Eating Your Own Lunch: Protection Through Preemption

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Abstract

Recent discussions of management practices among successful high-technology companies suggest that one key strategy for success is to "eat your own lunch before someone else does." The implication is that in intensely competitive, or hypercompetitive, markets, firms with a leading position should aggressively cannibalize their own current advantages with next-generation advantages before competitors step in to steal the market. Given the pace of technological and other types of change, such strategy often requires creating next-generation advantages while the current advantages are still profitable—that is, trading current profits for future market leadership.

We capture the tradeoff between a market leader's willingness to reap profits with its current set of advantages and its desire to maintain market leadership by investing in the next generation. Using a competitive model that determines the equilibrium launch time of a next generation advantage, we find that, in absence of lower launch costs for an entrant, the incumbent will be first to launch to maintain its market leadership. That is, regardless of the severity of penalties for being a follower in the next generation, it is optimal for the incumbent to preempt the entrant by launching early—even if the incumbent consequently loses money at the margin. We derive a straightforward condition to determine when an incumbent will make negative incremental profits from its investment in the next-generation advantage. The fact that the condition does not depend on the size of the incumbent's investment costs indicates that the severity of competition, rather than the costs of developing and introducing a next-generation advantage, is what forces firms to cannibalize at a loss.

Finally, we find that a preemptive launch can result in an earlier launch of the next generation than is socially optimal, and provide a sufficient condition for that to occur. Although customers are better off as a result of an earlier launch, their gain may be outweighed by the additional costs firms incur from launching prematurely.

(*First-mover*; *Hypercompetition*; *Management Practices*; *Competitive Strategy*)

1. Introduction

We address the question of whether it is better to sustain a current advantage or preempt it with a next-generation advantage. A recent *Fortune* article discussing the management practices of successful high-technology companies such as Intel, Hewlett Packard, and Microsoft gave one of the key strategies for success as "eat your own lunch before someone else does" (Deutschman 1994). This strategy suggests that in intensely competitive, or hypercompetitive, markets, firms with leading or dominant market positions should cannibalize their own current advantages—advantages in product, process, knowledge, and so on—with next-generation advantages before competitors step in to steal the market. Given the pace of technological and other types of change, such strategy often requires investing in and launching next generation advantages while current advantages are still profitable—that is, trading current profits for future market leadership. It has been employed successfully by Hewlett Packard to dominate both the laser and inkjet printer markets, and by Intel in its microprocessor business. In contrast, Seagate Technology, which did not cannibalize its favorable position in 5.25 inch disk drives with the emerging 3.5 inch format, and National Semiconductor, which delayed the upgrade to its market-dominating ethernet chipset, lost millions of dollars and market position by *not* "eating their own lunches."

The actions of several leading firms support an "eat your own lunch" strategy. Motorola began using "self-obsoleting tactics" when its frequency modulation (FM) development cannibalized its AM car radio business in the 1940s (Slutsker 1994), and continues to do so today in its paging and cellular phone businesses. Bell Northern Research, the research arm of Northern Telecom, uses an approach it calls "backcasting," working backward from the required market launch to track the progress of next-generation development projects

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(*Telesis* 1993). Many firms, such as Hewlett Packard, are investing in processes that reduce their product development times (House and Price 1991), whereas other firms, such as Intel, maintain their product development readiness by simultaneously working on several successive product generations (*Business Week* 1995a).

The preceding examples illustrate the appeal of a strategy we call "protection through preemption." We believe such a strategy is necessary to maintain market dominance. That is, a competitive advantage in an intensely competitive market can be sustained only by a series of preemptive moves designed to stay ahead of competitors. Each of those moves has the potential to cannibalize current strengths. D'Aveni (1994) supports that notion by suggesting that a protection-through-preemption strategy is appropriate in hypercompetitive markets. He argues that because no barriers are sustainable, to be successful, a firm must organize to create a series of temporary advantages, with self-cannibalization being one approach to building such an advantage.

Though many of our examples are of technology-intensive industries that have frequent introductions of next-generation products, our model results apply to any multi-generational setting where next-generation advantages of any kind can supersede current advantages. Examples of our protection-through-preemption strategy in non-technology-intensive product markets include Sealed Air Corporation's launch of "uncoated" bubble wrap to thwart potential competitors (Dolan 1982) and Hanes Corporations introduction of L'Eggs panty hose. Advantages outside product markets include information systems (e.g., American Airlines' SABRE reservation system and WalMart's inventory management system), supply chain management (e.g., Compaq), scale of R & D investment (e.g., Samsung in the DRAM market), manufacturing and management processes (e.g., Boeing Corporation), and service delivery (e.g., Walt Disney).

Despite being successful in practice, a protection-through-preemption strategy runs counter to many of the findings in the economics and marketing literature suggesting that incumbents should delay their launch of the next generation (e.g., Ghemawat 1991; Kamien and Schwartz 1982; and Reinganum 1983, 1985). The rationale for those results, which pertain almost exclusively to product markets, is that the incumbent will damage its current rent stream by launching the next generation. Because the entrant has less to lose by launching the next generation than the incumbent, the entrant will be compelled to launch first.

Ghemawat's (1991) model is typical of models supporting a delayed launch strategy by the incumbent. He develops a modified patent race model that allows for overlapping generations and imitation of the next generation by followers. The key result is that the incumbent (i.e., AT & T in the voice-only PBX business) is unwilling to innovate and launch the next generations (voice and data PBX technologies). As the entrant has little to lose by innovating and entering the next generation, doing so is in its best interest. Hence, the incumbent may be better off by not competing with the entrant in the next generation, thus limiting self-cannibalization. Such strategy is argued to be optimal in hotly contested markets—markets similar to those in which self-cannibalization strategies are now being practiced.

The limited empirical research on protection-through-preemption strategy provides mixed findings. While some empirical research has been done on first-mover advantage (Kerin et al. 1992), pioneering (Golder and Tellis 1993) and timing of entry (Lilien and Yoon 1990), most of the work has examined the performance of firms entering markets in a particular order rather than the entrant-incumbent interaction we study. Nonetheless, some of the findings are relevant. Analyzing 112 products from 52 French firms, Lilien and Yoon (1990) found that firms are more successful when they enter a market in the introduction phase of the product life cycle, but first entrants are not as successful as followers. Like other research on pioneering and timing of entry, the study concerned only the firm's entry into the market. Lilien and Yoon do not analyze the influence of changes and modifications in the firm's offerings *after* market entry. Therefore, it is difficult to determine whether self-cannibalization by incumbent firms has an effect on performance. In a study of the American diagnostic imaging industry, Mitchell (1991) found that incumbents in a segment have better performance than true entrants when a new segment is opened. For example, market leaders in computer tomography (CT) scanners are also leaders in magnetic resonance imaging (MRI) scanners even though they were not the first to enter the MRI market. To the degree than MRI scanners are the next-generation technology, Mitchell's findings run counter to our protection-through-preemption strategy—even if incumbents are late, assets they are able to transport from the current generation such as brand name, distribution, and experience allow them to succeed in the next-generation market. However, Mitchell found that when only incumbents are considered, there is a first-mover advantage. That result is consistent with our suggested strategy.

The objectives of our article are to determine conditions under which an incumbent will use a protection-through-preemption strategy and to refine those conditions to show when an incumbent will preemptively launch a next-generation advantage at a loss to preserve its market leadership. To achieve our objectives, we build a model in which competition between an incumbent (the recognized leader in the deployment of the current generation advantage) and an entrant (a challenger in the next generation) determines the equilibrium launch time of a next generation advantage. In doing so, we capture the tradeoff between the market leader's willingness to reap profits on the current generation and its desire to maintain market leadership by launching the next generation. We assume that the launch of the next-generation advantage incurs a one-time fixed cost for R & D and other costs necessary to bring the advantage to market, which we model as declining in real terms over time. In addition, firms' launch costs and profit flows are common knowledge. We employ the modeling approach and solution concept from games of timing by Fudenberg and Tirole (1985, 1986). That approach is general enough to accommodate differences in the diffusion processes between generations.

The results of our model indicate that regardless of the severity of penalties for being a follower in the next generation, it is optimal for the incumbent to preempt the entrant by launching early—even if the incumbent consequently makes lower overall profits after the next generation launch. We also provide a straightforward condition to determine when the incumbent's preemptive launch of the next generation makes negative profits at the margin. The condition does not depend on launch costs, but rather on the severity of competition, which therefore determines when firms will cannibalize at a loss. We also show that competition can result in a preemptive launch that is earlier than would be socially optimal, and derive a sufficient condition for that to occur. The results have significant implications for practicing managers and policy makers. For managers, our results imply that firms in intensely competitive industries should be willing to launch next-generation advantages preemptively to maintain market leadership, even if they lose money at the margin. For policy makers, our results imply that leaving next generation launch timing to the market may not be socially optimal.

