A Dynamic Model of Competitive Entry Response*

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Abstract

This paper develops a dynamic game in which an incumbent and an entrant can each invest in a new technology. The entrant can also invest in the old technology. Contrary to results from previous research, I show that an increase in the probability of successfully implementing a technology can cause the incumbent to *reduce* its investment. If the success probability is high, the incumbent allows the entrant to win the new technology so that the industry reaches a collusive equilibrium in which neither firm attacks the other due to fears of retaliation. However, if the success probability is low, such a collusive arrangement cannot be sustained, and in the long run both firms implement both technologies.

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1 Introduction

The question of why incumbents often fail to invest in new technologies or business models that threaten their existing business has attracted a lot of recent attention from popular and academic business press (e.g., Christensen 1997; Chandy and Tellis 1998, 2000). Classic results from economic theory show that an incumbent has *stronger* incentives to innovate than an entrant when the innovation process is deterministic (Gilbert and Newbery 1982), but *weaker* incentives to innovate when the innovation process is stochastic (Reinganum 1983). This paper derives boundary conditions in which these previous theoretical results hold, but also shows that if these boundary conditions fail then these previous results are reversed. In particular, I develop a model of dynamic competition in which an increase in the probability of successful innovation can cause an incumbent to avoid investing in a new technology.

The current paper differs from the previous work cited above in two key respects. First, I allow for the possibility that both firms implement a particular technology, which can happen in markets where patent protection and other preemption effects are relatively weak. Second, in order to allow for reactions and counter-reactions in investment decisions, I apply the methodology of dynamic investment games (e.g., Budd et al. 1993; Ericson and Pakes 1995; Hörner 2004) to the problem of competitive entry response. Whereas the previous dynamic investment game literature has focused primarily on competition along a single dimension, I allow firms to invest in two competing business "formats." A format could represent a particular technology or, more generally, an overall approach for conducting business. For example, one format might represent traditional bricks-and-mortar retailing, while the other represents Internet retailing.

The model assumes an incumbent using an old business format faces competition from a new entrant. Both firms can invest in a new format that has become available due to exogenous technological progress or changes in customer preferences. A single firm can potentially use both formats, for example, it can sell a product through traditional retail stores and over the Internet. In each period, a firm has a stochastic probability of successfully implementing a format in which it makes positive investment. If a firm's investment is not successful in a given period, it can try again in the following period. Once a firm's investment in a format succeeds, it continues using this format in all subsequent periods.

This model is simple enough to be analytically tractable, and yet flexible enough to generate a rich variety of competitive interactions. In some cases the incumbent's successful investment in the new format deters the entrant from making any investment at all, but in other cases it provokes the entrant to retaliate by investing in the old format. By varying the parameter values of the model, I derive equilibrium strategies for each firm under both of these scenarios.

The three key factors that determine equilibrium investment behavior are: (1) the strength of preemption effects (the extent to which one firm's implementation of a format make it less profitable for the other firm to implement this format); (2) the strength of cannibalization effects (the extent to which a firm's implementation of an additional format mostly just steals customers from its existing format, as opposed to attracting new customers); and (3) the difficulty of implementing a format (reflected in the probability that a firm that invests in a format will fail at an operational level to implement this format).

When preemption and cannibalization effects are strong, the incumbent faces a dilemma. Implementing the new format cannibalizes its existing sales, but also deters the entrant from investing. Consistent with results from Reinganum (1983), the incumbent is only willing to make such an investment if the probability of successfully implementing a format in a given period is high, which implies that the entrant poses an imminent threat that the incumbent has a strong incentive to deter.

