_{lm} is a global maximum where $\Pi_{lm}(T_{lm}) > 0$ since $\lim_{T \to 0^+} \Pi_{lm}(T) = -\infty$ and $\lim_{T \to \infty} \Pi_{lm}(T) = \frac{\pi_0}{r}(1 - e^{-r\theta})$. Hence, the SOC is satisfied. By inspection, it follows that $T_{lm} > T_S$ and $\partial T_{lm}/\partial \theta < 0$. Since $\theta < T_{lm}$, the leader does not cannibalize its existing advantage and, although cannibalization is invariant in θ, $F_S > F_{lm} = 0$. □

Proof of Corollary 1: (i) For additive advantages and continuous regression to the mean, the leader does not replace its existing advantage, so the profits in imitative environments are given by $\Pi^{\alpha}_{lm}(T) = \frac{\pi_0}{\delta + r} + \frac{\pi_1}{\delta + r} e^{-rT} - \frac{(1-d)^2 K^2 r}{e^{rT} - 1}$. The FOC is then $\Pi^{\alpha}_{lm}(T)' = -\frac{r}{\delta + r} \pi_1 e^{-rT} + \frac{K^2 r^2 (1-d)^2}{(e^{rT} - 1)^2} e^{rT} = 0$, which is equivalent to the FOC for Proposition 1 with $\pi_0 = 0$. Since $\pi_0 = 0$ is a special case of Proposition 1 for low values of π_0, all the results of that proposition apply. (ii) For additive advantages with imitation lags θ, the profits of the leader are the same as in the proof of Propositions 3 and 4, so the FOC is identical and the same results follow. □

Proof of Propositions 5–8 and Corollary 2 (Part 1): Assume that the new competitive advantage of the leader has low competitive value. (i) Profits in innovative environments are $\Pi_{ln}(T) = \frac{\pi_0}{\lambda + r} + \frac{\Delta}{\lambda + r} e^{-(\lambda+r)T} - \frac{(1-d)^2 K^2 r}{e^{rT} - 1}$ and the FOC is $\Pi_{ln}(T)' = -\Delta e^{-(\lambda+r)T} + \frac{K^2 r^2 (1-d)^2}{(e^{rT} - 1)^2} e^{rT} = 0$, where T_{ln} has no closed-form solution. Since $\lim_{\lambda \to 0} \Pi_{ln}(T)' = \Pi_S(T)'$ and $\partial \Pi_{ln}(T)' / \partial \lambda = T \Delta e^{-(\lambda+r)T} > 0$ then $\Pi_{ln}(T)' > \Pi_S(T)$ '$\forall_T$. For $T \leq T_S$, $\Pi_{ln}(T)' > 0$ because $\Pi_S(T)' \geq 0$ in the same interval. Then, as $\lim_{T \to 0} \Pi_{ln}(T) = -\infty$ and $\lim_{T \to \infty} \Pi_{ln}(T) = \frac{\pi_0}{\lambda + r} > 0$, any finite maximum must be such that $T_{ln} > T_S$. From the implicit function theorem, $\partial \mathrm{T}_{ln}/\partial \lambda = -\frac{\partial \Pi'_{ln}}{\partial \lambda} \Big/ \frac{\partial \Pi'_{ln}}{\partial T} \,|_{T=T_{ln}} > 0$ as $\frac{\partial \Pi'_{ln}}{\partial \lambda} > 0$. Since

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$T_{ln} > T_S$ and the potential expected forgone revenues from cannibalization at any time T are lower than in stable environments due to the probability of displacement by rival innovation, $F_{ln} < F_S$. Similarly, it follows that $\partial F_{ln}/\partial\lambda < 0$. Finally, leadership transition $L_{ln} = 1$ because the leader's advantages have no preemption value. (ii) When the advantages of the leader are additive, the profit function is $\Pi^{\alpha}_{ln}(T) = \frac{\pi_0}{\lambda + r} + \frac{\pi_1}{\lambda + r} e^{-(\lambda+r)T} - \frac{(1-d)^2K^2r}{e^{rT}-1}$. The FOC is $\Pi^{\alpha}_{ln}(T)' = -\pi_1 e^{-(\lambda+r)T} + \frac{K^2r^2(1-d)^2}{(e^{rT}-1)^2} e^{rT=0}$, which is equivalent to the FOC in (i) for $\pi_0 = 0$. Since $\pi_0 = 0$ is a special case of (i), it must be that all the results in (i) still apply. □

