從動態競爭觀點審視作業流程管理的創新與改進

Process Innovation and Improvement: A Competitive Dynamics Perspective

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摘 要

營運暨策略管理文獻已廣泛討論透過採用業界認可之最佳管理實務來提升作業流程效率及效力。過去相關研究主要探討一家處於追隨者地位的企業,如何學習該產業標竿企業的最佳作業流程實務來發展並積累自身組織能耐,用以改進其營運績效。本研究引用策略管理文獻之動態競爭觀點來深耕此研究脈絡。根據全球汽車產業的作業流程創新與改進歷史和相關管理文獻的理論框架與實證研究,本文發展出一個動態模型並藉此得到作業流程創新與改進的管理意涵。文章主要命題如下:雖然追隨企業可以投資作業流程創新能耐來追求長期組織成長,但此舉將引起標竿企業的激烈競爭性回應。為保持業界領先地位,標竿企業具有強烈的策略意圖來公開其最佳作業流程管理實務以供追隨企業學習和採用;其目的在於誘導追隨企業投資短期見效的作業流程改進能耐進而喪失創造嶄新業界作業流程管理實務的機會。本文闡述動態競爭對作業流程發展及管理實務的重要性並影響業界最佳實務的演進與開創。

【關鍵字】作業流程創新、作業流程改進、競爭策略、營運策略

Abstract

Operations and strategy literatures have consistently promoted the best practice of accredited management standards for process efficiency and effectiveness. Based on the capability theorizing, studies have investigated how a following firm can improve its operational performance by learning from a leading firm's best practices. Our study extends this research stream by applying competitive dynamics perspective from strategy literature to the context of process development and management. We develop insights by applying a dynamic, computational model based on an extensive appraisal of the history of process innovation and improvement in the global automobile industry and draws on the underlying theoretical relationships in the empirical literatures on operations and strategy. The core proposition in our study is that a follower firm's investment in process innovation capabilities for long-term growth will provoke strong retaliation from leading firms using the current best practice. We demonstrate that the leading firm can publicly signal its best practice to induce the follower firm to invest in process improvement capabilities but only for short-term survival, not for long-term purposes or goals. In this way, the leader firm maintains its leading edge. Our results also underscore the importance of competition in determining the firm-level process development and management practices.

【Keywords】 process innovation, process improvement, competition, operations strategy

1. Introduction

When developing an operational process (either manufacturing or service), a firm may face incumbents with well-established processes that are current industry standards. Operations management and organization researchers have long investigated the effects of process improvement and innovation on firm performance (Kim, Kumar, and Kumar, 2012; Rahmandad, 2012). Although progress has been made in this domain, the existing literature has a major limitation. While much research has examined a firm's decision to invest in process improvement capability for short-term survival, or in process innovation capability for long-term growth (Peng, Schroeder, and Shah, 2008); very few studies have explored how a new best-practice process emerges to replace an industry's existing best-practice process (Shepherd and Patzelt, 2013). Well-known examples of best-practice processes include Craft Production (CP) versus Mass Production System (MPS), and MPS versus Toyota Production System (TPS). This paper addresses this limitation and argues that competitive pressure imposed by the existing best-practice process can negatively impact a follower firm's capability-development trade-offs for building a new best-practice process.

The core proposition that we propose in this study is grounded in two distinctive theoretical perspectives. The capability theorizing perspective suggests that a firm's improvement capability facilitates the achievement of its full potential within the current best practice but that innovation capability creates new industrial operating frontiers (Schmenner and Swink, 1998; Peng et al., 2008). Various studies have examined the firm's capabilities as a primary construct to explain firm heterogeneity and sustainable advantage through effective process management (Boyer, Swink, and Rosenzweig, 2005; Swink and Hegarty, 1998). However, these arguments are problematic as they are based primarily in settings where capability development trade-offs is determined within the boundary of a single firm and overlooks the strategic importance of inter-firm competition. Chen (1996) proposes that the key driver of any competitive action is a set of strategic variables centered on awareness, motivation, and capability to manage interfirm rivalry. This competitive dynamics perspective suggests that process failure occurs when firms are unaware of and/or incapable of coping with possible retaliations from rivals (Schmenner and Swink, 1998; Ferrier, Smith, and Grimm, 1999). It is the missing piece in the operations management literature that captures the competitive dynamics of process improvement and innovation.

This study views the dynamics of process development and management as an evolution of *process competition*; that is, a firm improves and innovates its processes by considering rivals' reactions and their resulting effects on its operations strategy. This notion

explicitly considers the dynamic, disruptive nature of process development and management (Young, Smith, and Grimm, 1996). Our core argument is that the likelihood of effective process development and management for a focal firm depends not only on its own operational excellence (Micro-level), but also the (non-)responses of its rivals (Macro-level) (i.e., the multilevel interactions between inner-firm capability development trade-off and inter-firm competition).

We follow the work of dynamic computational theory proponents such as Sterman, Henderson, Beinhocker, and Newman (2007), Vancouver, Weinhardt, and Schmidit (2010), and Rahmandad (2012); to model process competition, and of scholars who espouse simulation methods for theory development in entrepreneurship, management and organization (see, Adner, Polos, Ryall, and Sorenson, 2009; Davis, Eisenhardt, and Bingham, 2007; Harrison, Lin, Carroll, and Carley, 2007; Yang and Chandra, 2013; Keyhani, Lévesque, and Madhok, 2015). Dynamic computational theory refers to the mathematical and empirical specifications of a theoretical account of how key constructs (or variables) influence each other over time (Vancouver et al., 2010). Such theory can be simulated to examine how variables in a multilevel, interconnected system changes from a given set of starting values (Jayanthi and Sinha, 1998). Moreover, in line with Bendoly, Croson, Goncalves, and Schultz (2010) and Nair, Narasimhan, and Choi (2009), we take the low church approach of capability theorizing, one that relies on a behavioral standpoint, as opposed to the high church approach that derives theory from equilibrium and rationality assumptions (Rahmandad, 2012). Although the findings are somewhat restricted by the model settings, this research can help decision makers make informed choices on process capability development and contribute to the process management and operations strategy literatures. The theory we develop depicts a dynamic, causal mechanism through which firms are "aware" of, "motivated" by, and "capable" of developing new best practices or improving the existing best practice in their focal industry.

Our main contribution is the simulations that produce new insights from established constructs and their relationships. Specifically, we re-examine the history of process innovation in car manufacturing (i.e., CP to MPS then to TPS) and use an in-depth review of the existing empirical and theoretical literatures coupled with the system dynamics methodology (Sterman, 2000; Repenning, 2002; Größler, Thun, and Milling, 2008; Bendoly et al., 2010; Cui, Zhao, and Ravichandran, 2011). We identify the key constructs of fundamental dynamics of process competition from the literature and assess their relationships parsimoniously using dynamic computational theory. Hence, our model is well

grounded in the literature and empirical evidence. The end result is an internally consistent theory that offers a deeper understanding of process competition (Schmenner and Swink, 1998; Choi, Dooley, and Rungtusanatham, 2001; Schroeder, 2008).