The remainder of the article is organized as follows. In the next section we discuss our model formulation and prior research. We then outline our notation and assumptions. In the subsequent section we provide the details of our model and report our main results, followed by an analysis of the welfare implications and limitations of our model. In the final section we discuss managerial implications, how our model could be validated, and directions for future research.

2. Model Formulation and Prior Research

Our model formulation incorporates standard assumptions and results from the marketing literature. Studying multigeneration product diffusion, Norton and Bass (1987) found that sales of each generation followed a single peaked distribution over time. Subsequently, Wilson and Norton (1989) found that the optimal time to launch a product line extension is either early in the original product's life cycle or not at all. Their results depend on the relationship between the sales of the two products, their relative margins, and the length of the firm's planning horizon relative to the original product's diffusion time. Purohit (1994) found that if the firm can decide the extent of innovation then a product replacement strategy (discontinuing the current product) is more profitable than a line extension. Our model's assumptions and results are consistent with those findings. Other research has examined the diffusion process as a function of such variables as price, quality, and promotion expenditures that are under the control of the firm (Kalish and Lilien 1986). Our model is formulated in terms of profit flows rather than unit sales, prices, and costs, and accounts for diffusion effects in the relationships among the profit flows over time and across generations. Although not explicitly part of our formulation, an equilibrium setting of marketing mix variables is reflected in our profit flows.

Although the problem we model is similar to the one modeled by Ghemawat (1991), discussed previously, our results are opposite to his because we model the problem differently. In our formulation the launch of next-generation advantages is a timing decision rather than a binary launch/no launch decision, so preemption is admitted as a strategy. In addition, the rivalry component in our model is less severe as we allow differentiated competition between the two generations, and declining launch costs play a role in our analysis.

Our approach is rooted in research in which irreversible capital commitments are viewed as a way to deter entry. That stream began with a static model showing that excess capacity could deter a new entrant by giving an incumbent a credible threat to expand output and reduce marginal cost, thereby lowering price (Spence 1977). Then Spence (1979) found that from a static view of a dynamic solution to entry deterrence through investment, firms overinvested, illustrating that entry-deterring investment that was not rational in a static setting could be rational in the larger dynamic context. Eaton and Lipsey (1980) extended the finding by showing that if capital is not durable, then an incumbent monopolist protecting its position may need to replace capital (e.g., plant) before the capital is economically obsolete. Thus, the protection of its incumbency under the threat of a new entrant forces the monopolist to invest earlier than it would otherwise choose to do. Dixit (1979, 1980) modeled excess capacity as deterrence where full use of the capacity is not precommitted and found that a new entrant could be deterred if the incumbent set output just over a threshold level, but could not solve for the equilibrium output level. Fudenberg and Tirole (1983) developed a model based on Spence's (1979) and established the existence of a set of perfect equilibria. Being unable to refine the set, they developed the solution concept we use here as a response. In our model the combination of timing dynamics and the threat from the entrant forces the incumbent to launch earlier than it would prefer to do, and Fudenberg and Tirole's equilibrium concept is necessary to resolve that combination of effects.

Although we characterize our model differently, it also follows in the spirit of "an endless race" described by Aoki (1991). His results suggest that if returns on investment in technology are deterministic, then a firm may cease to compete even if it is only one generation behind. It returns are stochastic, however, then a firm may invest in technology even if it is more than one generation behind because a future launch by a competitor may fail. Aoki's formulation fixes launch costs over time, makes technology proprietary, and most important, restricts positive profits to a single generation. In our model next-generation advantages have deterministic payoffs, launch costs decline in real terms over time, the entrant can launch the next generation without having launched the current generation, and both generations can generate positive profits simultaneously.

Our model is also related to work on first-mover advantage. Kerin et al. (1992) point out that the presence and magnitude of first-mover advantages are contingent on a number of economic and behavioral factors. We assume that there are positive first-mover advantages, which may be the result of technological leadership, preemption of scarce resources, and the introduction of buyer switching costs (Lieberman and Montgomery 1988). The magnitude of those advantages is reflected in the firms' profit flows resulting from the launch of the next generation.

Although we do not study probabilistic payoffs to next-generation advantages, another important stream of research addresses uncertainty as the key issue in managing new generations For example, several articles have examined how much costly information firms should gather prior to launch when the profitability of an innovation is unknown (Mamer and McCardle 1987, McCardle 1985). Timing is not a factor because there are no first-mover advantages, but firms gather information to lessen the chance of launching an unprofitable innovation and may modify their decisions because of potential competition. Our case is precisely the opposite—profitability resulting from next-generation launches is known and, because there may be first-mover advantages, timing is critical.

3. Notation and Assumptions

For ease of communication, we describe the setting as a duopoly consisting of an incumbent that markets a product or service based on the current-generation advantage and an entrant that may also have a current-generation advantage. The firms compete to launch the next-generation advantage. Our modeling of the setting, however, is less restrictive as we allow many firms to compete to launch the next generation. Our concentration on one incumbent and one entrant, as we define them, entails no loss of generality in our analysis, as the equations that determine our results involve only those two firms. Omitting additional firms has no effect. The assumptions we require for our results follow.

We represent the incumbent by superscript I and the entrant by superscript E. Let T^i be the launch time of firm $i \in \{I, E\}$. The notation in Table 1 gives the profit flows at a given time t for each firm, exclu-

Table 1 Profit Flows

Time	Incumbent	Entrant
$0 \le t \le \min\{T^I, T^E\}$	$\pi_0^I(t)$	$\pi_0^E(t)$
$T^I \le t \le T^E$	$\pi_1^I(t)$	$\pi_2^E(t)$
$T^E \le t \le T$	$\pi_2^I(t)$	$\pi_1^E(t)$
$t \ge \max\{T^I, T^E\}$	$\pi_3^I(t)$	$\pi_3^E(t)$

sive of the launch cost. $\pi_0^i(t)$ is the pre-launch profit flow, $\pi_1^i(t)$ is the profit flow to firm i when only that firm has launched, $\pi_2^i(t)$ is the profit flow to firm i when only the other firm has launched, and $\pi_3^i(t)$ is the profit flow when both firms have launched.

Our first assumption is partly definitional and partly a restriction on firms' relative profits. Assumption 1 defines the incumbent as the firm with the largest difference in the present value of profit flows between having launched the next-generation advantage and having had a competitor preempt that launch—the firm with the most to lose if it does not preempt. If there are more than two firms, then the entrant is the firm with the next largest difference. Assumption 1 requires that we rank the firms by the magnitude of the difference,

$$\int_T^\infty \left[\pi_1^i(t) - \pi_2^i(t)\right] e^{-rt}\, dt.$$

Assumption 1.

$$\int_T^\infty \left[\pi_1^I(t) - \pi_2^I(t)\right] e^{-rt}\, dt > \int_T^\infty \left[\pi_1^E(t) - \pi_2^E(t)\right] e^{-rt}\, dt > 0.$$

The assumption orders firms by what Katz and Shapiro (1987) call the incentive to preempt: which firm benefits the most from being the first mover. The restriction embedded in the assumption is that firms can be ordered in a way that does not depend on the time T when the ordering is computed. Thus, in absence of an exogenous event that affects only a proper subset of firms, we believe the order of the difference in profit flow between being first and being preempted should be a function of relative firm characteristics rather than the time of launch. For example, Intel, the market leader with an 80 percent share of the PC microprocessor business, would be classified as the incumbent because it has the most to lose from being preempted by the launch of a superior PC-based processor.

Assumption 1 follows directly when the incumbent is the only firm with a current-generation advantage. In this case, prior to the entrant's launch, profit flows for the entrant are zero $\pi_0^E(t) = \pi_2^E(t) = 0$. We can then rearrange Assumption 1 into

$$\int_T^\infty \pi_1^I(t) e^{-rt}\, dt > \int_T^\infty \left[\pi_2^I(t) + \pi_1^E(t)\right] e^{-rt}\, dt.$$

That inequality is true because, for a product-market example, a two-product monopoly has profits greater than the joint profits from two differentiated products offered by competing firms. Because the next generation supersedes the current generation, the resulting vertically differentiated competition lowers the profitability of current generations. Although not necessary for our analysis, it is plausible that the leader with the current generation advantage is the incumbent in our model. However, our analysis extends to situations in which the firm with the most to gain from being the first mover is not the market leader in the current-generation. For example, on the basis of its strong brand and inkjet printing capabilities, Hewlett Packard went from nowhere to being one of the leading firms in the plain paper fax market.

