

Waterfall and sprinkler new-product strategies in competitive global markets

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Abstract

How should a multinational firm introduce a new product into its global markets? Should it first attack and conquer the domestic market before moving into overseas markets or should it plan for a global attack by launching the product in all its global markets simultaneously? Using innovation diffusion models in a monopoly and a competitive game theory framework, this paper analytically examines waterfall (where the markets are entered sequentially) and sprinkler (where markets are entered simultaneously) strategies. Optimal conditions for the implementation of these two strategies are derived. The results generally suggest that the current nature of global competition requires a multinational firm to follow the sprinkler strategy in introducing a new product to its global markets.

Keywords: Marketing strategy; New products; Global markets

1. Introduction

In recent years, an increasing number of key industries such as automobile and motorcycle production, agricultural equipment, aerospace, military hardware, telecommunications, electronics, and luxury consumer goods have become global in scope. Firms in these industries originate, produce, compete, and market their products worldwide. In 1992 more than 50% of 3M's total revenues came from overseas operations.

Similarly, the overseas sales of Nestle account for 98% of its total annual sales (N.N. in *Business Week*, 1990).

Products made by foreign competitors have now penetrated almost every market in the free world. For example, 39% of Japan's total exports, 36% of Korea's, 81% of Canada's, and 87% of Mexico's come to the United States (Iacocca, 1987). Similarly, major U.S. companies in various industries, such as aerospace, computer equipment, oil field machinery, medical equipment, and chemicals, export a significant percentage of their products overseas (N.N. in *Business Week*, 1990).

To transform global challenges into new opportunities in the emerging global marketplace,

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multinational firms are realizing that the key to growth and survival is the continuous development and introduction of new products (Keegan, 1989; Samiee and Roth, 1992). However, the challenge facing a multinational firm is to develop a new product policy and strategy that is sensitive to market needs, competition, and company resources on a global scale.

Douglas and Craig (1992) observe that “Many large corporations are already involved in international markets and hence are making entry decision in the context of an existing network of international operation. But for small and medium size businesses who have not yet entered international markets, entry decisions constitute a critical step on the path to internationalization.”

There are two major issues facing firms in their decisions on the global launching of a new product. The first issue is the degree of standardization of the product across different countries and markets (e.g., Samiee and Roth, 1992). The second is entry strategy choice. According to Douglas and Craig (1992): “... attention needs to be paid to the timing and sequencing of entry into international markets relative to competitor moves and the stage of market development. This should include assessment of factors impacting the choice of incremental vs simultaneous entry into different country markets...” This last issue is precisely the subject of this paper.

How should a multinational firm introduce a new product into its global markets? Based on an earlier International Product Life Cycle notion (e.g., Wells, 1968), and the pioneering work of Ayal and Zif (1979), a popular model suggested for the global roll-over is the hierarchical, or waterfall model (Ohmae 1985, 1987, 1989). According to the waterfall model, innovations trickle down in a slow-moving cascade from the most to the least technologically advanced countries. That is, after the successful domestic launch of a new product, multinational firms introduce it into other advanced countries and then into the less developed countries. Evidence of such a diffusion phenomenon has been documented by Davidson and Harrigan (1977). Tracing the global sales of 733 commercially significant new products introduced by 44 U.S.-based multinational firms be-

tween 1945 and 1976, Davidson and Harrigan (1977) reported that during the time period examined, in planning for the global roll-over, U.S.-based multinationals initially focused on English-speaking markets (such as Canada or the United Kingdom), then on other industrial markets, and finally the less developed countries. They also found, however, that over the years, these multinational firms were also introducing new products into foreign markets more rapidly than ever before. For example, the percentage of new products introduced into a foreign market within one year of their introduction in the U.S. increased from 5–6 percent of all new products introduced between 1945 and 1950 to 38.7 percent of the new products introduced between 1971 and 1975. That is, over the years, there was a dramatic increase in the receptiveness of the U.S.-based multinationals to foreign market opportunities.

Despite the evidence reported by Davidson and Harrigan (1977), given the current competitive nature of the global marketplace, should multinational firms continue to follow the waterfall model for introducing their new products worldwide? A strong “No” in answer to this question has come from Ohmae (1985, 1987) and Riesenbeck and Freeling (1991). The sprinkler diffusion strategy advocated by Ohmae recommends a “simultaneous world attack.” It is suggested that the waterfall diffusion strategy, that required a multinational firm to enter one market (sometimes called the lead market) first before entering the other markets according to some pre-specified order, is a conservative strategy that has worked well in the past, but is no longer effective. With increased global competition, the sprinkler strategy of simultaneous entry in all markets is the only viable choice in today’s global marketplace.

Using innovation diffusion models in a competitive game theory framework, we analytically derive the marketplace conditions under which a waterfall strategy is optimal in a competitive game in which two competitors have to decide on the optimal market entry time of a new durable product. It is suggested that while these global marketplace conditions might have prevailed in the past, they may be nonexistent today.

2. The lead effect

An important concept of diffusion theory relevant to predicting the global diffusion of an innovative *durable* product is the nature of communications between two countries (Takada and Jain, 1991). The ability of change agents or adopters of an innovation in one country, called the lead market, to communicate with the potential adopters in the second country, referred to as the foreign market, provides an additional external source of information to the second country which influences the rate of adoption among its potential adopters (Gatignon et al., 1989). The potential adopters in the second country observe the success of the product in the lead market. If it is successful, the risk associated with the innovation is reduced. This reduction in risk is translated into a higher adoption rate in the second country. That is, it is the *lead effect* that creates an important source of information about the innovation from the lead market to the foreign market. The lead effect (if it creates positive information about the product) works in favor of a manufacturer and influences the lead time – the time interval between introduction of the new product into the lead market and the foreign market. In fact, by virtue of the lead effect, the manufacturer is likely to follow the waterfall model. If the lead effect is zero, the timing decision for the foreign market is not influenced by the diffusion effect of the lead market. In order to formalize the lead effect and demonstrate its influence on the diffusion process we start off with the monopoly case. The next section will deal with the competitive market structure. The monopoly section will be then helpful in understanding the cooperative case presented later on. In both cases, we use the new product diffusion model suggested by Bass (1969) (for a state-of-the-art survey of new product diffusion models, see Mahajan et al. (1990)). For a monopolist offering a new product in a single market, the Bass model proposes the following first-order differential equation, which captures the diffusion dynamics:

Lead (home) market:

$$\dot{x}(t) = dx/dt = (a + bx(t)/N)(N - x(t)) \quad (1)$$

where $x(t)$ denotes the cumulative number of adopters at time t , N represents the ultimate market potential, $\dot{x}(t)$ gives the rate of adoption and a and b denote the coefficient of innovation and the coefficient of imitation, respectively.