On the other hand, if preemption and cannibalization effects are weak, the incumbent faces a different type of dilemma. Implementing the new format expands its sales but also risks provoking the entrant to retaliate by investing in the old format. In this case, in markets where the probability of successfully implementing a format in a given period is high, the incumbent allows the entrant to win the new format; this strategy enables the firms to reach a collusive equilibrium in which they use different formats and neither firm attacks the other due to fears of quick retaliation. However, in markets where the probability of successful implementation is low, such a collusive arrangement is impossible to sustain because a firm cannot quickly retaliate against a successful attack; in this case, the only long-run equilibrium is for both firms to implement both formats. Thus, when preemption and cannibalization effects are weak, contrary to the results from Reinganum (1983), the incumbent's investment in the new format increases when the probability of success is *low*.[1]

As an example in which the entrant has implemented the new format and the threat of retaliation has compelled firms to stay focused on different formats, consider the package shipping industry. When FedEx first entered the market as an overnight delivery company with its own fleet of airplanes, the incumbent UPS continued to focus on its traditional business of ground-based transportation (Crowder 1996). Buying additional trucks or airplanes is, though capital intensive, a relatively straightforward investment, in the sense that if a company decides to makes these investments there is little uncertainty over whether it will acquire the vehicles it decides to purchase. We might expect that this ease of implementation would encourage firms to expand into multiple formats, but in fact UPS continues to focus

[1] Although I focus on the cases when preemption and cannibalization effects are either both strong or both weak (which are the most interesting cases), section 3.3 discusses what happens in the model when one effect is strong and the other is weak.

heavily on ground transportation, while FedEx focuses heavily on air transportation (Darell 2011).

Each firm's capacity for swift retaliation plays a key role in sustaining this arrangement. For instance, in 2001 UPS spent \$6 billion to purchase 60 cargo aircraft; that same year FedEx retaliated by investing \$4 billion in trucks and a distribution center for ground transportation. Both investments were successes in the operational sense, but they led to heightened competition that was damaging to both companies (Composit 2004). After this brief experiment with attacking each other's format, the companies have returned to staying focused on different formats. UPS continues to own far more trucks than FedEx, while FedEx owns far more airplanes than UPS (Darell 2011).

The current paper provides insight into why this industry has evolved in this manner. Given the possibility of swift retaliation to an attack on a competitor's format, the model implies that early on UPS made the right decision by staying out of air transportation. This decision has allowed the industry to reach a point where the firms focus on different formats, both firms are profitable, and neither wants to attack the other's format.

On the other hand, as an example in which firms have implemented multiple formats, consider the airline industry. When traditional full service airlines like American Airlines and British Airways first faced competition from discount airlines like Southwest and EasyJet, the traditional airlines found it difficult to imitate the cost-savings measures of these new low-price rivals. Changing the culture of an airline so that employees are more efficient (on one hand) or better at providing customer service (on the other hand) is a major organizational challenge (Sanchez 1994). Nonetheless, over time the traditional airlines have stopped offering free meals and checked bags, and successfully implemented many of the other cost-saving measures of the discount airlines (Moreno 2010), while the discount airlines have added additional routes, improved customer service, and offered optional services such as early boarding to attract business passengers (Cowell 2002). The prices set by the two types of airlines have converged to the point that Southwest, for example, can no longer be considered a discount airline (McCartney 2011). Both types of airlines now offer an efficient, "no-frills" level of service and better service at a higher price.

The current paper provides insight into why this has occurred. Because the probability of successfully implementing a new airline format in any given period is low, a firm cannot quickly retaliate against a successful attack on its format. Therefore, in the long run firms have reached an equilibrium in which both types, after years of investment, have successfully attacked each other's format.

Section 2 discusses related literature. Section 3 presents the formal model and results. Section 4 presents two model extensions that study asymmetric formats. Section 5 concludes.

2 Related Literature

Previous research has derived conditions in which multi-market contact helps firms collude in prices (Bernheim and Whinston 1990). By contrast, the current paper derives conditions in which such contact helps firms collude in investment decisions. I show that preemption and cannibalization effects must be weak in order for collusion to be necessary, and implementing a format must be easy in order for collusion to be possible. I also show that multi-format contact creates an asymmetry in the investment incentives of an incumbent and an entrant. In situations where collusion is sustainable, the entrant invests heavily in the new format, but the incumbent invests nothing, allowing the entrant to win the new format so that the industry reaches a collusive equilibrium.

Literature in strategy and marketing has also studied conditions in which multi-market contact leads to collusion (Karnani and Wernerfelt 1985; Bronnenberg 2008). As noted above, the current paper differs in that it shows how preemption effects, cannibalization effects, and the difficulty of implementing a format determine whether collusion is sustainable, and in that it explores differences between investment incentives of incumbents and entrants that can compete using multiple formats.