Kim and Kogut (1996) show that some technologies offer a better starting point, or platform, than others for the exploration and development of new advantages in different markets. The incumbent defined by Assumption 1 could be the leading firm in a second market where it has experience with a promising technology platform, a platform from which it could become the leader in the first market. As such, that firm has the most to lose by not being first to enter the new market.

Let r be the discount rate. Assumption 2 makes the discount rate strictly positive.

Assumption 2.

$$r > 0.$$

Let $K(t)$ be the present value of the cost of launching the next generation at time t. There is no superscript on launch costs because we give neither firm a launch cost advantage. Assumption 3 specifies that the nominal cost of launching the next generation falls over time at a decreasing rate. The launch costs reflect the improvement in technology—product or process—from basic research, which reduces current costs of development and launch. That feature is included to model the reality that, over time, the skills necessary to successfully complete R & D on a specific technology improve and become more widely available. Moreover, related technologies become further developed with time.

Assumption 3.

$$\frac{d\left[K(t)e^{rt}\right]}{dt} < 0 \quad \text{and} \quad \frac{d^2\left[K(t)e^{rt}\right]}{dt^2} > 0,$$
$$\forall t < \infty;\ \liminf_{t\to\infty} K(t) = 0.$$

From Assumption 3 the present value of launch costs, which we use subsequently, falls over time:

$$\frac{d\left[K(t)e^{rt}\right]}{dt} = \frac{dK(t)}{dt}e^{rt} + K(t)re^{rt} > 0$$

$$\Rightarrow \frac{dK(t)}{dt} < -K(t)r < 0. \qquad (1)$$

Using (1), we can show that their present value falls at a decreasing rate:

$$\frac{d^2\left[K(t)e^{rt}\right]}{dt^2}$$

$$= \frac{d^2K(t)}{dt^2}e^{rt} + 2\frac{dK(t)}{dt}re^{rt} + K(t)r^2e^{rt} > 0$$

$$\Rightarrow \frac{d^2K(t)}{dt^2} > -r\frac{dK(t)}{dt} > 0. \qquad (2)$$

The assumption is satisfied, for example, by exponential costs of the form $K(t) = e^{-(r+\beta)t}$, where β is the rate of current cost decay (Fudenberg and Tirole 1985).

The conditions in our next assumption in essence preclude a second launch of the next-generation advantage. We argue that there are several forms of competition in which we expect those conditions to hold.

ASSUMPTION 4. *When firm i is second to launch the next generation,*

(a) $$\left[\pi_2^i(T') - \pi_3^i(T')\right]e^{-rT'} - \frac{dK(T')}{dT'} > 0,$$

(b) $$\int_T^{\infty}\left[\pi_2^i(t) - \pi_3^i(t)\right]e^{-rt}\,dt + K(T) > 0.$$

Assumption 4(a) is stated in terms of the time of the second next-generation launch, T'. It implies that when the cost of launch is factored in for the follower, differentiated competition is more profitable than direct competition between the follower's and the leader's next generations. Because the last terms in Assumption 4(a) and (b) are positive, the profit flows from entering the next-generation market for the follower can be greater than those from not entering at all, but not enough greater to alter the launch decision.

This condition is weaker (i.e., less restrictive) than the scenario of direct and unencumbered Bertrand competition in the next-generation market, which would imply that profits from the next generation are zero, $\pi_3^i(t) = 0$. If the entrant and incumbent are able to differentiate their next-generation advantages, Assumption 4 implies that they are not sufficiently differentiated to cover launch costs. Bertrand competition can support profits between two undifferentiated goods if there are decreasing returns to scale from production, for example capacity constraints (Tirole 1988). In that case, Assumption 4 implies that those profits do not exceed the costs of launch. Traditional Cournot analysis is really a choice of capacity with subsequent price competition, and Assumption 4 could again imply that the profits do not cover launch costs. (Tirole argues that the assumption of Bertrand competition is more appropriate for fairly flat marginal cost production and Cournot competition is more appropriate with sharply rising marginal cost. We believe that high-technology firms, for example, are likely to have high fixed and low marginal costs of production.)

This condition is also weaker than the result from Judd (1985), employed by Ghemawat (1991) to set $\pi_3^i(t) = 0$, where, in a product-market scenario, an incumbent would rather not compete directly with an entrant that markets a differentiated product because the direct competition in the differentiated product cannibalizes profits from the current product. That result is one in which profits can increase due to abandonment of a product, in our case the incumbent not launching the next-generation product. It is also supported by Purohit (1994), who found that a product-replacement strategy—discontinuing sales of the current generation in favor of the next generation—was more profitable than a line extension where both generations are sold.

Finally, after the first mover launches its next-generation advantage, the first mover's goal will be to drive down the potential profits of any new entrant in the next generation quickly, providing a credible threat to prevent entry. In the particular case of the entrant that does not have a current-generation advantage, if the entrant is second with the next generation, then it may not be able to set the price of its offering higher than marginal cost.

Consistent with our Assumption 4, in his study of the Japanese beer industry Craig, (1996) found firms that launched copycat dry beers—second introductions of the next generation—all discontinued their dry beer brands within a few years because they did not sell well. Without Assumption 4, our model would yield very different results, a point we reexamine subsequently.

Assumptions 5 and 6 are used to ensure that the next generation is launched in the interior of the solution space. Assumption 5 ensures that no firm launches the next generation at time zero. The profit flows for the incumbent are used in Assumption 5.

ASSUMPTION 5.

$$\int_t^\infty \left[\pi_1^I(t) - \pi_2^I(t)\right] e^{-rt}\,dt < K(0).$$

Assumption 6 ensures that the next generation is launched in finite time. The profit flows for the entrant are used in Assumption 6.

ASSUMPTION 6.

$$\inf_t\{K(t)e^{rt}\} < \int_t^\infty \left[\pi_1^E(t) - \pi_2^E(t)\right] e^{-rt}\,dt.$$

In the fully general case, payoffs to firm i are

$$g_1^i(T^i, T^j) = \int_0^{T^i} \pi_0^i(t)e^{-rt}\,dt + \int_{T_i}^{T_j} \pi_1^i(t)e^{-rt}\,dt + \int_{T^j}^\infty \pi_3^i(t)e^{-rt}\,dt - K(T^i)$$

when firm i launches first and

$$g_2^i(T^i, T^j) = \int_0^{T^j} \pi_0^i(t)e^{-rt}\,dt + \int_{T_j}^{T^i} \pi_2^i(t)e^{-rt}\,dt + \int_{T^i}^\infty \pi_3^i(t)e^{-rt}\,dt - K(T^i)$$

when firm i launches second, where the superscript j means "not i."

4. Model

4.1. Equilibrium Launch Times

We begin by establishing the time of the second next-generation launch. That time is the solution to maximizing the payoffs to launching second by choosing when to launch, $\max_{T^i} g_2^i(T^i, T^j)$. Using Assumption 4(a), we know that the first derivative, marginal revenue less marginal cost, is positive for both the incumbent and the entrant,

$$\frac{\partial g_2^i(T^i, T^j)}{\partial T^i} = \left[\pi_2^i(T^i) - \pi_3^i(T^i)\right]e^{-rT^i} - \frac{dK(T^i)}{dT^i} > 0,$$

recognizing that in this case $\pi_3^i(t)$ applies to firm i being the second mover with the next generation. Therefore, because the payoffs are increasing as firm i waits longer, there is never a second time when the next generation is launched. That is, either only one firm launches the next generation or the next generation is launched simultaneously by both firms.

Solving for the optimal launch time assuming the other firm has not yet launched is equivalent to maximizing the payoffs from being first to launch by choosing when to launch, $\max_{T^i} g_1(T^i, T^j)$. For each firm, the necessary first-order condition equating marginal revenue and marginal cost is

$$\left[\pi_0^i(T^i) - \pi_1^i(T^i)\right]e^{-rT^i} - \frac{dK(T^i)}{dT^i} = 0. \quad (3)$$

The second-order condition sufficient for (1) to define a maximum is

$$\left[\frac{d\pi_0^i(T^i)}{dT^i} - \frac{d\pi_1^i(T^i)}{dT^i}\right]e^{-rT^i} - r\left[\pi_0^i(T^i) - \pi_1^i(T^i)\right]e^{-rT^i} - \frac{d^2K(T^i)}{[dT^i]^2} < 0. \quad (4)$$

Using (2) and (3), we know that the last two terms in (4) together are negative. Because profit flows are sure to increase at the time of the next-generation launch, $(d\pi_1^i(T^i)/dT^i) - (d\pi_0^i(T^i)/dT^i)$ is positive. Thus, (4) is satisfied.