This paper's primary contribution is demonstrating that the firm's competitive tension substantially impacts rivals' process development resisting them to replace its current best practice. Instead of treating competition as an exogenous factor as is the norm in the existing literature, we find that firms may act strategically to manage the competitive tension. Operations management literature suggests that a firm is more likely to invest in innovation when its rival builds greater barriers to its process improvement over time such that the frequency of process innovation increases in parallel with the intensity of competition (Mendelson and Pillai, 1999). Contrary to this accepted wisdom, our analysis shows that competition can decrease the frequency of process innovation for the followers. In other words, a leading firm with the current industrial frontier of operational processes can publicize its superior processes to elicit its rivals' investment in improvement capability. Thus, the ease of imitation, together with the threat of strong retaliation from the industry leader, curbs the follower firms' radical process innovation, and reduces their likelihood of developing innovative processes. We justify this insight and other results in subsequent sections.

2. Process Competition: An Illustration

Operational excellence plays a crucial role in the automobile industry, which organizes human and physical resources to manufacture vehicles in pursuit of a competitive edge. Since the dawn of the Industrial Revolution, manufacturing firms have faced increasing competition with every technology advancement. With the Digital Revolution, today's manufacturers are facing ever increasing pressure to improve and innovate processes at faster rates just to keep pace. From the days of CP to the rise of MPS, then TPS, manufacturing processes have co-evolved with competition. To better understand process competition in this industry, we surveyed literature and synthesized their empirical findings. One finding stands out: A revolutionary process emerges to improve the weaknesses of the existing best practice and outmaneuver it *during the action-reaction exchanges* under competition.

In the CP age, the manufacturing system served customers by making exactly what the customer requested, one at a time (Womack, Jones, and Roos, 1990). Yet the goods were rather costly. In the early twentieth century, a competing process, MPS, was developed to address the CP's flaw in affordability by offering low-priced mass-produced goods

(Fujimoto, 1999). The use of sophisticated, single-purpose machines and semi-skilled or unskilled workers greatly increased productivity (Womack et al., 1990).

MPS was the accepted standard as the best practice in the automobile industry, until Taiichi Ohno and his *Toyota Production System (TPS)* (also called *Lean Manufacturing*) joined the competition in 1950s. Far ahead of his peers using MPS manufacturing, Ohno identified and examined the flaws of MPS, experimented with alternative processes and devised a new system (Fujimoto, 1999). Mass producers had added many buffers to the MPS production system to ensure smooth production since the machinery was expensive and costly to fix production disruptions; in contrast, the revolutionary TPS employed just-in-time production and flexible machines to minimize the buffers, eliminating wastes of materials, machine time and worker hours (Schonberger, 2007). In essence, TPS is a synthesis of CP and MPS, but without the high cost as the CP system or the rigidity of the MPS system (Womack et al., 1990). Ultimately, TPS's superior productivity, quality, and flexibility successfully challenged the MPS practice in the industry.

Surprisingly, we observe in practice that the manufacturing leaders today deliberately explicate their processes to attract challengers' improvement efforts. The resulting constraints on challengers' process innovation capability development ultimately decrease the threat to the leading firms. For instance, the apprenticeship in the CP age, which enabled the greatest access to the leading process, did not trigger process innovation for hundreds of years. Furthermore, consider Toyota's openness to opening its process to its rivals via factory tours. Many rival firms have visited Toyota's factories and consequently developed "Toyota-like" operational processes with small improvements. Despite their efforts to replicate Toyota's success, its rivals have not been able to match Toyota's systematic improvement process, which continuously improves quality and cost competitiveness (Schonberger, 2007). To date, TPS remains the industry leader in process management and has been for over fifty years. In short, the pressure from competition prompts the leader to defend itself, for example, by "locking" rivals into small-scale process improvement.

3. Theoretical Background

Anecdotal evidence suggests that the firm generates a superior process that evolves during its interactions in competing with competitors' processes over time. The literature identifies two possible tensions in process competition. One is between competing processes (a firm's current process versus its rival's process) from the external view of competition in business strategy (Porter, 1980). The other tension derives from the internal view of

operations strategy (Peng et al., 2008) stemming from the trade-off between incremental improvement and radical innovation capabilities. These two tensions co-exist and interact to influence the firm's process management and development (Chen and Miller, 2012).

We introduce the competitive dynamics perspective to capture the essence of these two tensions. One major goal of competitive dynamics research is to investigate performance consequences of the firm's actions and the corresponding responses from the firm's competitors (see Chen and Miller (2012) and Smith, Ferrier, and Ndofor (2001) for a comprehensive review). In this research stream, a competitive move is the unit of analysis used to explore the micro dynamics of competition. Firms act strategically to enhance their competitive advantage and gain abnormal profits, but their successful actions attract rivals' countermoves that can erode the benefits of these competitive moves (Chen and MacMillan, 1992). Therefore, the best possible outcome can be achieved if continuous actions are unchallenged (Porter, 1980). In this study, we recognize the improvement or innovation of a process resulting from capability development as a competitive move. The focal firm improves its performance by successfully deterring rivals from challenging its business process.

We study the tensions in process competition by employing the cognitive framework of Awareness-Motivation-Capability (AMC) as applied to the firm, to make sense of the competitive environment and make corresponding re/actions (Chen, 1996; Chen, Su, and Tsai, 2007). As Figure 1 reveals, we embed the capability development trade-offs within the competitive context. Process competition is initiated when the firm is aware of, motivated by, and capable of developing the best practice, which in turn influences the dynamics of competition. The details of the cognitive process of strategic decision-making in process development and management are as follows.
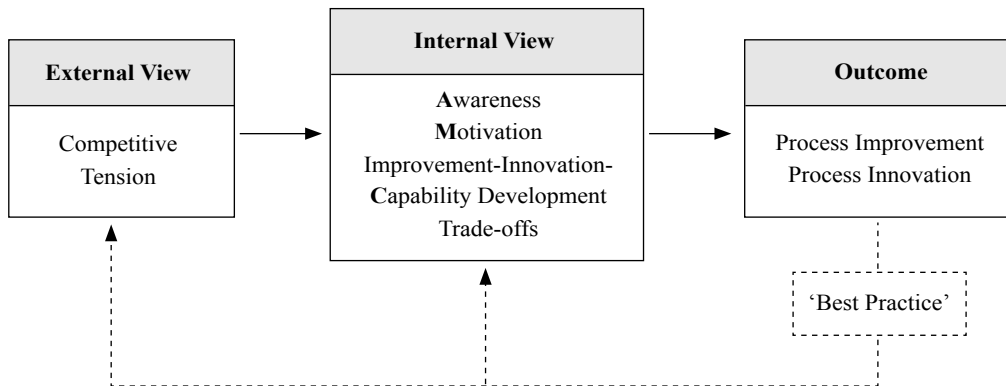

Figure 1 An Awareness-Motivation-Capability Perspective of Process Competition

3.1 Capability

The concept of "capability" refers to the firm's resource deployment and ability to implement an action during process competition. We follow Schmenner and Swink (1998) and Swink and Hegarty (1998) and focus on two key capabilities: improvement and innovation capabilities. "Improvement capabilities" are developed to carry out small-scale changes using the firm's existing physical assets and operating policy, such as enhancing technology utilization (March, 1991) and waste reduction (Swink and Hegarty, 1998). In contrast, "innovation capabilities" are characterized as the ability to pursue new manufacturing approaches by targeting large-scale, radical process changes, which generally require major structural changes in equipment and/or facilities (Schroeder, 2008; Eisenhardt and Martin, 2000; Peng et al., 2008).