Fudenberg and Tirole (1984) use a two-period model with investment along a single dimension to derive conditions in which an incumbent underinvests in order to deter or accommodate entry. By using an infinite-period model with investment along two dimensions, the current paper derives a new reason for underinvestment. In particular, in some cases the incumbent underinvests in the new format (relative to the monopoly case and relative to what it would invest if it did not account for competitive reaction) so that the industry reaches a collusive equilibrium in which firms stay permanently focused on different formats.

Another related stream of research has developed dynamic investment models in which there are increasing returns (Athey and Schmutzler 2001; Rob and Fishman 2005), which implies that firms invest more in areas of current strength than in areas of current weakness (Selove 2010). By contrast, the current paper does not rely on increasing returns. Instead, concerns over cannibalization and competitive retaliation compel firms to stay focused.

Previous theoretical literature in marketing has studied optimal defensive strategies (Hauser and Shugan 1983; Purohit 1994; Kalra, Rajiv, and Srinivasan 1998; Balasubramanian 1998) and entry strategies (Carpenter and Nakamoto 1990; Narasimhan and Zhang 2000; Joshi, Reibstein, and Zhang 2011). The current paper contributes to this literature by incorporating competition between an entrant and an incumbent into a dynamic investment game in which firms make repeated investments over multiple time periods. Because successful investment can lead to a series of reactions and counter-reactions, this model generates new insights into how threats of strategic retaliation influence investment behavior.

Empirical literature has studied factors that determine whether incumbents invest in new technologies (e.g., Christensen 1997; Chandy and Tellis 1998, 2000; Debruyne and Reibstein 2005) or lower-cost business formats (e.g., Ritson 2009). These papers have identified concerns over cannibalization and preemption as key factors that determine whether firms adopt new technologies, and whether defensive strategies are successful. This paper uses a formal game-theoretic model to clarify how these factors determine firms' optimal investment strategies.

This paper is also related to literature on structural estimation methods that assume firms play a Markov Perfect Equilibrium (e.g., Dubé, Hitsch, and Manchanda 2005; Bajari, Benkard, and Levin 2007; Dubé, Hitsch, and Chintagunta 2010; Ellickson, Misra, and Nair 2011; Goettler and Gordon 2011; Ryan 2011; Yao and Mela 2011). Whereas this previous research stream relies on numerical estimation procedures, the current paper provides a detailed analytical characterization of equilibrium behavior. Another important difference is that I allow for investment on multiple dimensions, introducing the possibility of cannibalization, which is an important driver of the results in this paper.

3 Model

Assume two firms, indexed by $i \in \{A, B\}$, compete using two different business formats, indexed by $j \in \{1, 2\}$. At any time t, the state of firms' assets is denoted by

$X_t = (X_{A,1,t}, X_{A,2,t}; X_{B,1,t}, X_{B,2,t})$, where:

$$X_{i,j,t} = \begin{cases} 1 & \text{if firm } i \text{ uses format } j \text{ at time } t \\ 0 & \text{otherwise} \end{cases}$$

Intuitively, this variable indicates whether a firm has successfully made the necessary investments in physical capital, human resources, and other areas to serve customers using a particular format. Restricting each firm's success in a given format to two states helps keep the analysis tractable and clear, while still making the model rich enough to illustrate the key ideas of the paper. The conclusion of the paper discusses how the model would change if we allowed more states.

The game begins in state $(1, 0; 0, 0)$. That is, firm A (the incumbent) initially uses only format 1, and firm B (the entrant) initially does not use either format. Once a firm implements a format, it always uses this format, that is, if $X_{i,j,t-1} = 1$, then $X_{i,j,t} = 1$.[2] If firm i has not yet implemented format j, then the probability that it will successfully implement this format in the current period is given by:

$$P(X_{i,j,t} = 1 | X_{i,j,t-1} = 0; e_{i,j,t}) = F(e_{i,j,t})$$

where $e_{i,j,t}$ is the amount firm i invests in format j at time t. I assume $F(0) = 0$, $F' > 0$, $F'' < 0$, and $F'(0)$ is finite. This is similar to the R&D success function used by Fudenberg and Tirole (1984), except that I assume $F'(0)$ is finite, so that in some cases a firm might want to invest nothing.