Proof of Propositions 5–8 and Corollary 2 (Part 2): Assume that the new competitive advantage of the leader has high competitive value. (i) The leader's profits are $\Pi_{ln}(T) = \frac{\pi_0}{\lambda + r} + e^{-(\lambda+r)T}\left(\frac{\pi_1}{r} - \frac{\pi_0}{\lambda + r}\right) - \frac{(1-d)^2K^2r}{e^{rT}-1}$. The FOC is $\Pi_{ln}(T)' = -\frac{\pi_1}{r}(\lambda + r)e^{-(\lambda+r)T} + \pi_0 e^{-(\lambda+r)T} + \frac{K^2r^2(1-d)^2}{(e^{rT}-1)^2} e^{rT} = 0$ and T_{ln} has no closed-form solution. The FOC is equivalent to $\Pi_{ln}(T)' = W + \Pi_S(T)' = 0$, where $W = \left(\Delta - \left(\pi_1\frac{\lambda}{r} + \Delta\right)e^{-\lambda T}\right)e^{-rT}$. Thus, for $\Pi_{ln}(T)' < \Pi_S(T)'$ I need that $W < 0$, or that $\Delta - \left(\pi_1\frac{\lambda}{r} + \Delta\right)e^{-\lambda T} < 0$, which is the same as having $T < \frac{1}{\lambda}\ln\left(\frac{\Delta}{\lambda\frac{\pi_1}{r} + \Delta}\right)^{-1}$. The RHS of this inequality is monotonically decreasing in r and $\lim_{r\to 0^+}\left(\frac{1}{\lambda}\ln\left(\frac{\Delta}{\lambda\frac{\pi_1}{r} + \Delta}\right)^{-1}\right) = \infty$. Then, for any value of π_1, π_0, and λ, there is a critical value of $\bar{r}$ such that the inequality is satisfied at $T = T_S$ for $r < \bar{r}$. Hence, when $r < \bar{r}$, I have that $\Pi_{ln}(T_S)' < 0$ and since $\lim_{T\to 0}\Pi_{ln}(T) = -\infty$, it must be that there is at least one maximum for $T < T_S$. There is no other maximum for $T \geq T_S$ because $\partial W/\partial T = \frac{1}{r}\lambda e^{-\lambda T}(r\pi_1 - r\pi_0 + \lambda\pi_1) > 0$ in the FOC. This establishes that $T_{ln} < T_S$. The comparative statics on T_{ln} w.r.t. λ using the implicit function theorem are $\partial T_{ln}/\partial\lambda = -\frac{\partial\Pi'_{ln}}{\partial\lambda}\Big/\frac{\partial\Pi'_{ln}}{\partial T}\Big|_{T=T_{ln}}$ where $\frac{\partial\Pi'_{ln}}{\partial\lambda} = e^{-(\lambda+r)T}\left(T\left(\lambda\frac{\pi_1}{r} + \Delta\right) - \frac{\pi_1}{r}\right)$. Hence, $\partial T_{ln}/\partial\lambda < 0$ if, and only if, $T_{ln} < \frac{\pi_1}{\lambda\pi_1 + \Delta r}$. Note first that a sufficient condition for $\partial T_{ln}/\partial\lambda < 0$ is that r and λ are jointly sufficiently small. For general λ, although T_{ln} has no closed-form expression, numerical analysis showed that $\partial T_{ln}/\partial\lambda < 0$ for r sufficiently small in the (large) subset of parameter space studied. The comparative statics on cannibalization $F_{ln} = \frac{\pi_0}{\lambda + r}e^{-(\lambda+r)T}$ w.r.t. λ is $\partial F_{ln}/\partial\lambda = -\pi_0 