Using T to represent the time of the next-generation launch, we can define payoff functions for the first firm to launch the next generation as L (leader), for the second firm to launch the next generation as F (follower), and for simultaneous launch of the next generation by both firms as M. Those payoff functions are

$$L^i(T) = \int_0^T \pi_0^i(t)e^{-rt}\,dt + \int_T^\infty \pi_1^i(t)e^{-rt}\,dt - K(T),$$

$$F^i(T) = \int_0^T \pi_0^i(t)e^{-rt}\,dt + \int_T^\infty \pi_2^i(t)e^{-rt}\,dt, \quad \text{and}$$

$$M^i(T) = \int_0^T \pi_0^i(t)e^{-rt}\,dt + \int_T^\infty \pi_3^i(t)e^{-rt}\,dt - K(T).$$

For both firms, leading with the next generation yields higher profits than simultaneous launch of the next generation, $L^i(T) > M^i(T)$. Using Assumption 4(b), we know that following is also more profitable than simultaneous launch, $F^i(T) > M^i(T)$. Therefore, we can safely stop further analysis of simultaneous launch as neither firm would choose it in equilibrium. We note that, in general, a simultaneous launch is not an equilibrium in models of this type (Fudenberg and Tirole 1985, Reinganum 1981).

For there to be a single time when each firm is indifferent between launching and not launching—that is, for the leader and follower functions to intersect only once—we require that four conditions be satisfied. We can describe them intuitively as follows. At time zero, payoffs to leading must be less than those to following (i.e., waiting). Later, there must be a time when leading is more profitable than following. Because of the nature of decay in launch costs and because of discounting of profit flows, for next-generation launch times far into the future the payoffs to leading must converge with those of following. Finally, once a time is reached when payoffs to leading are greater than those to following, payoffs to leading at any subsequent time are greater than payoffs to following. We can express Conditions 1 through 4 mathematically as follows.

Condition 1: $L^i(0) - F^i(0) < 0$.
Condition 2: $\exists T$ such that $L^i(T) - F^i(T) > 0$.
Condition 3: $\liminf_{T \to \infty} L^i(T) = 0$.
Condition 4: $L^i(T) - F^i(T)$ is strictly quasi-concave.

In our model, Condition 1 is

$$\int_0^{\infty} \left[\pi_1^i(t) - \pi_2^i(t)\right] e^{-rt}\, dt - K(0) < 0.$$

Condition 1 for the incumbent is directly satisfied by Assumption 5. Use of Assumptions 1 and 5 shows that Condition 1 is also satisfied for the entrant.

Condition 2 for the two firms is

$$\int_T^{\infty} \left[\pi_1^i(t) - \pi_2^i(t)\right] e^{-rt}\, dt - K(T) > 0.$$

Condition 2 for the entrant is directly satisfied by Assumption 6. Assumptions 1 and 6 are sufficient for Condition 2 to be satisfied for the incumbent.

Condition 3 is satisfied for both firms because the limits of integration over profit flows converge and the next-generation launch costs approach zero from Assumption 3.

Taking first and second derivatives of the function $L^i(T) - F^i(T)$, we can determine that Condition 4 is satisfied. Setting the first derivative to zero, we get

$$-\left[\pi_1^i(T) - \pi_2^i(T)\right] e^{-rT} - \frac{dK(T)}{dT} = 0 \qquad (5)$$

and

$$-\left[\frac{d\pi_1^i(T)}{dT} - \frac{d\pi_2^i(T)}{dT}\right] + r\left[\pi_1^i(T) - \pi_2^i(T)\right] e^{-rT} - \frac{dK^2(T)}{[dT]^2} < 0. \qquad (6)$$

Using (2) and (5), we know that the last two terms together in (6) are negative. From our discussion of (4), profit flows increase at the time of the next-generation launch so $d\pi_1^i(T)/dT$ is positive. $d\pi_2^i(T)/dT$ is nonpositive because a firm's current generation cannot be more profitable when the other firm launches the next generation.

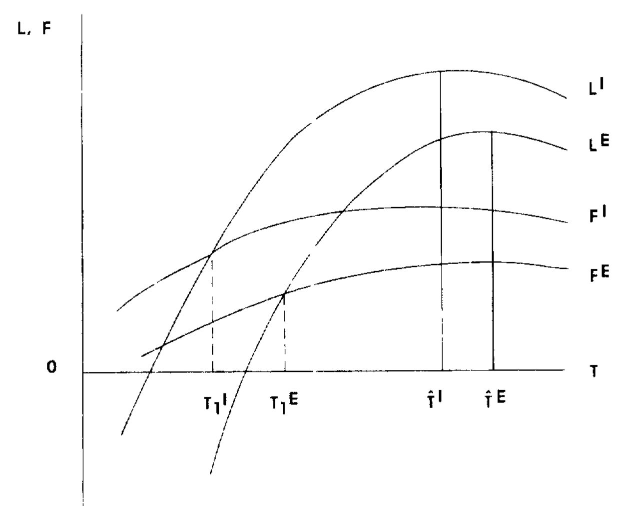
We use T_1^i to denote the unique time when each firm's leader and follower functions intersect, that is, when the payoffs to leading are equal to those from following. The following lemma determines the ordering of T_1^I and T_1^E.

LEMMA 1 *T_1^I occurs prior to T_1^E.*

PROOF. T_1^i is defined by $L^i(T_1^i) = F^i(T_1^i)$. Using Assumption 1, we know that at the same T, $L^I(T) - F^I(T) > L^E(T) - F^E(T)$. Therefore, at T_1^E, $L^I(T_1^E) - F^I(T_1^E) > 0$. As a result, $T_1^I < T_1^E$. □

The intuition is captured directly by Figure 1. Because the incumbent has a larger gain from launching

Figure 1 **Leader and Follower: Functions for the Incumbent and the Entrant**



the next generation versus being preempted than does the entrant (Assumption 1), the incumbent can launch (i.e., lead) with positive profits earlier than the entrant. Consider the case in which the entrant does not have a current-generation advantage. In a product market, for example, if the incumbent leads with the next-generation product, then it has a two-product monopoly. In contrast, if the entrant leads with the next generation, then it faces differentiated competition from the incumbent's current-generation product. Hence, the incumbent's leader function is sufficiently above the entrant's leader function that the time when payoffs to leading are equal to those from following is earlier for the incumbent. Using Lemma 1, we determine the equilibrium launch time of the next generation.

THEOREM 1. *The unique perfect preemption equilibrium is when the incumbent launches the next generation at T_1^E and the entrant never launches.*

PROOF. See Appendix.

Theorem 1 applies if $T_1^E \le \hat{T}^I$, where $\hat{T}^I$ solves the first-order Condition (3) that represents the optimal time for the incumbent to launch in absence of competition. Otherwise, the incumbent launches at the same time as it would if the entrant were not present, $\hat{T}^I$, the entrant never launches, and the equilibrium is not preemptive. We do not pursue the latter case because competition from the entrant plays no role in the incumbent's decision of when to launch.

Figure 1 also provides the intuition for Theorem 1. At any time beyond T_1^F, if the next-generation advantage has yet to be launched, then the entrant should immediately launch the next generation because leading is more profitable than following and a launch by the incumbent is imminent. At T_1^E, the entrant is indifferent between launching and not launching. However, at T_1^E the incumbent is better off leading than following, and can determine that the entrant's launch is imminent. Therefore, the incumbent launches the next generation precisely the instant before the entrant would unambiguously prefer to lead rather than follow. That result itself is not surprising because it is driven by our Assumptions 1 and 4, which give the incumbent the advantage and preclude a second launch of the next generation. What is surprising is the number of different models of competition, from various forms of Bertrand to Cournot that we discussed previously, under which those two assumptions hold. Moreover, we do not require additional assumptions about the diffusion process within or between generations. Theorem 1 holds regardless of the rate of migration of customers to the offering that incorporates the next-generation advantage.

The result holds as long as launch costs do not favor the entrant sufficiently to reverse the ordering of times when each firm's payoffs to leading are equal to those from following. We state that point as a necessary condition in a corollary.