Given Eq. (1), the following notation is set forth to formulate the global diffusion setting. Let $x(t)$ and $y(t)$ be the cumulative number of adopters at time t in the home and foreign country, respectively. Let N and M be the market potential for the two markets. Let a , b and α , β be the coefficients of innovation and imitation in the two markets. Further, let g and h be the profit margin in the lead and foreign market, respectively. We assume that price and variable cost either do not change or decline such that the profit margin remains constant over time. We relax this assumption in the last section of the paper.

Finally, let T be the entry time into the foreign market, δ the lead parameter, F the fixed cost of entry, and r the cost of capital of the firm. Thus Eq. (1) with the initial condition $x(0) = 0$ describes adoption in the lead (home) market, while adoption in the foreign market is described by the following equation:

Foreign market:

$$\begin{aligned} \dot{y}(t) &= dy/dt \\ &= (\alpha + \beta y/M + \delta x/N)(M - y)u(t) \quad (2) \end{aligned}$$

where $u(t)$ is a control variable that is zero up to time T (the introduction time) and one thereafter.

The term $\delta x/N(M - y)$ in Eq. (2) represents the lead effect – the influence of x , the number of adopters in the lead market, on the potential adopters, $M - y$, in the foreign market.

Some empirical support for our formulation could be found in Takada and Jain (1991) and in Eliashberg and Helsen (1987). The latter found a significant, positive, lead effect parameter (δ in Eq. 2) in many countries in black and white television adoption but only in few countries in color television adoption. There was no case in which the lead was negative and significant. A positive effect of the time lag on the *innovation* parameter was also found in Helsen et al. (1993). They also found, however, a negative effect of the

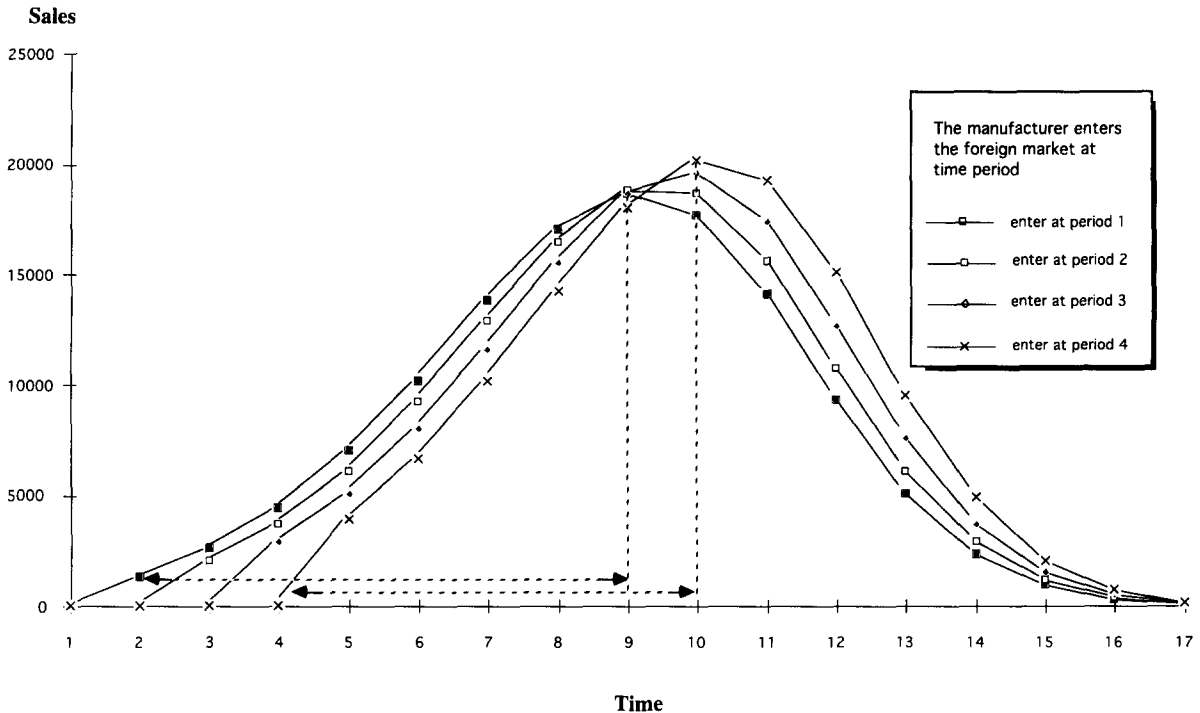


Fig. 1. The influence of the lead effect on product diffusion in the foreign market.

time lag on the *imitation* parameter, thus raising the possibility (which is not considered in this paper) of a negative lead effect.

Fig. 1 depicts the influence of entry time on the product growth in the foreign market.¹ It isolates the influence of the lead effect on product growth in the foreign market for four different values of entry time (one through four periods after entry into the lead market). This figure clearly shows that the lead effect results in a faster growth rate, giving a higher sales peak in a shorter period of time after product introduction. For example, as depicted, product entry into the foreign market two periods after entry into the lead market results in a sales peak of 18 840 units seven periods after its introduction into the foreign market. On the other hand, product entry into the foreign market after four periods yields a sales peak of 20 213 that occurs six periods after its introduction into the foreign market.

¹ The parameters chosen for Fig. 1 are: $N = 300000$, $M = 250000$, $\delta = 1$, $\alpha = 0.001$, $\beta = 0.42$.