e^{-(\lambda+r)T}\left(\frac{T\lambda + Tr + 1}{(\lambda + r)^2} + \frac{\partial T_{ln}}{\partial\lambda}\right)$. If $\frac{\partial T_{ln}}{\partial\lambda}$ is not too negative, $\partial F_{ln}/\partial\lambda < 0$. For sufficiently low values of r, I have that $\lim_{r\to 0^+}\partial F_{ln}/\partial\lambda = -\frac{2}{\lambda^2}\pi_0 e^{-\lambda T} < 0$, by using the implicit function theorem for $\frac{\partial T_{ln}}{\partial\lambda}$, where $\partial\Pi'_{ln}\big/\partial T_{ln} = -(\lambda + r)\left(-\frac{\pi_1}{r}(\lambda + r) + \pi_0\right)e^{-(\lambda+r)T} - r\frac{K^2r^2(1-d)^2e^{rT}}{(e^{rT}-1)^2}\frac{(e^{2rT}-1)}{(e^{rT}-1)^2}$. Since $F_{ln}(\lambda = 0) = F_S$ and $\partial F_{ln}/\partial\lambda < 0$ for small values of r, it must also be that $F_{ln} < F_S$ when $\lambda > 0$. Leadership frequency, $\partial L_{ln}\big/\partial\lambda = e^{-\lambda T}\left(T + \lambda\frac{\partial T_{ln}}{\partial\lambda}\right)$, is positive if, and only if, $\frac{\partial T_{ln}}{\partial\lambda}$ is not too negative. From the implicit function theorem for $\frac{\partial T_{ln}}{\partial\lambda}$, $\lim_{r\to 0^+}(\partial L_{ln}/\partial\lambda) = \frac{1}{\lambda}e^{-\lambda T} > 0$. Numerical analysis of a large subset of the parameter space confirmed these limit results. (ii) When the advantages of the leader are additive, the profit function is $\Pi^{\alpha}_{ln}(T) = \frac{\pi_0}{\lambda + r} + e^{-(\lambda+r)T}\frac{\pi_1}{r} - \frac{(1-d)^2K^2r}{e^{rT}-1}$. The FOC is $\Pi^{\alpha}_{ln}(T)' = -\frac{\pi_1}{r}(\lambda + r)e^{-(\lambda+r)T} + \frac{K^2r^2(1-d)^2}{(e^{rT}-1)^2}e^{rT} = 0$, which is equivalent to the FOC in (i) for $\pi_0 = 0$. Since $\pi_0 = 0$ is a special case of (i), it must be that all the results in (i) still apply. □

Proof of Proposition 9: Assume that the new competitive advantage of the leader has high competitive value and that $\delta > \lambda$ with dual hypercompetition. Profits are $\Pi_D(T) = \frac{\pi_0}{\delta + \lambda + r}(1 - e^{-(\delta+\lambda+r)T}) + e^{-(\lambda+r)T}\frac{\pi_1}{\delta + r} - \frac{(1-d)^2K^2r}{e^{rT}-1}$. The FOC is given by $\Pi_D(T)' = \pi_0 e^{-(\delta+\lambda+r)T} - \pi_1\frac{\lambda + r}{\delta + r}e^{-(\lambda+r)T} + \frac{K^2r^2(1-d)^2}{(e^{rT}-1)^2}e^{rT} = 0$ and T_D has no closed-form solution. The FOC is equivalent to $\Pi_D(T)' = e^{-rT}W + \Pi_S(T)' = 0$, where $W = \pi_1\left(1 - \frac{\lambda + r}{\delta + r}e^{-\lambda T}\right) - \pi_0(1 - e^{-(\delta+\lambda)T})$. (i) At $T = T_S$, $\lim_{\pi_0\to 0}\left(W|_{T=T_S}\right) = \pi_1\left(1 - \frac{\lambda + r}{\delta + r}e^{-\lambda T_S}\right) > 0$ and $\frac{\partial W}{\partial\pi_0}|_{T=T_S} < 0$ if π_0 is sufficiently small since $\partial T_S\big/\partial\pi_0 > 0$, $\lim_{\pi_0\to 0}T_S = \frac{1}{r}$