COROLLARY 1. *A necessary condition for the entrant to launch the next generation is that the entrant has lower launch costs than the incumbent.*

PROOF. For the entrant to launch first requires that at some T, $L^E(T) - F^E(T) > L^I(T) - F^I(T)$. From Assumption 1, that is possible only if $K^E(T) < K^I(T)$. □

4.2. Cannibalizing at a Loss

Although the incumbent is the first and only firm to launch the next generation, it does not necessarily follow that the incumbent makes positive incremental profits with the next generation. Consider a calculation of the post-launch profit flows for the incumbent that isolates the marginal profit flow obtained from launching the next generation. Taking the incumbent's profit flow after launch less the pre-launch profit flow that would have occurred if the launch had not taken place, $\pi_{new}(t)$, we have

$$\pi_{new}(t) = \pi_1^I(t) - \pi_0^I(t). \tag{7}$$

At the equilibrium launch time for the next generation, T_1^E, the incumbent prefers to lead rather than follow, which means that

$$\int_{T_1^E}^{\infty} [\pi_{new}(t) + \pi_0^I(t)] e^{-rt}\, dt - K(T_1^E) > \int_{T_1^E}^{\infty} \pi_2^I(t) e^{-rt}\, dt > 0,$$

after substitution for $\pi_1^I(t)$ from (7). Reorganizing, we obtain the following inequalities:

$$\int_{T_1^E}^{\infty} \pi_0^I(t) e^{-rt}\, dt + \int_{T_1^E}^{\infty} \pi_{new}(t) e^{-rt}\, dt - K(T_1^E) > \int_{T_1^I}^{\infty} \pi_2^I(t) e^{-rt}\, dt > 0.$$

If the present value of profits from the current generation for the incumbent should there be no launch of the next generation is larger than the present value of profits from the current generation for the incumbent should the entrant have launched the next generation,

$$\int_{T_1^E}^{\infty} \pi_0^I(t) e^{-rt}\, dt > \int_{T_1^I}^{\infty} \pi_2^I(t) e^{-rt}\, dt,$$

then it is possible that

$$\int_{T_1^E}^{\infty} \pi_{new}(t) e^{-rt}\, dt - K(T_1^E) < 0. \tag{8}$$

In other words, the net present value of the marginal profits obtained by launching the next generation is negative. Assumption 1 is sufficient, but certainly not necessary over all t, for the condition prior to (8) to occur. We can prove a surprising theorem about when an incumbent will launch the next generation losing money at the margin.

THEOREM 2. *A necessary and sufficient condition for the incumbent to make negative profits at the margin from the next generation is that, at the time of launch, the present value of additional profit flows from the next generation for the incumbent is less than the present value of the difference in profit flows between leading and following with the next generation for the entrant.*

PROOF. Using the definition of the marginal profit flow from the next generation provided in (7) and substituting into (8) gives

$$\int_{T_1^E}^{\infty} \left[\pi_1^I(t) - \pi_0^I(t)\right] e^{-rt}\, dt - K(T_1^E) < 0.$$

But we know T_1^E is defined as the time when the payoffs to leading are equal to those of following for the entrant, $L^E(T_1^E) = F^E(T_1^E)$, which is

$$\int_{T_1^I}^{\infty} \left[\pi_1^E(t) - \pi_2^E(t)\right] e^{-rt}\, dt - K(T_1^E) = 0.$$

Combining and rearranging the preceding equations gives

$$\int_{T_1^E}^{\infty} \left[\pi_1^I(t) - \pi_0^I(t) - \pi_1^E(t) + \pi_2^E(t)\right] e^{-rt}\, dt < 0.$$

Therefore, we have the following relation between profits flows:

$$\pi_1^I(t) - \pi_0^I(t) < \pi_1^E(t) - \pi_2^E(t). \quad \square$$

Theorem 2 is important because it does not depend on launch costs. Thus, it shows that the incumbent cannibalizing its current-generation advantage at a loss with the next generation, or *eating its own lunch*, depends on the nature of competition.

When the entrant does not have a current-generation advantage, the necessary and sufficient condition in the theorem is that, at the time of launch, the present value of profit flows for the incumbent from the current generation advantage (status quo) is greater than the present value of the difference between profit flows for the incumbent from leading with the next generation and profit flows for the entrant from leading with the next generation. In that case, cannibalization at a loss depends on the returns to an incumbent that has acquired both the current- and next-generation advantages versus the intensity of competition should the entrant be first to launch the next-generation advantage.

5. Welfare and Limitations

5.1. Welfare Results

General results from prior research in several disciplines suggest that if prices and diffusion patterns do not change, then customers are better off when they receive the benefits of the next-generation advantage earlier (Balcer and Lippman 1984, Gaimon 1989). If having a common provider across generations also increases customer welfare because of continuity in style, design, operation, and service, then the incumbent would carry an additional advantage across generations. Whether customers are actually better off depends on the extent to which the incumbent can derive economic rents from providing such continuity. Those economic rents are captured in the profit flows.

The social welfare equation is made up of a producer component as well as a customer component. On the producer side, launching early—the preemption result—dissipates profits simply as a result of higher launch costs because real launch costs fall over time. The costs of early launch are higher because related technology and expertise may not be sufficiently developed, and some basic research relating to the advantage may be incomplete. On the customer side, if we assume prices and diffusion patterns are not altered, then customers are better off with an earlier launch unless the early launch causes some type of product failure that would not occur if the next generation were launched later.

Writing social welfare as a function of the launch time T, we have

$$W(T) = CS^i(T) + L^i(T),$$

where the present value of social welfare, $W(T)$, is the sum of the present value of customer surplus, $CS^i(T)$, and the leader's profits, $L^i(T)$. Customer surplus is decreasing with a later launch time, or larger T, and is used instead of consumer surplus as the beneficiaries of the next-generation advantage may be in an industrial rather than a retail market. Both of the latter terms have the superscript i because they depend on which firm launches the next-generation advantage. The socially optimal time for the next generation to be launched solves the first-order condition equating marginal social benefit with marginal cost,

$$\frac{dW(T^*)}{dT^*} = \frac{dCS^i(T^*)}{dT^*} + \left[\pi_0^i(T^*) - \pi_1^i(T^*)\right]e^{-rT^*} - \frac{dK(T^*)}{dT^*} = 0, \tag{9}$$

where the firm that launches is the one that yields the greatest welfare at its optimal launch time. Thus, the social optimum specifies which firm launches and the time of that launch. Using (4), we know that the condition $d^2CS^i(T^*)/[dT^*]^2 < 0$ is sufficient for concavity. The last two terms in (9) are identical to those in the first-order condition for the firm's optimal launch time, (3). Because customer surplus is decreasing in T, the socially optimal launch time is earlier than the optimal launch time of either firm. That is, for the firm that launches in the social optimum, the socially optimal launch time is earlier than the time it would otherwise choose.

Reinganum (1989) suggests that because each firm ignores the effect of its actions on others, the industry is less profitable, as above, and that the social good may be reduced. Hence, an important question is whether the next generation is launched earlier than is socially optimal because of preemption in response to the intensity of competition. The following theorem provides a sufficient condition for the preemptive launch to occur earlier than is socially optimal. It requires that we account for the possibility that in some cases launch by the entrant is socially optimal and in other cases launch by the incumbent launching is socially optimal.

THEOREM 3. *Case (i): If launch by the entrant is socially optimal, then a sufficient condition for the preemptive launch to occur earlier than is socially optimal is that, at the time of the preemptive launch, the difference in the present value of the entrant's profit flow between the status quo and being the follower with the next generation is greater than the marginal loss in customer surplus.*

Case (ii): If launch by the incumbent is socially optimal, then a sufficient condition for the preemptive launch to occur earlier than is socially optimal is that, at the time of the preemptive launch, the difference in the present value of the incumbent's profit flow between the status quo and being the follower with the next generation is greater than the marginal loss in customer surplus AND that the difference in the present value of the incumbent's profit flow between leading and following with the next generation is smaller than the marginal decline in launch costs.