The firm chooses time of introduction (by choosing $u(t)$) so as to maximize net present value of the cash flow from the sales of the product in the two countries.

This net present value is given by:

$$\pi = \int_0^T e^{-rt} \{g\dot{x} + h\dot{y} - Fru(t)\} dt. \tag{3}$$

In order to state our first proposition we need the concept of the shadow price of an adopter μ . In control theory this is the auxiliary variable of $y(t)$ (or the multiplier) and it acts exactly as a dynamic Lagrange multiplier. At introduction time, μ_0 is the value to the firm of an additional adopter. It is this parameter, in addition to F , the fixed cost of entry, and r , the discount rate, that play a major role in the timing decision of the monopolist.

Proposition 1. The timing decision of the monopolist is characterized by the following three cases:

- a) For small values of fixed cost, i.e., when $rF < \alpha M(h + \mu_0)$, the firm introduces the product into the foreign market right away at $T = 0$.

- b) For large values of fixed cost, i.e., when $rf > (\alpha + \delta)Mh$, the firm delays introduction of the product into the foreign market indefinitely.
- c) For intermediate values of fixed cost introduction time is given by

$$rF = (\alpha + \delta x(T)/N)M(h + \mu(T)). \quad (4)$$

The proposition is proved in Appendix 1. The quantity rf is the periodic payment the firm would pay instead of the one-time fixed cost F , for introduction of the product into the foreign market. If this periodic cost is too high, the firm is better off not introducing its product into the foreign market at all. If it is small (or zero) the firm should introduce the product at time zero and thus employ a *sprinkler* strategy, i.e., introduce both products into the two markets at the same time. In Eq. (4) the firm equates the marginal cost of entry rF to the marginal benefits. These include current (periodic) units sales (for $u = 0$) multiplied by their current dollar value h and their future (discounted) value μ . When these two values are equal the firm introduces the product into the foreign market, thus employing a *waterfall* strategy. In the case of multiple countries, this argument could be extended assuming the countries differ in terms of their parameters F , α , M , or h .

3. Competitive global markets

In the presence of competition, the benefits of the lead effect shown in the previous section could be negated. By means of earlier product introduction into the foreign market, a competitor can preempt the manufacturer's competitive advantage arising from the lead effect.

Given the intertwined relationship between the lead effect and the competitive effect, the following question can be raised in relation to the lead time (and hence the choice between waterfall versus sprinkler strategies):

Does competition always reduce a manufacturer's lead time? That is, does it always force a manufacturer to introduce the new product into the foreign market earlier than if no competition was

present? If so, is the sprinkler strategy always the optimal strategy?

Clearly, the answers to the above question will shed light on the desirability of the sprinkler strategy advocated by Ohmae (1985). In order to derive the answer, we formulate the entry timing decision for the foreign market in the context of a competitive global diffusion game. For the sake of tractability, we consider a market game in which: (a) two manufacturers offer a competitive, durable consumer product (and hence each buyer buys only one unit) in two markets (the lead market and the foreign market) and (b) having introduced the product into the lead market, the manufacturers have to make their decisions regarding its introduction into the foreign market (following either sprinkler strategy or waterfall strategy).

We follow the same notations as in the previous section with the obvious extension to the two-player case. Since the product is a durable one (and we assume that each potential consumer buys only one unit), a unit sold by each manufacturer is a lost customer for the other manufacturer. Hence, extending Eqs. (1) and (2), the following equations describe the growth of the competitor's products in the two markets:

Lead market:

$$\text{Competitor 1: } \dot{x}_1 = \left(a_1 + \frac{b_1}{N} x_1 \right) (N - x_1 - x_2). \quad (5)$$

$$\text{Competitor 2: } \dot{x}_2 = \left(a_2 + \frac{b_2}{N} x_2 \right) (N - x_1 - x_2). \quad (6)$$

$$x_1(0) = x_2(0) = 0.$$

Foreign market:

Competitor 1:

$$\dot{y}_1 = \left(\alpha_1 + \frac{\beta_1}{M} y_1 + \frac{\delta_1}{N} x_1 \right) (M - y_1 - y_2) u_1(t). \quad (7)$$

Competitor 2:

$$\dot{y}_2 = \left(\alpha_2 + \frac{\beta_2}{M} y_2 + \frac{\delta_2}{N} x_2 \right) (M - y_1 - y_2) u_2(t). \quad (8)$$

Eqs. (5) and (6) describe the diffusion dynamics in the lead market. It is assumed that both competitors are present in this market from the beginning (entry time zero). Note that the remaining market potential for the product at any time is $N - x_1 - x_2$.

Eqs. (7) and (8) describe the diffusion dynamics in the foreign market. (These equations are similar to the diffusion models proposed by Peterson and Mahajan (1978) for the growth of interrelated products.) It is assumed that the two competitors introduce their products at times T_1 and T_2 , respectively. If $T_i = 0$, competitor i follows a sprinkler strategy. A nonzero value of T_i implies a waterfall strategy.

The firms choose the entry times T_1 and T_2 , by choosing $u_1(t)$ and $u_2(t)$ that have a zero value up to time T_i and achieve the value of 1 thereafter. Thus Eqs. (7) and (8) imply that with this choice of $u_i(t)$ the following holds

$$y_1(T_1) = y_2(T_2) = 0. \quad (9)$$

In addition, from Eqs. (5) and (6) it is clear that we assume that in the lead market word-of-mouth effects for brand i are generated only via its own previous adopters. In line with this assumption, in the foreign market word-of-mouth effects are generated by its own adopters *in both markets*. Thus the term $\beta_1 y_1/M$ is the word-of-mouth effect generated by adopters of product 1 in the foreign market, while $\delta_1 x_1/N$ is the effect generated by adopters of product 1 in the lead market.

It is possible to formulate the process so that the least effect will be product category based and not brand based as we have assumed. Thus in Eqs. (7) and (8) the terms $\delta_i x_i/N$ will be replaced by the terms $\delta_i(x_1 + x_2)/N$. This does not change any of our results qualitatively (although, of course, it affects the timing decisions quantitatively).