Scholars suggest that firms can simultaneously develop improvement and innovation capabilities (Adler, Goldoftas, and Levine, 1999), but they require rather distinct resources (Peng et al., 2008). Therefore, constrained by scarce organizational resources, firms often make trade-offs between the two capabilities: improvement and innovation (Swink and Hegarty, 1998; Rahmandad, 2012). The strategic decision of capability development trade-offs can get more complicated in the presence of competition, as explained in the following section.

3.2 Awareness and Motivation

In a competitive environment, full awareness is a prerequisite for process competition initiatives (Chen, 1996). "Awareness" refers to the firm's perception of the competitive environment including major rivals. Fully understanding its rivals' processes gives the firm relative broad range of knowledge, which is necessary to anticipate the various consequences of proposed process change actions. A firm with low awareness may underestimate the competitive pressure imposed by rivals or allow a rival's action to go unnoticed, hence hinder its ability to attain anticipated outcomes (Tsai, Su, and Chen, 2011).

"Motivation" stimulates a firm to engage in process competition. A firm is likely to make a commitment to a process change action when it perceives large gains from taking action or great losses from non-action (Smith et al., 2001). Competitive tension is frequently used to capture this decision-making threshold (Chen et al., 2007). Specifically, competition favors a firm's bias towards improvement capabilities that pay off in the relative short term, i.e., "short-termism" (Rahmandad, 2012). For instance in production planning and control, reactive maintenance is chosen over preventive maintenance (Sterman, 2000), and

firefighting behaviors (or ad hoc problem solving) get more attention from managers and even more credit than preventive actions (Repenning and Sterman, 2002).

The dynamism of the market is a primary reason for the recent increased investment in process innovation. The firm can use breakthroughs in process management as strategic weapons to destabilize the market and threaten rivals' competitive position (Teece, Pisano, and Shuen, 1997). Indeed, the firm experiences "worse-before-better" dynamics when shifting away from improvement capabilities (Sterman, 2000). From a long term perspective, however, innovation capabilities ultimately compensate the firm for the initial performance loss. Accordingly, investment in innovation capabilities is vital to improve performance.

We argue that managing process improvement and innovation requires a dynamic, strategic orientation so that firms can simultaneously analyze multiple interdependent relationships within the underlying, complex dynamic system (Choi et al., 2001; Größler et al., 2008; Bendoly et al., 2010). While most contemporary methodologies are static in nature, dynamic modeling offers a powerful method to capture simultaneously on-going processes and procedures that influence each other (Davis et al., 2007). Dynamic modeling is particularly useful in developing dynamic computational theory by highlighting feedback processes (i.e., circular causal relationships) in which variables influence and, in turn, respond to each other (Sterman, 2000; Repenning, 2002; Cui et al., 2011). Hence, such methodology can reveal novel insights into the means by which firms improve and innovate their operational processes in dynamic competition.

4. Model

In this section, following the lead of Sterman et al. (2007) about dynamic competition and simulation settings as well as the lead of Größler et al. (2008) about the role of feedback in process management, we develop a dynamic systems model of process competition based on the AMC perspective with consideration of both internal capability development trade-offs and external competition. The model starts with the firm's awareness of the external environment derived from multimarket contacts with competing firms. We then turn to an analysis of competitive tension impacting the firm's motivation. The capability section captures the trade-off between improvement and innovation efforts and the resulting market performance.

This model considers a duopoly for the analysis of process development and management from the viewpoint of rent searching. The *leader* maintains dominant position in the industry because it employs the current best practice. The *follower* aims to improve its

strategic position by incrementally improving the leader's process (i.e., process improvement) and/or radically creating a new one (i.e., process innovation). In the model, we take the follower firm's viewpoint to examine the causal mechanism through which the follower recognizes the leader's best practice, and then imitates and develops it.

The model was formulated in continuous time as a set of nonlinear differential equations as do Sterman et al. (2007) and Rahmandad (2012). To justify our model, we present the theoretical foundations and empirical evidence for the proposed causal relationships with each model equation.

4.1 Awareness: Multimarket Contact

The literature on multimarket competition suggests that firms interacting across multiple markets are familiar with each other's mindset and action patterns (Gimeno and Woo, 1996; Tsai et al., 2011). Therefore, the follower firm's awareness is expected to increase with market commonality, M, defined as the degree of its presence in the common markets (Chen, 1996). Market commonality serves as a state variable in our model with a 0 to 1 range, increases in Entry into Rival's Markets, I, and decreases in Withdrawal from Common Markets, E:

$$dM/dt = I - E. \tag{1}$$

When firms competes in common markets they create substantial deterrent effect because the firms establish a mutual foothold, f, to signal their ability to enter into each other's markets (Baum and Korn, 1999). Consequently, they are less likely to be forced to exit the common markets due to mutual forbearance. Specifically, the multimarket contact literature has identified a curvilinear relationship between multimarket contact and market entry/exit with a diminishing increase rate (Gimeno and Woo, 1996; Baum and Korn, 1999). Therefore, we assume a logarithmic relationship between market commonality and the follower's established mutual footholds in the model:

$$E = 1/(a_1 \cdot f \cdot t_w), \tag{2}$$
$$f = \ln(M + a_2), \tag{3}$$

where a_1 and a_2 are set at constant to ensure that market commonality is within the 0 to 1 range, and t_w is the average time spent by the follower to withdraw from one market.

The ever-increasing mutual footholds eventually lead to restraint and competitive stability, which lower the follower firm's entry rate (Baum and Korn, 1999). That is, the risk of retaliation, r, tends to outweigh the benefits of the follower's additional market-entry actions (Gimeno and Woo, 1996). The leading firm is likely to react aggressively to the follower firm's market entry. In addition, such retaliation may not only be limited to the localized markets, but also escalate to all the other shared markets. Therefore, within the context of a multimarket rivalry, the follower has an incentive to avoid entering a new market that is occupied by the leader to discourage potential multimarket retaliation (Chen and MacMillan, 1992). Formally:

$$r = \exp(f + a_3) + m, \tag{4}$$

where a_3 is a constant to ensure that market commonality is within the range from 0 to 1, and m represents the tension derived from small-scale improvement actions, which will be explained later.