PROOF. The condition in case (i) is identical to the first condition in case (ii). That condition is

$$\left[\pi_0^i(T_1^E) - \pi_2^i(T_1^E)\right]e^{-rT_1^E} > -\frac{dCS^i(T_1^E)}{dT_1^E}.$$

Adding $[\pi_1^i(T_1^E) - \pi_0^i(T_1^E)]e^{-rT_1^E}$ to both sides gives

$$\left[\pi_1^i(T_1^E) - \pi_2^i(T_1^E)\right]e^{-rT_1^E} > -\frac{dCS^i(T_1^E)}{dT_1^E} + \left[\pi_1^i(T_1^E) - \pi_0^i(T_1^E)\right]e^{-rT_1^E}.$$

Multiplying by -1 and rearranging the last term on the right hand side yields

$$-\left[\pi_1^i(T_1^E) - \pi_2^i(T_1^E)\right]e^{-rT_1^E} > \frac{dCS^i(T_1^E)}{dT_1^E} + \left[\pi_0^i(T_1^E) - \pi_1^i(T_1^E)\right]e^{-rT_1^E}. \tag{10}$$

Now consider case (i). Let T^{LF} be the T defined by (5) for the entrant. Using the definition of T_1^E, together with the strict quasi-concavity of $L^E(T) - F^E(T)$, we know that $T_1^E < T^{LF}$. Again using the strict quasi-concavity of $L^E(T) - F^E(T)$ and the fact that (5) defines the extrema of $L^E(T) - F^E(T)$, we know that the following inequality must hold.

$$-\left[\pi_1^E(T_1^E) - \pi_2^E(T_1^E)\right]e^{-rT_1^E} > \frac{dK(T_1^E)}{dT_1^E}$$

For case (ii) the second condition directly assumes that inequality for the incumbent. Combining it with (10), we get

$$\frac{dCS^I(T_1^E)}{dT_1^E} + \left[\pi_0^I(T_1^E) - \pi_1^I(T_1^E)\right]e^{-rT_1^I} - \frac{dK(T_1^I)}{dT_1^E} > 0.$$

From (9) and the concavity of the social welfare function, $T_1^E < T^*$. □

Theorem 3 is important because it signifies a lose-lose outcome as a result of hypercompetition that results in a preemptive launch. That is, producers' profits are dissipated from competition to such an extent that the losses are larger than the gains customers receive from an earlier launch of the next-generation advantage. Consequently, society loses as well.

Thus, we find that customers are always better off with an earlier launch, meaning that the earlier launch is a wealth transfer from firms to customers. If the customers' gain is greater than the firms' loss from launching prematurely, then society is better off. At some point, however, the customers' gain is less than the firms' loss, and at that point society begins to lose. Although strictly outside our model, should we choose to define society as a country, then society could be better off even when customers' gain is less than firms' loss if the premature launch preempts a foreign entrant from launching the next-generation advantage, possibly preventing a loss of jobs and technological know-how.

5.2. Limitations

Aside from conditions that ensure an interior solution to the launch-timing game—neither firm launches immediately and a launch is made eventually—our results rely on two key assumptions, Assumptions 1 and 4. We believe those assumptions are representative of a large number of cases. Assumption 1 embodies the presence of a strong first-mover advantage with the next generation by strictly ordering the gains to preemption versus the losses from being preempted. It allows us to determine unambiguously which firm launches the next generation first. Assumption 4 captures the futility of following. It ensures that after the first launch of the next generation there will not be a following launch of the same generation, and helps us restrict the range of our analysis. Relaxing Assumption 4 is the focus of our future efforts.

As we discuss through the main steps of the analysis, Assumptions 1 and 4 are even less severe when the entrant does not have a current-generation advantage. In that case, Assumption 1 should be automatic: in a product-market scenario, the profit flow from a two-product monopoly is larger than the combined profit flows of two firms competing with differentiated products. Assumption 4 is also supported in that case. First, Assumption 4(a) directly relies on differences in profit flows at the time of the second next-generation launch. Second, in the absence of positive externalities, differentiation, or decreasing returns to scale, the result of Bertrand competition would preclude positive profits from the next generation. If the entrant were the follower, then at the time of the second next generation launch the entrant would have no externalities with which to work, and it would be in the incumbent's interest to see that none are gained by being willing to undercut the entrant temporarily until the entrant is forced to exit. If the incumbent were the follower, then the differentiated competition result from Judd (1985) would apply: being second with the next generation would intensify competition for its current generation, so the incumbent may be better off not following with the next generation.

The profit flows, and our assumptions about relationships between them, are flexible enough to incorporate the effects of a diffusion process on market demand. Moreover, we made no assumptions about launch cost asymmetries between firms—neither firm has a launch cost advantage. We address that point in the corollary to Theorem 1: it is not possible for the entrant to launch the next generation first without a launch cost asymmetry in its favor.

6. Discussion

The results of our model have clear implications for firms competing in intensely competitive markets. Individual advantages are not sustainable and market leadership may require the development of a series of temporary advantages. In product markets, for example, older products are continually being replaced by next-generation products that typically provide superior functionality. Although gaining a competitive advantage in a particular generation may be very profitable, continued investment must be made in the development and launch of future generations to protect the original advantage. Without subsequent launches of more advanced generations, a firm can expect to be leapfrogged by a competitor. Our results validate the "eat your own lunch before someone else does" strategy outlined by Deutschman (1994). However, our results go further by implying that to protect the gains created by a competitive advantage, it may be necessary for the next generation to lose money at the margin. That is, a firm may incur incremental losses from the launch of the next-generation advantage to maintain its leading position in the market. In addition, our welfare results imply that preemption can cause a next-generation advantage to be launched earlier than is socially optimal. In other words, because society bears the cost of a premature introduction, social welfare may be reduced by hypercompetitive forces that lead to an early launch of the next-generation advantage. Therefore, not only can firms be forced to eat their own lunches, they can be forced to eat society's lunch as well.

The conditions under which our series of results is obtained are reasonably intuitive. For a given firm to employ a protection-through-preemption strategy requires that the firm be the one with the most to lose if it does not preempt, that the time value of money be accounted for, that launch costs fall at a decreasing rate over time, and that following by another firm is futile. In addition, for the incumbent to cannibalize at a loss requires that the present value of the incumbent's additional profit flows from the next-generation advantage be less than the difference in profit flows between leading and following for the entrant—essentially the incumbent is forced to launch to maintain its current leadership.

Thus, our results suggest that firms in hypercompetitive markets cannot afford the luxury of extending the life of a current advantage. The market dynamics are such that firms must become accustomed to repeatedly leapfrogging their own current advantages with next generations to maintain market dominance. Those dynamics serve to shift the distribution of profits within the life cycle toward the early stages, as in the case of personal computers where most of the profits from a given generation are made within months, and sometimes weeks, of launch (*Business Week* 1995b). Similarly, firms competing on their expertise in supply chain management find that the process of improvement can never stop as early advantages are competed away by rivals that employ similar or more advanced strategies (Henkoff 1994).

The managerial prescription implied by our model is straightforward: when there is competition to be first in a market, incumbents should strive to maintain leadership in the next generation even if they must cannibalize their current (market-leading) advantages. That prescription is consistent with Craig's (1996) observation that hypercompetition can play out in a series of hypercompetitive "rounds"—periods of intense competition on a particular dimension—similar to the setting we model. In the Japanese beer industry, Craig found that following an initial market share loss as a result of a competitor's preemptive strike, the Kirin brewery retained its market leading status by instituting a series of self-cannibalizing moves—moves that maintained rather than increased market share and profitability. Those findings, obtained from a detailed case study—a vastly different methodology than the one we employ—are consistent with our results in Theorems 1 and 2. Together, those theorems indicate that a preemptive launch of a next-generation advantage can be optimal, not necessarily resulting in increased performance, but rather protecting the firm's market position.

Despite the clarity of the prescription, several practical difficulties make implementation of a protection-through-preemption strategy difficult. One difficulty is the fact that the competition to be first to market leads to a premature market entry. That is, rather than waiting for the optimal launch time (when profits related to the current-generation advantage decline and launch costs fall), a firm is forced to launch early because of competition. The implication is that firms in rapidly evolving markets must be well organized to execute a preemptive strategy effectively. As noted in the introduction, several leading companies appear to be instituting policies that enable them to carry out such a strategy.

A second impediment that firms face in implementing a strategy of protection-through-preemption is that the returns to the next generation may be significantly less than the returns to the current generation. In fact, as outlined in Theorem 2, once the cannibalization of the current generation is taken into account, the next generation may lose money at the margin. That feature makes it increasingly difficult for next-generation development projects to survive an internal "business case" evaluation. For example, questions are being raised about the viability of microchip projects slated for production around the year 2000 because the escalating fixed costs of entry (R & D and wafer fab facility costs) will preclude a return given today's short life of product generations (*Business Week* 1994).

Third, a protection-through-preemption strategy may be sidelined by the management structure of the incumbent. For example, if the projects leading to two separate generations of advantages are managed by different people, the current-generation manager may demand that the next-generation launch be delayed so profits can accrue to the current generation advantage. That delay, which may occur at the business case stage rather than the launch stage, can result in the incumbent losing the race to launch. To counter such individually optimal but firm-suboptimal behavior, some companies such as Northern Telecom and Motorola Communications have taken steps to ensure that they are ready with the next generation on time.