The noncooperative game is one in which the strategy space is the choice of $u_i(t)$ (i.e., the choice of entry times T_1 and T_2), chosen independently and without cooperation by the two players, so as to maximize the objective function

π_i given by Eq. (10) subject to the constraints (5)–(8).

$$\pi_i = \int_0^{\bar{T}} e^{-rt} \{g_i \dot{x}_i + h_i \dot{y}_i - F_i r u_i(t)\} dt \quad (10)$$

where \bar{T} is the planning horizon.

As in the monopolist case, let μ_i be the shadow price of an adopter of product i to firm i . The next proposition generalizes Proposition (1) for the two-firm case.

Proposition 2. The Nash equilibrium entry time of the noncooperative game is characterized by the following three cases:

- For small values of fixed cost, i.e., when $rF_i < \alpha_i M(h_i + \mu_i(0))$, firm i introduces the product into the foreign market right away at $T_i = 0$.*
- For large values of fixed cost, i.e., when $rF_i > (\alpha_i + \delta_i) M h_i$, the firm delays introduction of the product into the foreign market indefinitely.*
- For intermediate values of fixed cost, the Nash equilibrium entry times T_i are given by*

$$rF_i = (\alpha_i + \delta_i x_i(T_i)/N) M(h_i + \mu_i(T_i)). \quad (11)$$

The proposition is proved in Appendix 2.

Each firm in this game setting chooses an optimal entry time, given the entry time of the rival. If cost of entry, growth parameters, and profitability are different for the two firms, it is possible for the first firm to adopt a *sprinkler strategy* (if for example $rF_1 < \alpha_1 M(h_1 + \mu_1(0))$) while at the same time the second firm will choose a *waterfall strategy* according to case c) or even give up this market totally if its cost of entry is to high, i.e., if $rF_2 > (\alpha_2 + \delta_2) M h_2$.

With equal parameters they will both choose the same strategy. What we wish to demonstrate is that competition between the two players will result in shortening the lag between introduction of the product in the home country and its introduction in the foreign market. In order to do so, we choose the same parameters for both firms, and compare the noncooperative case to the monopolist case. Therefore, we formulate the *cooperative game* as one in which the demand and cost conditions are the same, but the two players coordinate their entry time. The cooperative game

Table 1
Net present values of coordinated entry into the foreign market

Period	NPV
1	113596
2	114102
3	114395
4 ^a	114455
5	114268

^a Optimal entry period.

thus is one in which the firms agree to enter the foreign market in the same time period. They may decide to enter later or sooner, depending on the lead parameter, but they act in coordination with respect to entry time as if they were a single monopolist facing the same conditions.

Proposition 3. The Nash equilibrium time of entry of the noncooperative game (T^) is sooner (smaller) than the equilibrium time of entry of the cooperative game (T^c).*

The proposition is proved in Appendix 3.

Thus, the existence of the competitor (who presumably will not cooperate) will shorten the lead time and force a multinational firm to introduce the product earlier. The question now is whether this pressure from competition will *always* force a simultaneous introduction strategy. As is demonstrated in the next proposition the answer is negative.

Proposition 4. There is no uniform sprinkler or waterfall strategy for all cases. The noncooperative game can generate either one as an equilibrium depending on the problem's parameters.

The proof is by example. We present two examples; one in which the parameter configuration is such that the Nash equilibrium is $T^* = 0$ and one in which $T^* > 0$.

The equations describing the two games, (5)–(8), were solved on a Lotus 1-2-3 program using an Euler–Cauchy (first-order) solution. For each combination of entry times (e.g., $T_1 = 2$, $T_2 = 3$) the equations were solved for a finite time horizon of 40 periods. As can be seen in Fig. 1, this

time horizon is long enough to make sales reach a zero level, and cumulative adoption is at maximum. Net present value is then computed for each such combination of entry times.² The parameter values are as follows: $a_i = \alpha_i = 0.001$, $b_i = \beta_i = 0.6$, $M = N = 300\,000$, $\delta_1 = \delta_2 = 0.5$, $r_1 = r_2 = 0.08$, $F = 30\,000$, $h_i = g_i = 1$. Since discrete values of time are considered, sprinkler strategy occurs at $T^* = 1$.

The optimal entry time T^c can be observed from Table 1. The largest net present value is obtained when $T^c = 4$, i.e., when the two players agree to enter together in period four. This requires a great deal of coordination, since it is in the best interest of each player to cheat his opponent and gain both share and profits. In this sense we view the intended cooperation in the somewhat cynical view of the stability of a cartel. Unless it is a game played over and over again, there is a very real incentive for cheating on the cartel agreement. Table 2 illustrates this phenomenon. Using the same parameters, this table shows the numerical solution for the noncoordinated entry. The arrows in the table correspond to the player who has cheated at this stage. Thus the first player enters in period 3, instead of 4 and increases his/her own NPV to \$119 286, while at the same time reducing the NPV for the opponent to \$109 610. Given that she/he enters in period 3, the opponent also enters at this period and increases his/her own NPV to \$114 395. Player 1 cheats again and gets \$118 637 by entering in period 2 as well. Player 2 responds by entering in period 2 as well. Player 1 cheats once again and enters in the first period increasing the NPV from \$114 102 to \$117 889, firm 2 completes this cycle by entering in period 1 as well.

The Nash equilibrium of the noncooperative game thus calls for both players to enter simultaneously in period 1. They therefore follow a sprinkler strategy. To see that this is a Nash equilibrium observe that if player 2 delays entry to period 2, his/her own NPV will drop to

² The numerical solutions are available from the third author in Lotus 1-2-3 files.