Accordingly, we obtain an inverted U-shaped relationship between the firms' multimarket contact and the follower's rate of market entry as stated in Baum and Korn (1999):

$$I = (f - r)/t_i, \tag{5}$$

4.2 Motivation: Competitive Tension and Commitment

Competitive tension, H, is affected by the levels of survival pressure derived from direct competition, D, and growth pressure derived from indirect competition, N (Rahmandad, 2012). A direct (i.e., head-on) competition will greatly raise the tension between opponents, and in an indirect competition, their devious actions will lower the tension:

$$dH/dt = D - N. \tag{6}$$

In fact, the leader's various actions could cause the follower to interpret the competitive tension in different ways. Notice that the (re)actions taken to developing process improvement and/or innovation capabilities, such as a TQM program, which often involves a large lump sum investment (Repenning and Sterman, 2002; Kim et al., 2012). This investment signals a firm's commitment and the irreversibility of its actions (Chen and

MacMillan, 1992). Chen, Venkataraman, Black, and MacMillan (2002) further distinguish internal and public commitments: Internal commitment, q, is generated from sunk costs, consistent leadership, and organizational inertia; public commitment, p, is generated from social and institutional pressures to protect the firm's reputation. They have diverse impacts on competitive tension, explained as follow.

With high public commitment, the follower firm tends to decrease its response delay and offers a matching response to signal its commitment to its self-defense (Chen et al., 2002). The competitor's subsequent response will consequently escalate to a direct (head-to-head) competition (Smith et al., 2001). The resulting competitive tension will increase the likelihood of a next-round, action-reaction exchange:

$$D = (p \cdot H)/s, \tag{7}$$

where s is the response speed of the follower to protect the reputation and defend the existing product markets.

Consider the follower's market-entry decision. Often it will require approval from top management as it could receive much public attention (high p). Once the leader reacts, A (i.e., leader's attack), the follower will have great incentive to justify its past action by escalating its resource commitment. Formally:

$$p = \ln(f + a_4) + A, \text{ and} \tag{8}$$

$$A = \begin{cases} a_5 \cdot r, & \text{if } x \leq r \leq y, \\ 0, & \text{otherwise,} \end{cases} \tag{9}$$

where a_4 is a constant employed to ensure that public commitment remains positive, and a_5 is the coefficient to reflect the leader's attack volume. Note that the leader does not respond to the follower's every move because of risk incurred with (re)actions. The leader attacks only within a given range of retaliation risk between x and y, that is, when the follower's threat is substantial (i.e., above x) and before such (re)action becomes too risky (i.e., below y).

In contrast, the follower's internal commitment tends to lessen the competitive tension in an indirect competition. Recall that mutual market footholds of both the follower and leader increase the likelihood of retaliation from each other. To avoid such retaliation, the follower may turn its attention to internal development. The strategic evasion from an

intensive conflicting inter-firm relationship gives the follower a chance to enhance its competency. That is,

$$N = (q \cdot H)/g, \tag{10}$$
$$q = a_6 \cdot r, \tag{11}$$

where g is the response delay due to the follower's internal concentration of resources on self-development; a_6 is the coefficient that reflects the follower's commitment to internal capability development.

4.3 Capability: Process Development Trade-Off

The follower often faces a substantial barrier when learning from the leader's superior processes (Cohen and Levinthal, 1990). If the follower possesses similar types of resources as the leader, the follower is more likely to digest the leader's process knowledge and make improvements based on this knowledge (Swink and Hegarty, 1998). For Chen (1996) and Laamanen and Wallin (2009), resource similarity, S, reflects the extent to which the follower possesses strategic endowment comparable to that of the leader. The resource similarity will increase based on the follower firm's investment in improvement capabilities, V, and will decrease based on the amount of innovation capabilities, O:

$$dS/dt = V - O. \tag{12}$$

The follower's sustained incremental process improvement, m, grounds the existing process, creating small wins that collectively translate into superior performance (Bessant and Francis, 1999). The follower's efficiency gain and cost reduction from m further reinforce its commitment to continuous improvement:

$$m = S \cdot u_i, \tag{13}$$

where u_i reflects the effectiveness of developing process improvement capabilities.

In contrast, the follower may recognize the value of process innovation in pursuit of competitive advantages (Schroeder, Scudder, and Elm, 1989; Rahmandad, 2012). Indirect competition offers it a break to explore new and promising technologies to enhance its process effectiveness and improve innovation differentiation, l. Innovation differentiation is

achieved by superior or unique product performance and patented technologies resulting from strong process innovation capabilities (Swink and Hegarty, 1998). The follower can then effectively defend itself against quick retaliations from the leader. In other words, its self-invented capabilities can create learning barriers for the leader. Formally,

$$l = O \cdot v_i, \tag{14}$$

where v_i reflects the effectiveness of developing innovation capabilities, such as the ability to integrate the innovation with a wider range of process capabilities.

Generally, the follower firm prefers to see the leader's process as a benchmark and as a target goal, largely due to the great achievement, high visibility, and institutionalization of this process (Ferrier et al., 1999). In particular, intensive competition forces the follower to take an imitative strategy to avoid falling behind other rivals in the market which rewards fast responders (Rahmandad, 2012). To be fast, the follower then must limit its action to only small-scale process improvements (Repening and Sterman, 2002; Rahmandad, Repenning, and Sterman, 2009). In other words, the strong competitive tension limits the follower because of the survival pressure, and thus it will choose to concentrate on the logical competitive advantage option of developing process improvement capabilities:

$$V = (1 - z)D, \tag{15}$$

where z reflects the follower's resource percentage invested in process innovation capabilities. This tension reflects the capability development trade-off; given the total resources, an increase in innovation capability means a decrease in improvement capability. Alternative formulations for modeling diverse trade-offs are discussed in the next section.

When there is not enough resource similarity to support continuous process improvement, the follower needs to switch to search for new opportunities (Schmenner and Swink, 1998). To illustrate this, Toyota's Just-in-Time process was, remarkably, largely the firm's response to the historical imperative and its low resource similarity of MPS firms (Fujimoto, 1999). Meanwhile, established MPS firms, acknowledging Toyota's weaknesses, did not treat it as a major competitor (threat) (Womack et al., 1990). Likewise, such 'constraints' on the follower side can single-handedly generates a less intensely competitive environment, reduce the leader's retaliation threat, and facilitate the follower's process innovation:

$$O = z \cdot N. \tag{16}$$

4.4 Methodology and Justification

Davis et al. (2007), Harrison et al. (2007), and Nair et al. (2009) note that when a study does not seek to predict the outcome of a particular set of equations, as is the case in our study, a computational model using a set of parameter values qualifies as a carefully planned and valid experimentation process as long as it satisfies the general conditions of the problem being studied and shows the existence of some property of general interest. If the outcome from computer simulations matches the behavior of the dynamic systems theorized, the computational model then presents a viable explanation, at least until another contender better matches or more parsimoniously matches it (Vancouver et al., 2010). In the next section, we follow the practice for developing dynamic computational theory through a computer simulation (Sterman, 2000).