Finally, Kim and Kogut (1996) show that firms having proprietary experience with a promising technology platform possess a strength that can be turned into a next-generation advantage. In a study of start-ups in the semiconductor industry, they found that firms founded on strong technology platforms were more likely to survive than those founded on weak platforms. A key to the success of surviving firms was the ability to grow by diversification into related subfields, developing next-generation technologies that replaced old ones. That process of survival and growth by going on to new advantages may explain the emergence and persistence of market-dominating firms—especially in technology-intensive industries. Indeed, several exemplars we use to illustrate our protection-through-preemption strategy (e.g., Intel and Motorola) have their origins in promising technology platforms.

The results of our model provide the foundation for future research in several areas. One area is the longer-run implications of a protection-through-preemption strategy for the entrant and the incumbent. First, if an incumbent following such a strategy leads in each generation, then the optimal strategy for the entrant is an open question. Second, although we illustrate that it may be optimal for the incumbent to launch a next generation that loses money at the margin, if that strategy is used repeatedly, then the rewards for achieving market-leading competitive advantage may diminish over time. The firm may be better off alternating as leader and follower in successive generations. Such a strategy would allow the firm to achieve a higher return on each generation it pursues by reducing cannibalization and lowering launch costs.

Another area is relaxation of the requirements imbedded in our Assumption 4 which, in essence, precludes a second launch of the next generation advantage. We have done some preliminary work showing that the results reported here continue to hold under less restrictive conditions where second launches of the next generation do occur—consistent with our argument that Assumption 4 is representative of many forms of price and quantity competition. Completely eliminating the restrictions associated with Assumption 4 is likely to change our results drastically—and may also be a fruitful avenue to pursue.

Yet another important area for future research is empirical validation of our model's results. Though many firms *seem* to be following a protection-through-preemption strategy (i.e., Intel in microprocessors and Hewlett Packard in its printer division), whether they are making their decisions as a result of that strategy or on some other basis is unclear. In-depth case analyses of a set of firms would be useful to clarify the relationship between their decision-making processes and our suggested strategy.

An alternative empirical approach would be to determine whether next generation advantages have diminishing returns (when cannibalization is factored in) or are losing money at the margin. That issue has important implications for investment decisions in diversified firms because it may be in the best interest of the overall firm *not* to protect its advantage in some markets in favor of alternative investment opportunities. An investigation of the issue would require information about individual companies and their specific markets.

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Appendix

The proof of Theorem 1 makes use of the strategy spaces and payoff functions formalized in Section 4 B of Fudenberg and Tirole (1985, p. 392–393). Our notation is slightly modified as we employ superscripts to denote firms, and use T as a subscript in place of t as a superscript to the function G.

Strategy Spaces and Payoff Functions

DEFINITION 1. A simple strategy for firm i in the game starting at T is a pair of real-valued functions (G^i, α^i): $[T, \infty) \times [T, \infty) \to [0, 1] \times [0, 1]$ satisfying

(a) G^i is nondecreasing and right-continuous.

(b) $\alpha^i > 0 \Rightarrow G^i(T) = 1$.

(c) α^i is right-differentiable.

(d) If $\alpha^i(T) = 0$ and $T = \inf(s \geq T | \alpha^i(\cdot) > 0)$, then $\alpha^i(\cdot)$ has a positive right derivative at T.

Let the "first interval of atoms" be represented by

$$\tau^i(T) = \begin{cases} \infty & \text{if } \alpha^i(s) = 0\ \forall s \geq T, \\ \inf(s \geq T \mid \alpha^i(\cdot) > 0) & \text{otherwise.} \end{cases}$$

$\tau(T) = \min(\tau^I(T), \tau^E(T))$. $a^i(s) = \lim_{\epsilon \to 0}[G^i(s) - G^i(s - |\epsilon|)]$ Let $G^{i-}(T)$ be the left limit of $G^i(\cdot)$. at T. The game begins at $T \geq 0$ so set $G^{i-}(T) = 0$. Payoffs are

$$V^i(T, (G^I, \alpha^I), (G^E, \alpha^E))$$

$$= \left[\int_T^{\tau(T)^-} \left(L(s)(1 - G^j(s))\, dG^i(s) \right.\right.$$

$$\left.+ F(s)(1 - G^i(s))\, dG^j(s)\right) + \left.\sum_{s < \tau(T)} a^i(s) a^j(s) M(s)\right]$$

$$+ \left[\left(1 - G_T^{i-}(\tau(T))\right)\left(1 - G_T^{j-}(\tau(T))\right)\right.$$

$$\left. W^i\left(\tau(T), (G^I, \alpha^I), (G^E, \alpha^E)\right)\right],$$

where $W^i(\cdot)$ is defined as follows: If $\tau^j(T) > \tau^i(T)$, then

$$W^i\left(\tau(T), (G^I, \alpha^I), (G^E, \alpha^E)\right)$$

$$= \left[\frac{G^i(\tau) - G^{i-}(\tau)}{1 - G^{i-}(\tau)}\right]\left[\left(1 - \alpha^i(\tau)\right)F(\tau) + \alpha^i(\tau)M(\tau)\right]$$

$$+ \left[\frac{1 - G^i(\tau))}{1 - G^{i-}(\tau)}\right] L(\tau).$$

If $\tau^i(T) > \tau^j(T)$, then

$$W^i\left(\tau(T), (G^I, \alpha^I), (G^E, \alpha^E)\right)$$

$$= \left[\frac{G^i(\tau) - G^{i-}(\tau)}{1 - G^{i-}(\tau)}\right]\left[\left(1 - \alpha^j(\tau)\right)L(\tau) + \alpha^i(\tau)M(\tau)\right]$$

$$+ \left[\frac{1 - G^i(\tau)}{1 - G^{i-}(\tau)}\right] F(\tau).$$

Finally, if $\tau^I(T) = \tau^E(T)$, then

$$W^i\left(\tau(T), (G^I, \alpha^I), (G^E, \alpha^E)\right) = M(\tau) \quad \text{if } \alpha^i(\tau) = \alpha^j(\tau) = 1,$$

$$\frac{\alpha^i(\tau)(1 - \alpha^j(\tau))L(\tau) + \alpha^j(\tau)(1 - \alpha^i(\tau))F(\tau) + \alpha^i(\tau)\alpha^j(\tau)M(\tau)}{\alpha^i(\tau) + \alpha^j(\tau) - \alpha^i(\tau)\alpha^j(\tau)}$$

$$\text{if } 2 > \alpha^i(\tau) + \alpha^j(\tau) > 0,$$

$$\frac{\alpha^{\prime i}(\tau)L(\tau) + \alpha^{\prime j}(\tau)F(\tau)}{\alpha^{\prime i}(\tau) + \alpha^{\prime j}}(\tau) \quad \text{if } \alpha^i(\tau) = \alpha^j(\tau) = 0.$$

DEFINITION 2 A pair of simple strategies (G^I, α^I) and (G^E, α^E) is a Nash equilibrium of the game starting at T (with neither firm having yet launched) if each firm's strategy maximizes its payoff, $V^i(T, \cdot, \cdot)$, with the other firm's strategy held fixed.

DEFINITION 3. A closed-loop strategy for firms is a collection of simple strategies $(G_T^i(\cdot), \alpha_T^i(\cdot))_{T \geq 0}$ for games starting at T satisfying the intertemporal consistency conditions:

(e) $G_T^i(T + v) = G_T^i(T + u) + (1 - G_T^i(T + u))G_{T+u}^i(T + v)$ for $T \leq u \leq v$.

(f) $\alpha_T^i(T + v) = \alpha_{T+u}^i(T + v) = \alpha^i(T + v)$ for $T \leq u \leq v$.

DEFINITION 4. A pair of closed-loop strategies $\{(G_T^I(\cdot), \alpha_T^I(\cdot))\}_{T \geq 0}$ and $\{(G_T^E(\cdot), \alpha_T^E(\cdot))\}_{T \geq 0}$ is a perfect equilibrium if for every T the simple strategies $(G_T^I(\cdot), \alpha_T^I(\cdot))$ and $(G_T^E(\cdot), \alpha_T^E(\cdot))$ are a Nash equilibrium.

Let $\eta^i(T) = \inf\{s \geq T \mid G_s^i(s) > 0\}$. Note that if $\eta^i(0) < \tau^i(0)$, then $\eta^i(0)$ is the first time of an isolated jump. And let $\eta(0) = \min\{\eta^I(0), \eta^E(0)\}$.