Table 2

Net present values of noncoordinated entry into the foreign market. (The lead market and the foreign market are the same in size, $N = M = 300\,000$)

Firm 1 enters at period:	4 → 3	3 → 2	2 → 1	1**			
Firm 2 enters at period:	4	4 → 3	3 → 2	2 → 1**			
NPV for firm 1	114,455	119,286	114,395	118,637	114,102	117,889	113,596**
NPV for firm 2	114,455	109,610	114,395	109,900	114,102	109,847	113,596**

** Nash equilibrium: period 1 (sprinkler strategy) is the result of competitive behavior.

\$109 847. Since the firms are symmetric, this is true with respect to firm 1 as well.

Is the result of this process always a sprinkler strategy? The answer is negative, as can be seen

in the second case summarized in Table 3. In this case, the foreign market potential is reduced to 100 000. In Table 3 we observe that the Nash equilibrium calls for both players to enter in

Table 3

Net present values of noncoordinated entry into the foreign market. (The foreign market is smaller than the lead market, $N = 300\,000$ and $M = 100\,000$)

Firm 1 enters at period:	4 → 3	3 → 2	2** ← 1	1			
Firm 2 enters at period:	4	4 → 3	3 → 2**	2 ← 1			
NPV for firm 1	64,984	65,418	63,788	63,932	62,420**	62,311	60,880
NPV for firm 2	64,984	63,369	63,788	62,290	62,420**	61,002	60,880

** Nash equilibrium: period 2 (waterfall strategy) is the result of competitive behavior when the foreign market is smaller than the lead market.

period 2. If firm 1, for example, enters earlier, given that the opponent remains at his/her equilibrium time, then his/her NPV is reduced to \$62311. Thus they have no incentive to play different and $T^* = T_1 = T_2 = 2$ is their equilibrium time. They, therefore, follow the waterfall strategy. Note that this does not need coordination at all. It is sustainable by the fact that it is in each player's best interest to enter at period 2.

The results for Proposition 4 clearly demonstrate that even in the presence of competitive pressure the sprinkler strategy is not always the optimal strategy.

4. Conditions favoring a waterfall strategy

Proposition 4 states that it is not always optimal for a multinational firm to follow a sprinkler strategy in response to global competition. That is, under certain conditions it may be profitable for the firm to follow a waterfall strategy rather than a sprinkler strategy. Under what conditions should a multinational firm choose a waterfall strategy over sprinkler strategy? Assuming that the multinational is not constrained by supply-side considerations (i.e., considerations concerning the production and the distribution of the product), Table 4 lists such *market* conditions that pertain to the nature of the product, cost conditions, the foreign market, and competition.

In order to obtain these conditions, numerical results were derived by assuming various relation-

ships among the parameters of the competitive diffusion model, Eqs. (5)–(8). These relationships are also summarized in Table 4 and elaborated below.

For all these conditions, we obtained results similar to the result depicted in Table 3. That is, the Nash equilibrium of the noncoordinated game yielded a waterfall pattern, i.e., T_1^* and T_2^* are positive. Thus, the waterfall strategy is optimal under the following conditions:

4.1. The life cycle of the product is long

In this case, the lead effect will have a larger impact and the result will be delayed entry. The shorter the life cycle, the less the incentive to delay entry. In a Bass framework, the time \bar{T} needed to reach a given level of penetration \bar{F} is given by

$$\bar{T} = [1/(a + b)] \ln[(1 - \bar{F})/(1 + \bar{F}b/a)].$$

Thus if we increase a and b proportionally, so that b/a remains constant, the life cycle, \bar{T} , is inversely related to $a + b$. Hence the higher $a + b$, the less time it takes to reach a given level of penetration. Thus in a long life cycle we reduce the coefficients of innovation (a and α) and imitation (b and β) proportionally. Waterfall strategy ($T^* = 2$) begins to be the equilibrium when we lower these parameters by more than 48 percent ($a = \alpha < 0.00052$, $b = \beta < 0.312$). When these parameters are lowered more than 64 percent, the Nash equilibrium is obtained at period 3 or later.

Table 4
Market conditions favoring waterfall over sprinkler strategy

Conditions favoring waterfall strategies	Relationships among parameters of the competitive diffusion model
1. <i>Very long life cycle of the product</i>	Small diffusion parameters $\alpha + \beta$
2. <i>Unfavorable conditions in the foreign market</i>	
2a. Small foreign market (vs. home market)	$M < N$
2b. Slow growth in the foreign market (vs. home market)	$\beta < b$
2c. Low innovativeness in the foreign market	$\alpha < a$
2d. High fixed cost of entry into the foreign market	relatively high rF
3. <i>Weak competitiveness of the foreign market</i>	
3a. Very weak competitors in the foreign market	$\alpha_2 < \alpha_1, \beta_2 < \beta_1$
3b. Cooperative behavior among competitors	$T_1 = T_2 = T^c$
3c. No competitors in the foreign market	$\alpha_2 = \beta_2 = \delta_2 = 0$

4.2. Less favorable conditions in the foreign market

These conditions can be grouped into the following three categories.

4.2a. Small foreign market:

In this case the lead effect will be greater than when the market potential is large. The two players will therefore find it unilaterally advantageous to delay entry.

Numerically, we set M to be smaller than N ($M < N = 300\,000$). When $M > 113\,000$ the sprinkler strategy is still optimal. When $95\,000 < M < 113\,000$, the Nash equilibrium is obtained when both competitors enter at period 2 (the waterfall strategy). When $M < 95\,000$ the Nash equilibrium is obtained at period 3, or later. An example of setting $M = 100\,000$ can be found in Table 3.

4.2b. Slow growth in the foreign market:

In this case, the lead effect will have a large impact as compared to the fast-growth case. This higher impact will cause a delayed entry. Growth is largely effected by the coefficient of imitation.

Thus the coefficient of imitation (β) in the second market is small relative to that of the lead market ($\beta < b = 0.6$). When we set $\beta < 0.333$, the optimal strategy is no longer the sprinkler strategy, because the Nash equilibrium is obtained at period 2 (or later).

4.2c. Low innovativeness in the foreign market:

This could be the result of a number of factors such as conservativeness of consumers, restriction on advertising, or local protection on imports. The lead effect will counteract this low innovativeness but it requires delaying entry. Thus we decrease the coefficient of innovation in the foreign market. The sprinkler strategy is still optimal when $\alpha > 0.00002$, but for smaller values of α , the Nash equilibrium is obtained when the competitors delay entry (the waterfall strategy).