5. Analysis

In this section, we evaluate the follower firm's various process capability development trade-offs. We begin by addressing the effect of competition on process improvement and innovation, emphasized by Rahmandad (2012), and follow Laamanen and Wallin (2009) process of varying the three types of capability development trade-offs: constant-fraction, short-termism, and long-term development. We then evaluate how each trade-off shapes the follower's process management and development to address its competitive interactions with the leader. We derive the subsequent effect of the investment on follower's ability to survive and grow in a competitive environment.

Specifically, the follower's capability development trade-off with constant fraction between innovation and improvement capabilities is consistent with prior studies in the absence of competition (Repenning and Sterman, 2002). In this case, the follower does not consider competitive tension at all and is likely to develop process improvement capability as a general rule as long as it has adequate resources to support learning from the leader. Otherwise, the follower will shift its investment to continuously develop its process innovation capabilities. Second, a short-termism follower might appreciate the value of process innovation, but the competition will pressure it to commit only to incremental process improvement (Rahmandad, 2012). In this case, the percentage of innovation capability is negatively related to competitive tension. Finally, the follower adopting a long-term-growth capability development trade-off is not satisfied with the small wins from its

incremental changes. Rather, it tends to keep searching for new opportunities and differentiate itself from its competitor (Porter, 1980). That is, the percentage of innovation capability here is positively related to competitive tension in the model.

To characterize the range of behavior our model produces, and to understand the impact of each parameter including competitive tension and resource similarity, we have extensively analyzed the model using a variety of methods. To highlight its most interesting dynamics, we present a small subset of these experiments. In the simulation experiments that follow, we rigorously examine the dynamics between two competing processes during a 10-year period, and observe process evolvement patterns to further understand the interrelationship between process competition and process capability development trade-offs. We use Vensim™ software to simulate the model by Euler integration with a time step of 0.25 months. The results are insensitive to the use of smaller time steps or high-order integration methods such as fourth-order Runge-Kutta. Table 1 provides the parameter values used in the base case reported in this paper.

Table 1 Parameters and Initial Conditions for the Base Case

| Parameter			
t_i	Time to entry into rival's market		6
t_w	Time to withdraw from common market		3
s	Response speed		1.5
g	Response delay		3
u_i	Effectiveness of developing process improvement capabilities		0.3
v_i	Effectiveness of developing process innovation capabilities		0.3
a_1	Adjustment value for logarithmic value of market commonality		3
a_2	Weight on the established mutual footholds		4
a_3	Adjustment for exponential value of established mutual footholds		-3
a_4	Adjustment value on public commitment without competition		1
a_5	Weight on the volume of retaliation attack		0.6
a_6	Weight on internal commitment by considering competition		0.8
Initial Conditions			
M_0	Initial value of market commonality		0.2
H_0	Initial value of competitive tension		0.1
S_0	Initial value of resource similarity		0.2

5.1 Process Capability Development Trade-Off with Constant Fraction

First, consider the case in which the follower manages the capability development trade-off with constant fraction. Our simulations reveal that without considering competition,

the follower cannot replace the leader's best practice regardless of the similarity of resources. In the left panel of Figure 2, low resource similarity cannot provide the follower effective learning from the leader's process. Therefore, the follower has to experiment with various innovative processes, bearing the risk of exploring unknown territories. Figure 2c, however, shows that the competitive tension drops below zero at month 18.5, which indicates that the follower is no longer a threat to the leader's market position; that is, the follower's process terminates.
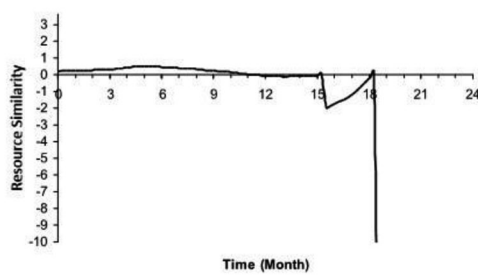
2a) Resource Similarity ($S_0 = 0.2$)
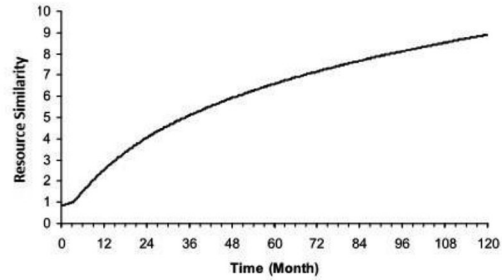
2d) Resource Similarity ($S_0 = 0.85$)
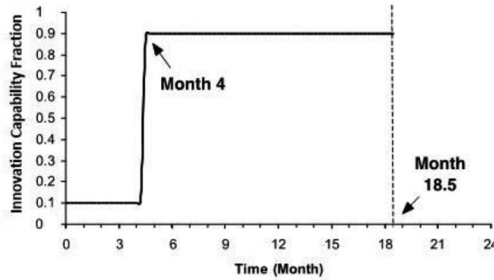
2b) Innovation Capability Fraction ($S_0 = 0.2$)
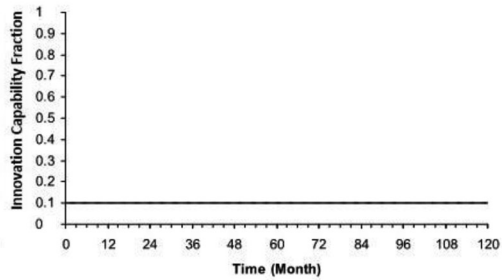
2e) Innovation Capability Fraction ($S_0 = 0.85$)
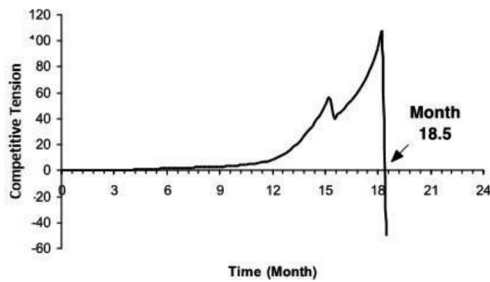
2c) Competitive Tension ($S_0 = 0.2$)
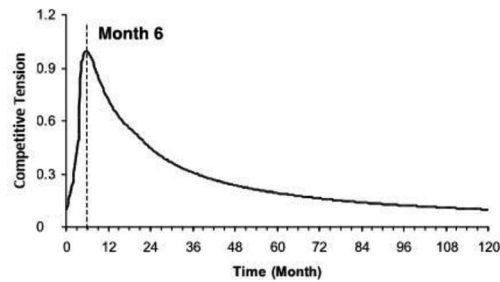
2f) Competitive Tension ($S_0 = 0.85$)

Figure 2 Operational Performance under Constant-Fraction Capability Development Trade-Off

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As we move to the right panel, high resource similarity facilitates the follower's investment in continuous process improvement (see Figure 2d); following this, the resource similarity increases as expected. Surprisingly, the competitive tension shown in Figure 2f, with an initial (slight) increase, drops gradually after month 6. We carefully analyze our results to uncover the cause of this intriguing issue, to be discussed later.