PROOF OF THEOREM 1. $G_T^i(s)$ is the cumulative probability that firm i has launched by time s, in the game starting at T, given the other firm has not already launched. $\alpha^i(T)$ measures the intensity of G in the interval $[T, T + dT]$. Consider the following simple strategies for the two firms.

$$G_T^I(s) = \begin{cases} 0 & \text{if } s < T_1^E \\ 1 & \text{if } s \geq T_1^E \end{cases}$$

$$\alpha^I(s) = \begin{cases} 0 & \text{if } s < T_1^E \\ \dfrac{L^E(T) - F^E(T)}{L^E(T) - M^E(T)} & \text{if } s \geq T_1^E \end{cases}$$

$$G_T^E(s) = \begin{cases} 0 & \text{if } s \leq T_1^E \\ 1 & \text{if } s > T_1^E \end{cases}$$

$$\alpha^E(s) = \begin{cases} 0 & \text{if } s \leq T_1^E \\ \dfrac{L^I(T) - F^I(T)}{L^I(T) - M^I(T)} & \text{if } s > T_1^E. \end{cases}$$

All games starting at T must be considered, $G_T^{i-}(T) = 0$. We examine strategies starting at T_1^E, that is, $T \in [T_1^E, \infty)$. Prior to T_1^E, waiting is a dominant strategy for both firms.

We begin by examining the incumbent's strategy and payoffs. Assume first that $T \in [T_1^E, \infty)$. From the entrant's equilibrium strategy $\alpha^E(T)$, $\tau = \tau^E(T) = T$. If $G_T^I(T) = 0$, then the resulting payoff is $F^I(T)$. If $G_T^I(T) = \lambda$, $0 < \lambda < 1$, then it must be that $\alpha^I(T) = 0$ and $\tau^I(T) > \tau^E(T)$. The resulting payoff is

$$\lambda\left[\alpha^E(T)M^I(T) + \left(1 - \alpha^E(T)\right)L^I(T)\right] + (1 - \lambda)F^I(T) \quad (11)$$

$$= \lambda\left[\frac{\left(L^I(T) - M^I(T)\right)\left(-L^I(T) + F^I(T)\right)}{L^I(T) - M^I(T)} + L^I(T)\right]$$

$$+ (1 - \lambda)F^I(T) = F^I(T). \quad (12)$$

If $G_I^I(T) = 1$, then $\alpha^I(T) > 0$ and $\tau^I(T) = \tau^E(T)$ With $2 > \alpha^I(T) + \alpha^I(T) > 0$, the resulting payoff is

$$\frac{\alpha^I(T)(1-\alpha^E(T))L^I(T) + \alpha^E(T)(1-\alpha^I(T))F^I(T) + \alpha^I(T)\alpha^E(T)M^I(T)}{\alpha^I(T) + \alpha^E(T) - \alpha^I(T)\alpha^E(T)}, \tag{13}$$

which, using (11) and (12), yields

$$\frac{\alpha^I(T)F^I(T) + \alpha^E(T)(1-\alpha^I(T))F^I(T)}{\alpha^I(T) + \alpha^E(T) - \alpha^I(T)\alpha^E(T)} = F^I(T). \tag{14}$$

Thus, the incumbent is indifferent between those strategies over $T \in (T_1^E, \infty)$

Next, consider $T = T_1^E$. Again from the entrant's equilibrium strategy, $\alpha^E(T) = 0$ and $G_T^E(T) = 0$. If $G_T^I(T) = 0$, then $\alpha^I(T) = 0$. Thus, $\tau^I(T) \geq \tau^E(T) = \tau > T_1^E$, and $2 > \alpha^I(\tau) + \alpha^I(\tau) > 0$. The resulting payoff is calculated as in (13) and (14), and is therefore $F^I(\tau)$. If $G_T^I(T) = \lambda$, $0 < \lambda \leq 1$, then the situation is the same as when $G_T^I(T) = 0$, and the resulting payoff is equivalent, $F^I(\tau)$. If $G_I^I(T) = 1$, then $\alpha^I(T) > 0$, and therefore $\tau = T_1^E = \tau^I(T) < \tau^E(T)$. Because the remaining terms cancel, the resulting payoff is $L^I(\tau)$. Because $L^I(\tau) > F^I(\tau)$ when $\tau = T_1^E$, the incumbent prefers $G_T^I(T) = 1$.

Now we check the entrant's strategy and payoffs. Examine first $T \in (T_1^E, \infty)$ From the incumbent's equilibrium strategy, $\alpha^I(T) > 0$, thus, $\tau^I(T) = \tau(T) = T$ If $G_T^E(T) = 0$, then $\alpha^E(T) = 0$, and $\tau^E(T) > \tau^I(T)$. With the remaining terms dropping out, the resulting payoff is $F^E(T)$ If $G_T^E(T) = \lambda$, $0 < \lambda \leq 1$, then again $\alpha^E(T) = 0$, and $\tau^E(T) > \tau^I(T)$. The payoff is therefore

$$\lambda\left[\alpha^I(T)M^E(T) + \left(1 - \alpha^I(T)\right)L^E(T)\right] + (1-\lambda)F^E(T)$$

Analogous to (11) and (12), the result is $F^E(T)$. If $G_I^E(T) = 1$, then $\alpha^E(T) > 0$, $\tau^E(T) = \tau^I(T)$, and $2 > \alpha^I(T) + \alpha^E(T) > 0$. Similar to (13) and (14), the payoff is

$$\frac{\alpha^E(T)(1-\alpha^I(T))L^E(T) + \alpha^I(T)(1-\alpha^E(T))F^E(T) + \alpha^I(T)\alpha^E(T)M^E(T)}{\alpha^E(T) + \alpha^I(T) - \alpha^I(T)\alpha^E(T)}$$

$$= F^E(T)$$

Consequently, the entrant is indifferent over those strategies for $T \in (T_1^I, \infty)$

Consider $T = T_1^E$ From the incumbent's equilibrium strategy, $\alpha^I(T) > 0$, $G_I^I(T) = 1$, and $\tau = T_1^E$ If $G_T^E(T) = 0$, then $\alpha^E(T) = 0$, $\tau^E(T) > \tau^I(T)$. If $G_I^I(T) = \lambda$, $0 < \lambda \leq 1$, then again $\alpha^E(T) = 0$, and $\tau^E(T) > \tau^I(T)$. If $G_T^E(T) = 1$, then $\alpha^E(T) > 0$, $\tau^E(T) = \tau^I(T) = \tau$, and $2 > \alpha^I(\tau) + \alpha^E(\tau) > 0$. Each payoff is the same as when $T \in (T_1^I, \infty)$, $F_1^E(T)$. Hence, the entrant is also indifferent over those strategies

Therefore, those simple strategies are a Nash equilibrium for every T, and are intertemporally consistent over T. As a result they are a perfect equilibrium

We now show that there are no other perfect equilibria. Assume first $\tau(0) \leq \eta(0)$ Prior to T_1^I neither firm wants to launch because $F^I(T) > L^I(T), M^I(T)$. Prior to T_1^E the entrant does not want to launch because $F^E(T) > L^E(T), M^E(T)$. In fact, $F^I(T), L^I(T) > M^I(T)\ \forall T$. For $T \in [T_1^I, T_1^I)$ the incumbent prefers to wait because $L^I(T + \epsilon) > L^I(T)$ for small but positive ϵ. At any $T \in (T_1^E, \infty)$ each firm's best response is to launch at $\tau(T) + \epsilon$ because $L^i(\tau(T) - \epsilon) > F^i(T)$ Now consider $T = T_1^E$ The incumbent's dominant strategy is to launch because $L^I(T) > F^I(T)$. By definition of T_1^I, the entrant is indifferent between following and leading at that time For both firms those payoffs exceed the payoff from simultaneous launch, therefore, the entrant is better off not launching at T_1^I

Assume next that $\eta(0) < \tau(0)$ Prior to T_1^I waiting is optimal for both firms. For $T \in [T^I, T_1^I)$, $\eta(T) = \eta^I(T)$ because the entrant is still better off waiting. But $L^I(T)$ is increasing in this interval so launching at T is not optimal for the incumbent either. At $T = T_1^I$, if $\eta(T) = \eta^I(T)$, then the entrant can avoid a possible mistake (simultaneous launch) by waiting For $T \in (T_1^E, \infty)$, if $\eta(T) = \eta^i(T)$, then firm j is better off launching with probability one at $T - \epsilon$ Finally, at T_1^I the incumbent can avoid a positive probability of a mistake by launching with probability one. □

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