4.2d. High fixed costs of entry into the foreign market:

As shown in Proposition 2, the waterfall strategy is preferred if the cost of entry is relatively high. If the costs are excessive the firm may give

up its planned expansion into foreign markets altogether.

4.3. Weak competitiveness of the foreign market

This case can be further categorized as follows.

4.3a. Weak competitors:

In this case, if the firm enters late, the threat of a competitor preempting and entering earlier is a small, since the competitor's growth will be small and few consumers will be lost. Thus we set α_2 and β_2 to be small and solve for the nonsymmetric Nash equilibrium. For example, when $\alpha_2 = 0.0005$ and $\beta_2 = 0.05$ the equilibrium occurs at $T_1 = 2$ and $T_2 = 3$.

4.3b. Cooperative competitors:

As we have shown in the previous section, coordination of entry will lead to a waterfall strategy, provided the lead parameter is large relative to the fixed cost and cost of capital (see Table 1).

4.3c. Monopoly position in the foreign market:

This is the extreme case of category 4.3a, and if the firm enters late it will not suffer any loss of customers, as the latter do not have the choice of adopting a competing brand. This might be true with respect to certain patented products in which the firm has been enjoying a monopoly position for an extended period of time. Even in this case, the knowledge that the patent's lifetime is limited and that competitors may succeed in legally coming up with an almost identical product will considerably shorten the lead time of this strategy.

5. Discussion and conclusions

In this paper we have demonstrated that global competition does not always force a multinational firm to introduce a new product simultaneously in all its markets. Although diffusion dynamics (the lead effect), economic factors (fixed costs of introduction), and competitive forces influence the choice of either a waterfall or sprinkler strat-

egy, when all these effects are present, under certain market conditions, a multinational firm may choose to follow a waterfall strategy rather than a sprinkler strategy. These conditions pertain to the nature of the product, the market, cost conditions, and the competition. A multinational firm is shown to prefer the waterfall strategy if: (1) the product has a very long life cycle, (2) the foreign market, as compared to the home (domestic) market, is small, (3) the foreign market is characterized by a slow growth rate, (4) the foreign market is not innovative, (5) there are weak competitors in the foreign market, (6) competitors engage in collusive behavior, and (7) the firm enjoys a monopoly position in the foreign market.

It may be argued that most of these conditions do not hold in today's global marketplace. Very few firms can really attain absolute monopoly power in their global markets or count on "gentlemanly" behavior from their competitors (see, e.g., Green and Larsen (1987) for issues related to the behavior of Japanese firms in the U.S. or in other global markets). Planning a global roll-over based on the assumption that foreign competitors are very weak is myopic (as has been proved by several foreign competitors in the U.S. automobile market). Although some foreign markets may be small, and cost of entry high, the trend towards the integration of markets, such as the planned unification of Western Europe (N.N. in Fortune, 1992a, b) make more non-American markets attractive for a sprinkler entry. Finally, the emergence of global consumers, a growing trend towards shorter product life cycles (see, e.g., Olshavsky, 1980) and increased world pressure for less trade barriers, as well as other factors that might lead to less innovative markets (such as, the recent pressure from the U.S. on Brazil, India, and Japan for less trade barriers) make the conditions for delayed entry (i.e., the waterfall strategy) less likely. The market conditions thus, in general, seem to favor a sprinkler rather than a waterfall strategy.

One of the competition variables that we have not included in our analysis is price. Price may influence the diffusion process either via its effect on the market potential or its effect in the growth

parameters (see Dolan et al., 1986). Based on recent empirical evidence of Jain and Rao (1990), we have chosen to model the price effect on the growth parameters of the diffusion process.

For the monopoly market structure, the new equations describing the growth of the product in the home (lead) market and foreign market are given by

$$dx/dt = (a + bx/N)(N - x) e^{-\epsilon_x P_x} \quad (12)$$

$$dy/dt = (\alpha + \beta y/M + \delta x/N) \times (M - y) e^{-\epsilon_y P_y} u(t) \quad (13)$$

where P_x and P_y are the price of the product in the home and foreign market, respectively. ϵ_x and ϵ_y are the price elasticities of demand in the home and foreign markets, divided by the respective prices (for the function $e^{-\epsilon P}$, the price elasticity of demand is ϵP).

In Appendix 4 we show that for the monopoly case, incorporation of price results in replication of Proposition 1, mutatis mutandis. A similar proof is available from the authors for replication of Proposition 2 when price is incorporated into the competitive market structure.

We can thus conclude that our main results hold when the price variable is included in the diffusion process in both monopoly and competitive market structure.

When dealing with a specific product one could ask the following question: Does this general recommendation fit all product categories? The answer relies on the categorization of Williams (1992), who classifies products according to their scope of resource imitation pace:

Class 1: Slow cycle resources: These are products that are strongly shielded from competitive pressures.

Class 2: Standard cycle resources: Products in this class face higher resource imitation pressures.

Class 3: Fast cycle resources: These are idea driven products that face the highest degree of resource imitation.

The conditions specified in Section 4 favoring waterfall strategies seem to fall exactly in the class 1 category where the life cycle is long, product category is not too innovative, and com-

petitive pressure is low. As we move into class 2 and class 3 categories, the recommendation is reversed, and sprinkler strategy becomes the optimal strategy.

Finally, some real-life support for our findings can be found in Riesenbeck and Freeling (1991), who present several examples to demonstrate the superiority of the sprinkler model in present-day competitive environment such as Mars Ice Cream bar, Unilever's Timotei shampoo, P&G's Vidal Sassoon Wash and Go, and others, clearly all fast cycle (class 3) products.