5.2 Process Capability Development Trade-Off with Short-Termism

Under short-termism, we illustrate the operational performance of a start-up follower as shown in Figure 3. Initially, the firm must accumulate capabilities via modest process innovation as a result of low resource similarity to the leader. Yet its increased operational performance soon attracts the leader's attention. The resulting high level of competitive tension imposes strong survival pressure to the follower at month 6 (see Figure 3b). Ignorance of such pressure may eventually lead to firm termination. Consequently, the follower must adjust its capability trade-off to match the leader's responses. As shown in Figure 3a, the follower almost withdraws all efforts to develop innovation capabilities after approximately the second year of experimentation. From then on, it turns its attention to small-scale improvements with predictable short-term outcomes.

The result here is rather similar to those of the capability development trade-offs with constant fraction. Neither can facilitate sustained process innovation. This suggests that a steady and continuous investment in innovation capabilities is required to achieve long-term benefits.

5.3 Process Capability Development Trade-Off with Long-Term Growth

The long-term growth shown in Figure 4 sheds light on the answer to the opening question: how does a new best-practice process emerge to replace an existing best-practice process? In this setting, competitive tension first increases resulting from the follower's large-scale efforts to learn the leader's process. In hopes of relaxing the ever-increasing competitive pressure, the follower increases investments in process innovation capabilities. This smart move effectively distracts the leader's attention from the follower's escalation of competition due to its perception of the follower's subordinate (i.e., weaker) role. However, the less intense competitive market environment allows the innovated process to develop, facilitating increased operational performance. Ultimately, in the long run, the follower can take over the leader's position. Thus, the competitive tension eventually rises between the follower and leader.
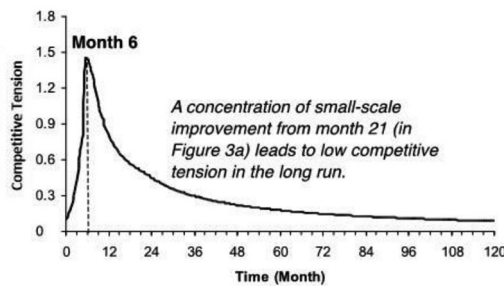
This capability development trade-off reveals another important feature of process competition: A continuous investment in innovation capabilities, while relaxing the competitive pressure in the short term, will increase the tension in the long run.
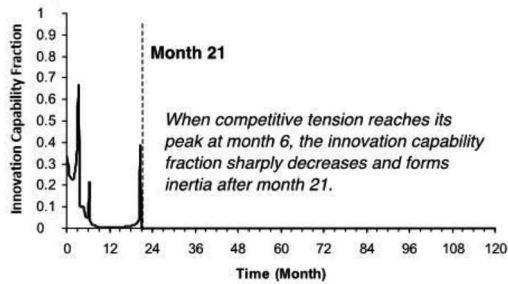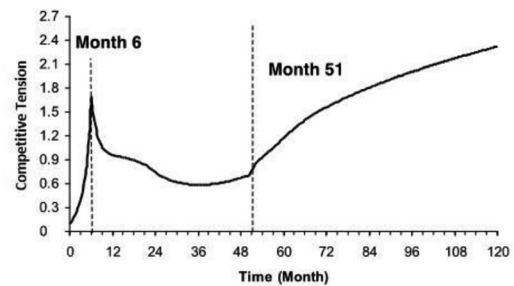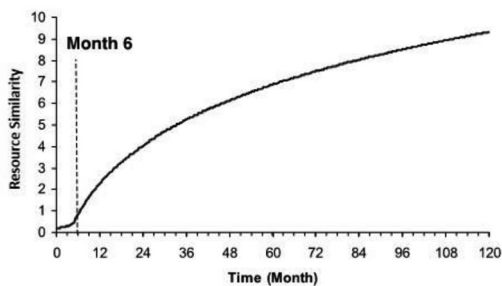

3a) Innovation Capability Fraction
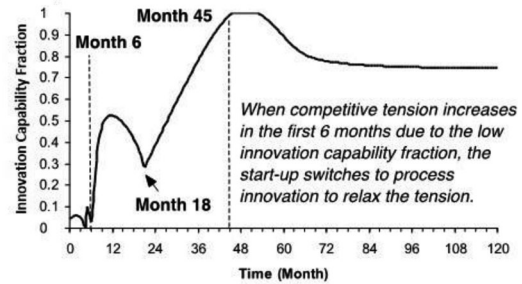
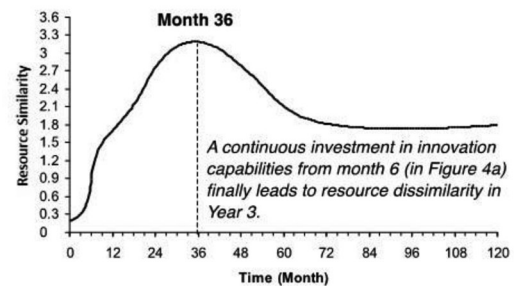4a) Innovation Capability Fraction

3b) Competitive Tension

4b) Competitive Tension

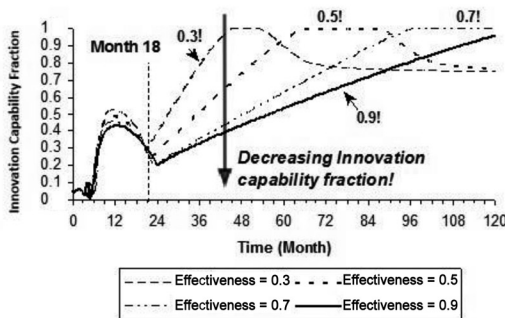3c) Resource Similarity

4c) Resource Similarity

Figure 3 Operational Performance under Short-Termism Capability Development Path

Figure 4 Operational Performance under Long-Run Growth Capability Development Path

5.4 Impact of Process Improvement and Innovation Effectiveness

The trade-offs are influenced by the effectiveness of improvement and innovation capability development. As the two parameters are exogenous in our model, a sensitivity analysis is conducted to further understand the impact of capability development trade-offs on competitive tension.