$\ln \frac{\sqrt{\Delta}}{\sqrt{\Delta} - r(1-d)K} > 0$. Thus, there is a critical $\overline{\pi_0}$ such that when $\pi_0 < \overline{\pi_0}$, $\Pi_D(T_S)' > \Pi_S(T_S)' = 0$. It also follows that $\Pi_D(T)' > \Pi_S(T)'$, $\forall_T$. For $T \leq T_S$, $\Pi_D(T)' > 0$ because $\Pi_S(T)' \geq 0$ in the same interval. Then, as $\lim_{T\to 0} \Pi_D(T) = -\infty$ and $\lim_{T\to\infty} \Pi_D(T) = \frac{\pi_0}{\delta + \lambda + r} > 0$, any finite maximum must be such that $T_D > T_S$. Thus, cannibalization is necessarily less than in stable environments. From the implicit function theorem, $\partial T_D/\partial \delta > 0$ if π_0 is sufficiently small (π_1/π_0 high), as $\partial \Pi'_D/\partial \delta = \pi_1 e^{-(\lambda+r)T} \frac{r+\lambda}{(\delta+r)^2} - T\pi_0$ $e^{-(\delta+\lambda+r)T}$ is positive under the same condition. Thus, cannibalization is decreasing in δ, whereas leadership transition probability is increasing in δ. Finally, the FOC with additive advantages is also $\Pi^{\alpha}_D(T)' = e^{-rT}W + \Pi_S(T)' = 0$ where $\pi_0 = 0$. Since this is just a special case of sufficiently low π_0, all the results derived above should apply. (ii) At $T = T_S$, $\lim_{\pi_0\to\infty} \left(W|_{T=T_S}\right) = -\infty$ and $\frac{\partial W}{\partial \pi_0}|_{T=T_S} < 0$ if π_0 is sufficiently large since $\partial T_S \big/ \partial \pi_0 > 0$, $\lim_{\pi_0\to\infty} T_S = \infty$. Thus, for π_0 sufficiently large, $\Pi_D(T_S)' < \Pi_S(T_S)' = 0$, which together with $\lim_{T\to 0} \Pi_D(\mathrm{T}) = -\infty$ establish that there must be a maximum for $T < T_S$. Because also $\Pi_D(T)' < \Pi_S(T)'$, $\forall_T$ and $\Pi_S(T)' < 0$ for $T > T_S$, there is not a maximum for $T > T_S$. Hence, $T_D < T_S$ for π_0 sufficiently high (π_1/π_0 small). Also, $\partial \Pi'_D/\partial \delta = \pi_1 e^{-(\lambda+r)T} \frac{r+\lambda}{(\delta+r)^2} - T\pi_0$ $e^{-(\delta+\lambda+r)T}$ is negative for π_0 sufficiently large (π_1/π_0 small) and so $\partial T_D/\partial \delta < 0$. Under that same condition, when $\pi_0 > \pi_1 - r^2(1-d)^2K^2$, then $T_S = \infty$ and it must be that $F_D > F_S$. The comparative statics on $F_D = \frac{\pi_0}{\delta + r} e^{-(\delta+\lambda+r)T}$ w.r.t. δ is $\partial \mathrm{F}_D/\partial \delta = -\frac{\pi_0}{\delta + r} e^{-(\delta+\lambda+r)T} \left(\frac{1}{\delta + r} + T + (\delta + \lambda + r)\frac{\partial T_D}{\partial \delta}\right)$, which is positive if $\frac{\partial T_D}{\partial \delta}$ is sufficiently negative. I have that $\lim_{\pi_0\to+\infty} \frac{\partial T_D}{\partial \delta} = \lim_{\pi_0\to+\infty} \left(-\frac{\partial \Pi'_D}{\partial \delta} \Big/ \frac{\partial \Pi'_D}{\partial T}\right) = -\frac{T}{\delta + \lambda + r}$, which is sufficiently negative for δ (and, thus, λ since $\delta > \lambda$) and r sufficiently small. Numerical analysis further showed that π_0 large (π_1/π_0 small) was generally a sufficient condition for $\partial \mathrm{F}_D/\partial \delta > 0$ in the subset of parameter space studied. Finally, since $\frac{\partial T_D}{\partial \delta} < 0$ (and λ constant), it follows that $\frac{\partial L_D}{\partial \delta} < 0$. (iii) With additive competitive advantages, profits are $\Pi^{\alpha}_D(T) = e^{-(\lambda+r)T} \frac{\pi_1}{\delta + r} - \frac{(1-d)^2K^2r}{e^{rT} - 1}$ and the FOC is $\Pi^{\alpha}_D(T)' = -\frac{\lambda + r}{\delta + r}\pi_1 e^{-(\lambda+r)T} + \frac{K^2r^2(1-d)^2}{(e^{rT}-1)^2} e^{rT} = 0$, which is equivalent to the FOC without additive advantages with $\pi_0 = 0$. Since $\pi_0 = 0$ is a special case of (i) (which assumes π_0 sufficiently small), all the results in (i) apply. □

Proof of Proposition 10: Assume that the new competitive advantage of the leader has high competitive value and that $\delta \ll \lambda$. The profits and FOC are as in the proof of Proposition 9. (i) I have that $\partial W \big/ \partial r = \pi_1 \frac{e^{-\lambda T}}{(\delta + r)^2}(\lambda - \delta) > 0$ for $\delta < \lambda$, $\forall_T$. Also, $\lim_{r\to 0} W = \pi_1 \left(1 - \frac{\lambda}{\delta} e^{-\lambda T}\right) - \pi_0(1 - e^{-(\delta+\lambda)T}) < 0$ if δ is sufficiently small. So, for δ sufficiently smaller than λ, there is a critical $\overline{r}$ such that $r < \overline{r}$, $\Pi_D(T)' < \Pi_S(T)'$, $\forall_T$. As in the proof of Proposition 9, this establishes that $T_D < T_S$ for $\delta \ll \lambda$. Also, $\partial T_D/\partial \lambda < 0$ if $\frac{\partial \Pi'_D}{\partial \lambda} = -T\pi_0 e^{-(\delta+\lambda+r)T} - \frac{\pi_1}{\delta + r} e^{-(\lambda+r)T}(1 - (\lambda + r)T) < 0$, which is satisfied when $T < \frac{1}{\lambda + r}$. Note first that r and λ small are sufficient for this inequality to hold. Without a closed-form expression for T_D, numerical analysis was used to show that r sufficiently small is generally sufficient for $\partial T_D/\partial \lambda < 0$ for a large subset of parameter values studied. The comparative statics on cannibalization w.r.t. λ is $\partial \mathrm{F}_D/\partial \lambda = -\frac{\pi_0 e^{-(\delta+\lambda+r)T}}{\delta + \lambda + r} \left(\frac{1}{\delta + \lambda + r} + T + (\delta + \lambda + r)\frac{\partial T}{\partial \lambda}\right)$, which is negative if $\frac{\partial T_D}{\partial \lambda}$ is not too negative. From the implicit function theorem, it follows that $\lim_{r,\delta\to 0} \left(\frac{\partial T_D}{\partial \lambda}\right) = -\frac{1}{\lambda^2}(\lambda T - 1)$, which is not too negative when λ is sufficiently large. Under the same conditions $\partial \mathrm{L}_D/\partial \lambda > 0$ because $\partial \mathrm{L}_D \big/ \partial \lambda = e^{-\lambda T}(T + \lambda \frac{\partial T_D}{\partial \lambda})$, which is positive if, and only if, $\frac{\partial T_D}{\partial \lambda}$ is not too negative. These results are consistent with numerical analysis. (ii) As in the proof of Proposition 9, the FOC with additive advantages is equivalent to the FOC without additive advantages with $\pi_0 = 0$. Since $\pi_0 = 0$ is a special case of (i), it must be that all the results in (i) still apply. □