Appendix 1

Proof of Proposition 1:

The objective function of the monopolist is:

$$\pi = \int_0^{\bar{T}} (g\dot{x} + h\dot{y} - rFu) e^{-rt} dt. \tag{1.1}$$

The current value Hamiltonian is therefore:

$$H = g\dot{x} + h\dot{y} - rFu + \lambda\dot{x} + \mu\dot{y} \tag{1.2}$$

where λ and μ are the current value multipliers of x and y , respectively.

$$\begin{aligned} \partial H/\partial u &= (\alpha + \beta y/M + \delta x/N)(M - y) \\ &\quad \times (h + \mu) - rF, \end{aligned} \tag{1.3}$$

$$\partial H/\partial u > 0 \text{ implies } u = 1, \tag{1.4}$$

$$\partial H/\partial u < 0 \text{ implies } u = 0,$$

and

$$\dot{\mu} = -(h + \mu)uA + r\mu, \quad \mu(\bar{T}) = 0 \tag{1.5}$$

where

$$A = \beta - \alpha - 2\beta y/M - \delta x/N. \tag{1.6}$$

a) At time $t = 0$, $\partial H/\partial u = \alpha M(h + \mu(0)) - rF$, and thus according to (1.4), if $\alpha M(h + \mu(0)) - rF > 0$ the firm is better off introducing the product at $t = 0$.

b) If $u = 0$ for all $0 < t < \bar{T}$, and at \bar{T} $\partial H/\partial u = (\alpha + \delta x(\bar{T})/N)Mh - rF < 0$ then at no intermediate time period is $\partial H/\partial u$ nonnegative, and thus the firm is better off not introducing the product. Since $x(\bar{T}) < N$ it follows that $(\alpha + \delta x(\bar{T})/N)Mh - rF < (\alpha + \delta)Mh - rF$. Thus it

is enough to require that the right-hand side of this last inequality be negative for this case to hold.

c) If the condition specified in case b) above is not satisfied, then for some $T < \bar{T}$ the following holds: $\partial H/\partial u = (\alpha + \delta x(T)/N)M(h + \mu(T)) - rF = 0$. At this time T the firm sets $u = 1$ and introduces the product. Formally, we should also check whether the firm could withdraw the product before \bar{T} . This could happen under the following circumstances. Since we did not assume any salvage value to the firm, if \bar{T} is long enough so that $M - y$ is negligible, it is worthwhile for the firm to withdraw the product. Since this is an artifact of our formulation of the fixed costs as periodic payment of rF , we assume that this does not happen by requiring that in case c) \bar{T} is not long enough for it to happen.

Appendix 2

Proof of Proposition 2:

Each player i maximizes his/her own objective function (9) subject to Eqs. (4) through (7). The current value Hamiltonian of player 1, and similarly for player 2, is given by

$$H_1 = g_1\dot{x}_1 + h_1\dot{y}_1 - rF_1u_1 + \lambda_1\dot{x}_1 + \mu_1\dot{y}_1 + \lambda_{12}\dot{y}_2 \tag{2.1}$$

where λ_1 and μ_1 are the multipliers of x_1 and y_1 , and λ_{12} is the multiplier (i.e., shadow price) of y_2 to player 1.

$$\begin{aligned} \partial H_1/\partial u_1 &= (\alpha_1 + \beta_1 y_1/M + \delta_1 x_1/N)(M - y_1) \\ &\quad \times (h_1 + \mu_1) - rF_1, \end{aligned} \tag{2.2}$$

$$\partial H_1/\partial u_1 > 0 \text{ implies } u = 1, \tag{2.3}$$

$$\partial H_1/\partial u_1 < 0 \text{ implies } u = 0,$$

$$\dot{\mu}_1 = (h_1 + \mu_1)u_1A_1 + r\mu_1 + \lambda_{12}B_2u_2, \tag{2.4}$$

$$\dot{\lambda}_{12} = (h_1 + \mu_1)B_1u_1 - \lambda_{12}A_2u_1 + r\lambda_{12}, \tag{2.5}$$

$$A_i = \beta_i - \alpha_i - 2\beta_i y_i/M - \delta_i x_i/N - \beta_i y_j/M, \tag{2.6}$$

$$B_i = \alpha_i + \beta_i y_i/M + \delta_i x_i/N, \tag{2.7}$$

$$\mu_1(\bar{T}) = \lambda_{12}(\bar{T}) = 0.$$

Mutatis mutandis, the three cases now follow the corresponding cases of Appendix 1.

Appendix 3

Proof of Proposition 3:

When the parameters of the two players are identical, the common Nash equilibrium of the noncooperative game T^* is the solution to the following equation:

$$rF_1 = M(\alpha_1 + \delta_1 x_1(T^*)/N)(h_1 + \mu_1(T^*)). \tag{3.1}$$

(The same solution of T^* will be achieved from the equation for the second player, as the parameters are identical.)

The cooperative game is set by letting $u_1 = u_2$, i.e., agreeing to enter at precisely the same time, and solving for the optimal entry time. The Hamiltonian of the first player is

$$\begin{aligned} H &= g_1 \dot{x}_1 + h_1 \dot{y}_1 - rF_1 u_1 + \lambda_1 \dot{x}_1 + \mu_1 \dot{y}_1 + \lambda_{12} \\ &\quad \times (\alpha_2 + \beta_2 y_2/M + \delta_2 x_2/N) \\ &\quad \times (M - y_1 - y_2) u_1. \\ \partial H_1 / \partial u_1 &= (\alpha_1 + \beta_1 y_1/M + \delta_1 x_1/N)(M - y_1) \\ &\quad \times (h_1 + \mu_1) - rF + \lambda_{12} \\ &\quad \times (\alpha_2 + \beta_2 y_2/M + \delta_2 x_2/N) \\ &\quad \times (M - y_1 - y_2), \end{aligned} \tag{3.2}$$

$$\partial H_1 / \partial u_1 > 0 \text{ implies } u = 1, \tag{3.3}$$

$$\partial H_1 / \partial u_1 < 0 \text{ implies } u = 0,$$

$$\dot{\mu}_1 = (h_1 + \mu_1) u_1 A_1 + r\mu_1 + \lambda_{12} B_2 u_2, \tag{3.4}$$