The attractiveness of short-termism trade-off increases in the effectiveness of process improvement capability development. Then the investment in innovation capabilities is expected to decrease over time. Our simulation result is consistent with intuitive expectations as illustrated in Figure 5a. Even though the follower eventually recognizes the importance of developing firm-specific capabilities through process innovation, it significantly delays committing to such investments due to the high improvement effectiveness. Consequently, we expect that firm resources become more similar to each other as shown in Figure 5b. The innovation differentiation (Figure 5c) and competitive tension (Figure 5d) both decrease in terms of process improvement effectiveness.
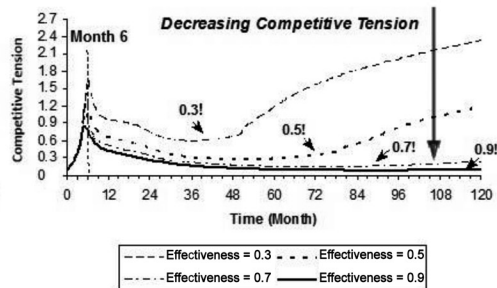

5a) Innovation Capability Fraction
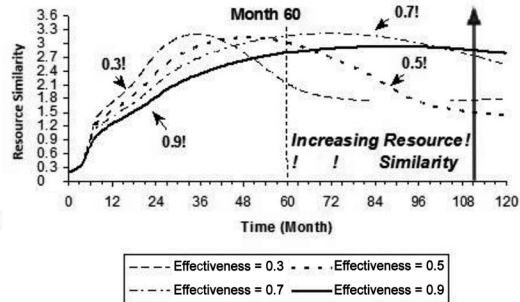
5b) Resource Similarity
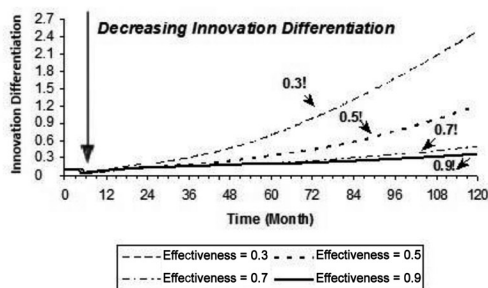
5c) Innovation Differentiation

5d) Competitive Tension

Figure 5 Operational Performance for Various Improvement Effectiveness

In Figure 5, we show that while the increasing improvement effectiveness results in a lock-in effect of the follower's behavior, its additional benefit also decreases. The follower can diminish this effect by increasing its process innovation effectiveness, as illustrated in Figure 6.
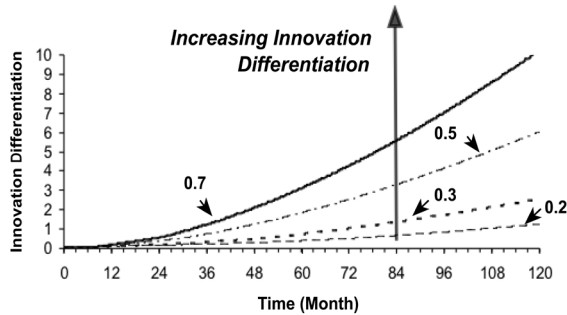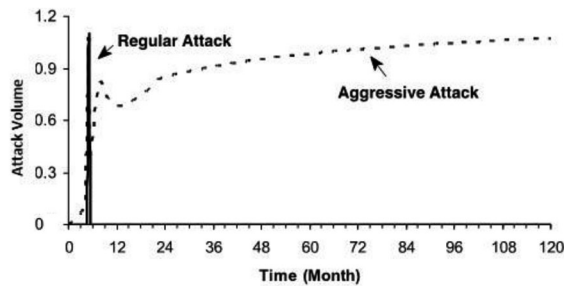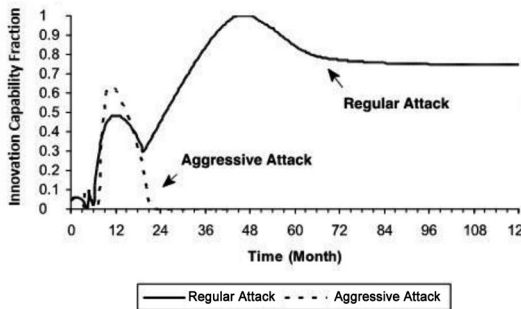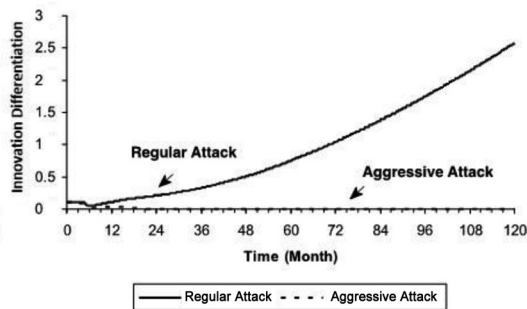

Figure 6 Innovation Differentiation for Various Innovation Effectiveness

7a) Leader's Attack Volume

7b) Innovation Capability Fraction under Different Leader's Attack Volume

7c) Innovation Differentiation under Different Leader's Attack Volume

Figure 7 Capability Development Trade-Offs under Various Leader's Attack

5.5 Impact of Leader's Attack

We test two types of leader attacks. In one setting, the leader regularly attacks the follower. In another setting, the leader acts aggressively to clearly signal its intent to protect its leading position. A comparison of the two attack types shows remarkable differences, as illustrated in Figure 7. We can see that aggressive attacks make the follower less likely to invest in innovation since it is under constant survival pressure. In this circumstance, the follower makes a capability development trade-off in the short term at the expense of long-term growth.

6. Implications and Discussion

Anecdotal evidence shows that a firm's superior operational process is generated and evolves during interactions with its competitor's competing process over time (Fujimoto, 1999). By re-conceptualizing process capability development as a competitive move at the firm level, we develop a dynamic computational theory of process competition (Sterman, 2000; Peng et al., 2008; Vancouver et al., 2010; Chen and Miller, 2012). This study depicts a two-way interaction between inner-firm capability development trade-off (Operations Strategy Perspective) and inter-firm competition (Business Strategy Perspective). To the best of our knowledge, research on conditions and causal mechanisms that influence process development and management practice under this interaction effect has not yet been reported in the operations and strategy literature. We therefore ask a fundamental question: Under which conditions can the new and best process development and management practice emerge in a competitive environment?

6.1 Capability Development Trade-Offs as a Feedback to Process Competition

The conceptualization of process competition relies on a dual consideration of firm-level capability development trade-offs and industry-level competition. On one hand, competition shapes the firm's capability development trade-offs while pursuing survival and/ or growth. On the other hand, the trade-offs and the resulting operational performance feeds back to the competitive environment.

Without this integration, the literature can only suggest that the leader will vigorously defend its pioneer position against the follower's investment in imitative and small-scale improvement capabilities (Chen et al., 2002). As a result, the intensity of competitive tension rises sharply (Chen et al., 2007). Likewise, process innovation capabilities, due to their associated high risk and resource commitment, result in a relatively long response lag, which

alleviates the competitive tension (Chen and MacMillan, 1992). By comparing different capability development trade-offs (Figures 2 to 4), however, our analysis shows the opposite outcomes: surprisingly, through the phase plot analysis (Figure 8), we find the follower's investment in improvement capability may relax the competitive tension, a counterintuitive positive relationship.
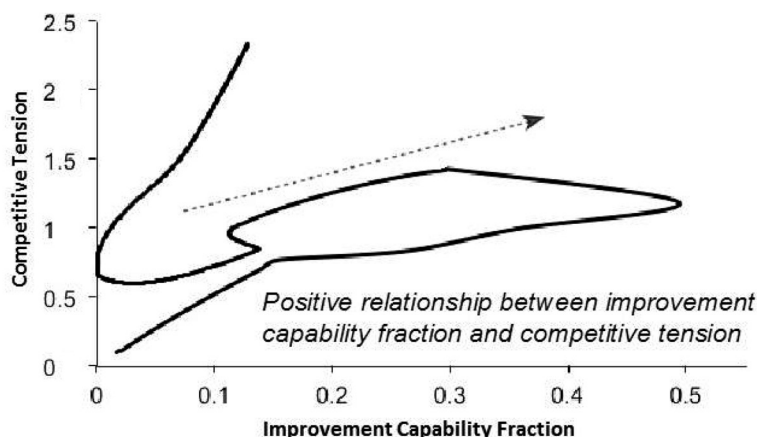

Figure 8 The Impact of Improvement Capability Fraction on Competitive Tension

Now consider process improvement, as illustrated in Figures 2b and 3a. Indeed, by developing process improvement capabilities, the follower clearly signals its attempt to eliminate operational inefficiencies. It invests massive resources, signaling high internal commitment, to achieve this objective. Yet such improvement occurs within the current frontier rather than by creating a new frontier (i.e., a new best practice) (Swink and Hegarty, 1998). Therefore, this is rather good news to the leader since he/she needs not to worry about being dethroned. In other words, the follower's apparent public commitment to its investment discourages the leader from reacting aggressively. Consequently, the follower falls into improvement inertia so that resource similarity increases and the intensity of competition decreases in the long run (as illustrated in Figures 2f and 3b). In terms of process innovation capabilities, the follower publicly commits to developing new processes that go beyond the frontier occupied by the leader. The follower's ultimate objective is to compete with and surpass the leader for rent generation. Therefore, the leader expects to engage in direct competition as long as the follower achieves any positive outcome through developing innovation capabilities (see Figure 4b). Formally,

Proposition 1a. In process competition, an increase in investment in process innovation capabilities leads to an increase in competitive tension.

Proposition 1b. In process competition, an increase in investment in process improvement capabilities leads to a decrease in competitive tension.

The premise of our theory is highlighted by the findings that competition is a key driver of process innovation. Our simulation results clearly depict that the three capability development trade-offs lead to distinct operational performance under competition. Specifically, if the follower fails to consider competition (i.e., a capability development trade-off with constant fraction) or simply focuses on survival pressure (i.e., a short-termism capability development trade-off), its chances of adjusting its process capabilities to align with the dynamic competitive environment are slim. Ultimately, it will not generate a revolutionary process. On the contrary, the competitive tension will motivate the follower to recognize the value of radical innovation for long-term capability development. As proposed by Mendelson and Pillai (1999), today's dynamic and highly competitive global environment has dramatically increased the pace of firms' internal operations development. Therefore, a sustained investment in innovation capabilities will facilitate a better operational performance. Formally,

Proposition 2. In process competition, the positive relationship between process innovation capabilities and competitive tension is mediated by process capability development trade-offs: This positive relationship is negatively mediated by either the constant-fraction or short-termism capability development trade-off but positively mediated by the long-term-growth capability development trade-off.

6.2 The Lock-In Effect

Our conceptualization of process competition captures the action-reaction exchanges between rivals. In a competitive environment, the leader can directly influence the follower's capability development trade-offs in two ways. The first is to build barriers to prevent effective learning of the current best practice, which, in our model, is measured as improvement effectiveness. The second way is to embrace intensive retaliation threat to raise the follower's survival pressure, which in our model, is measured as the leader's aggressive attack.

In terms of learning barriers, the simulation outcomes (Figure 5a) show a counterintuitive phenomenon. Low barriers effectively enhance the follower's level of improvement effectiveness. Remarkably, this creates a lock-in effect, i.e., the follower sticks to incremental changes in its operational process. Hence, the leader effectively restrains the follower's process innovation capability, thus preventing radical changes. This outcome contradicts the prevailing wisdom in the strategy literature: A leading firm should create causal ambiguity to raise learning barriers, thus preventing the diffusion of its successful processes and resources (Dierickx and Cool, 1989; Cohen and Levinthal, 1990). Rather, we find that the follower's process improvement effectiveness increases due to the leader's open and explicit process, but that the follower's motivation to carry out process innovation simultaneously decreases. As a result, the likelihood for the follower to lock in process improvement increases. Indeed, it is not rare that many leading firms readily share their superior business processes even with their rivals. For example, General Electric (GE) and Motorola enthusiastically exhibited their innovative process methodology, the six sigma, to the public. Additionally, in our background case, Toyota has never hesitated to give a factory tour to its rivals that were eager to import its famed JIT system. While the current literature cannot fully rationalize such behavior, our framework sheds lights on this unexplained puzzle. Formally:

Proposition 3. In process competition, an increase in investment in process innovation capabilities leads to a decrease in process improvement effectiveness. This negative relationship is weakened by process innovation effectiveness.

The retaliation risk from the leader threatens the success of the follower's process capability development. In particular, the leader is expected to prioritize process innovation before it is too late (Gimeno and Woo, 1996). Process capability development takes time. To protect its market position, the leader must be alert to the follower firm's actions and prepare to launch attacks when necessary. Facing an aggressive leader who initiate attacks with an early (action timing) and continuous fashion (action volume), the follower will experience difficulties in developing process innovation capabilities (Ferrier et al., 1999). Formally:

Proposition 4a. In process competition, the lock-in effect is positively moderated by the speed of the leader's attack.

Proposition 4b. In process competition, the lock-in effect is positively moderated by the volume of the leader's attack.

6.3 Conclusion

Whereas researchers and practitioners have substantially investigated methods to guide the balance between process improvement and innovation capabilities in a monopoly setting, competition greatly influences firm-level capability development trade-offs. We suggest that researchers and decision makers use a dynamic framework to further explore such effects and the disruptive nature of process innovation. The dynamic modeling used in our study shows a promising future for advancing management, organization, and psychology studies (Davis et al., 2007; Harrison et al., 2007; Vancouver et al., 2010) due to the model's ability to depicting nonlinear relationships and dynamic competition (Sterman et al., 2007; Rahmandad, 2012). This approach is based on differential equations and has been widely used in the study of biology, ecology, evolutionary economics, and strategy. According to Bendoly et al. (2010), Schroeder (2008), and Größler et al. (2008), dynamic modeling is useful for investigating specific operational problems since the operations management field is characterized by feedback, resource accumulation, and delay. Dynamic modeling therefore enables us to further explore the complicated and unforeseen interactions within this complex adaptive system (Choi et al., 2001; Repenning, 2003; Keyhani et al., 2015).

We offer a dynamic, competition lens to better understand improvement-innovation capability trade-offs in process development and management. This perspective fills the void in the operations management literature that overlooks rivals' retaliation, which has blocked the examination of the interaction between inner capability trade-offs and outer competition. Specifically, we show that one firm, in pursuit of process superiority, can take the long-term-growth capability development path. Yet it can be led astray by imitating leading firms that intentionally make their superior processes easy to imitate. This study adds a unique message to market leaders about the potential benefits of easy-to-imitate capabilities: In publicizing the best practice to follower firms, leading firms experience less threat of radical process innovation from them.

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