$$\dot{\lambda}_{12} = (h_1 + \mu_1) u_1 B_1 - \lambda_{12} A_2 u_1 + r\lambda_{12} \tag{3.5}$$

where

$$A_i = \beta_i - \alpha_i - 2\beta_i y_i/M - \delta_i x_i/N - \beta_i y_j/M, \tag{3.6}$$

$$B_i = \alpha_i + \beta_i y_i/M + \delta_i x_i/N, \tag{3.7}$$

$$\mu_1(\bar{T}) = \lambda_{12}(\bar{T}) = 0. \tag{3.8}$$

In both cases, initially the u_i are set to zero, until the time that $\partial H_i / \partial u_i$ vanishes. Thus, since $y_i = 0$

for this period, T^c , the solution of the cooperative game is given by

$$\begin{aligned} rF &= M(\alpha_1 + \delta_1 x_1(T^c)/N)(h_1 + \mu_1(T^c)) \\ &\quad + \lambda_{12}(\alpha_2 + \delta_2 x_2(\bar{T})/N)M. \end{aligned} \tag{3.9}$$

In the next paragraph, we will show that $\lambda_{12}(t) < 0$ for all $t < \bar{T}$. Under this condition the following argument holds. The systems of boundary value differential equations for λ_i , λ_{12} , μ_i , and x_i (Eqs. (4)–(7), (2.4)–(2.7) and (3.4)–(3.7)) are identical, with the same boundary conditions $x_i(0) = y_i(0) = 0$ and $\lambda_i(\bar{T}) = \lambda_{ij}(\bar{T}) = \mu_i(\bar{T}) = 0$. Thus if T^* that satisfies (3.1) is plugged into (3.2), because of the negative value of λ_{12} , $\partial H_1 / \partial u_1$ of (3.2) will still be negative. Thus $\partial H_1 / \partial u_1$ of the cooperative game vanishes *after* $\partial H_1 / \partial u_1$ of the noncooperative game (both start out negative). Thus $T^* < T^c$ as claimed.

It remains to be shown that $\lambda_{12}(t) < 0$ for all $t < \bar{T}$. The differential equation for $\lambda_{12}(t)$ is given by Eq. (3.5), with boundary condition $\lambda_{12}(\bar{T}) = 0$. At \bar{T} , $\dot{\lambda}_{12}(\bar{T}) = h_1 B_1 > 0$. Thus for t in the neighborhood of \bar{T} , λ_{12} is negative. If it ever vanishes *before* \bar{T} , then at the last time that it does so, its derivative must be negative, by continuity. We will show a contradiction and therefore λ_{12} does not vanish before \bar{T} , and therefore $\lambda_{12}(t) < 0$ for all $t < \bar{T}$. If λ_{12} vanishes before \bar{T} , then at this time either $u_1 = 1$ or $u_1 = 0$. If it is zero then $\dot{\lambda}_{12} = 0$ at this point, which is a contradiction. If it is one, then necessarily $\partial H_1 / \partial u_1 > 0$ at this time. Since at this time $\lambda_{12} = 0$ (by assumption) $\partial H_1 / \partial u_1$ is given by

$$\partial H_1 / \partial u_1 = M(\alpha_1 + \delta_1 x_1/N)(h_1 + \mu_1) - rF_1.$$

The fact that it is positive implies the positivity of $h_1 + \mu_1$ at this point of time. Thus $\dot{\lambda}_{12} = (h_1 + \mu_1) B_1 > 0$, which is a contradiction.

Appendix 4

Proof of the equivalent of Proposition 1 with optimal prices:

The dynamic equations describing the growth of the product on the home country and in the

foreign country are given in Eq. (12) and (13), respectively.

The monopolist maximizes net present value given by:

$$\pi = \int_0^T \{(P_x - c_x)\dot{x} + (P_y - c_y)\dot{y} - rFu\} e^{-rt} dt \quad (4.1)$$

where P_x and c_x are the price and marginal cost of the product in the home country and P_y and c_y those in the foreign country.

The Hamiltonian is given by

$$H = (P_x - c_x + \lambda)\dot{x} + (P_y - c_y + \mu)\dot{y} - rFu. \quad (4.2)$$

Differentiating the Hamiltonian with respect to P_x and P_y and rearranging terms, one arrives at the following familiar equations for the optimal prices:

$$P_x - c_x + \lambda = 1/\epsilon_x, \quad (4.3)$$

$$P_y - c_y + \mu = 1/\epsilon_y. \quad (4.4)$$

Differentiation of the Hamiltonian with respect to y and substitution of Eq. (4.4) result in the following:

$$\dot{\mu} = -uA(1/\epsilon_y) + r\mu, \quad \mu(\bar{T}) = 0 \quad (4.5)$$

where A follows:

$$A = (\beta - \alpha - 2\beta y/M - \delta x/N) e^{-\epsilon_y P_y}. \quad (4.6)$$

Differentiation with respect to $u(t)$ yields

$$\partial H/\partial u = (\alpha + \beta y/M + \delta x/N)(M - y) \times (P_y - c_y + \mu) e^{-\epsilon_y P_y} - rF \quad (4.7)$$

and

$$\partial H/\partial u > 0 \quad \text{implies} \quad u(t) = 1,$$

$$\partial H/\partial u < 0 \quad \text{implies} \quad u(t) = 0.$$

The three cases of Appendix 1, mutatis mutandis, will prove the following proposition:

Proposition 1'. The timing decision of the monopolist is characterized by the following three cases:

a) For small values of fixed cost, i.e., when $rf < \alpha M(1/\epsilon_y) e^{-\epsilon_y P_y(0)}$, the firm introduces the product into the foreign market right away at $T = 0$.

b) For large values of fixed cost, i.e., when $rf > (\alpha + \delta)M(1/\epsilon_y) e^{-\epsilon_y P_y(T)}$, the firm delays introduction of the product into the foreign market indefinitely.

c) For intermediate values of fixed cost introduction time is given by:

$$rF = (\alpha + \delta x(T)/N)M(1/\epsilon_y) e^{-\epsilon_y P_y(T)}. \quad (4.8)$$

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