I also make two simplifying assumptions that make analysis of this dynamic

[2]If a firm could stop using a format it has implemented, while still retaining the ability to use this format, in some cases this would make collusion easier to sustain. The assumption used here is reasonable if a firm needs to keep using a format in order to retain the ability to do so (for example, so its employees retain their skills). Also, for some profit functions, conditional on both firms having incurred the sunk costs of implementing both formats, collusion would not be sustainable even if each firm could quickly stop and re-start the use of a format. In such cases, allowing firms to stop using a format would not significantly affect the results in this paper.

investment game more tractable. First, I assume a firm cannot simultaneously invest in both formats in a given period, that is, at any time t each firm i's investment is subject to the constraint $\min\{e_{i,1,t}; e_{i,2,t}\} = 0$. Intuitively, due to limitations on managerial time and attention or other internal resource constraints, there are often diseconomies of scope to investment during a given time period. Limiting the firm to investing in at most one format is one way to operationalize diseconomies of scope while also helping to make the model more tractable. I also assume that firms alternate their investments, so firm A only invests in odd-numbered periods and firm B only invests in even-numbered periods. This avoids the need to worry about "ties" in which both firms simultaneously succeed in adopting a format. For another example of a dynamic model in which firms alternate moves, see Maskin and Tirole (1988). None of the results in the current paper depend on which firm moves first. Assuming that in each period a single firm moves and can only invest in a single format makes it possible to derive clear analytical results, but in principle either or both of these assumptions could be relaxed without substantially changing my results.

Let $\pi^A_{(X_t)}$ and $\pi^B_{(X_t)}$ represents firm A's profits and firm B's profits, respectively, as a function of the current state X_t. I assume the profit functions are symmetric across firms, for example, $\pi^A_{(1,1;1,0)} = \pi^B_{(1,0;1,1)}$. I initially assume the profit functions are also symmetric across formats, for example, $\pi^B_{(1,1;0,1)} = \pi^B_{(1,1;1,0)}$. I later relax the latter assumption and present a model extension in which there is a fixed expense associated with operating the old format which is not associated with the new format (for example, physical retail space which is not needed by online retailers); and another model extension in which either firm's use of the new format makes the old format unprofitable for both firms (for example, in some markets online retailing creates severe channel conflict by free-riding on customer service from physical retail locations).

Each firm has discount factor δ and maximizes expected discounted profits. Firm A's objective is to maximize:

$$E\left[\sum_{t=0}^{\infty} \delta^t \pi^A_{(X_t)}\right] \tag{1}$$

Firm B's has an analogous objective function.

I assume firms play a Markov perfect equilibrium (MPE) of this dynamic investment game. The restriction to MPE is important in that it implies a firm can only retaliate in response to a change in the game's state, that is, in response to its competitor's successful implementation of a format. This assumption is reasonable if each firm can keep its strategic investments a secret from competitors, so that a firm cannot immediately retaliate against a mere attempt to adopt a new format.

Table 1. Variables in the Model

$i \in \{A, B\}$	Index of firms
$j \in \{1, 2\}$	Index of formats
$t \in \{0, 1, 2, \ldots\}$	Index of time
$X_{i,j,t} \in \{0, 1\}$	Indicator of whether firm i uses format j at time t
$e_{i,j,t}$	Firm i's investment in format j at time t
$F(e_{i,j,t})$	Function that gives the probability firm i will successfully implement format j at time t
$\pi^A_{(X_t)}$	Firm A's profits as a function of the current state
$\pi^B_{(X_t)}$	Firm B's profits as a function of the current state
δ	Each firm's discount factor

3.1 Weak preemption and cannibalization effects

The nature of the profit function π plays a key role in determining equilibrium investment behavior. This function reflects the extent to which cannibalization effects compel a firm not to invest in a second format, and the extent to which preemption effects compel a firm not to invest in a format that its competitor is already using. I first focus on the case where these effects alone are not strong enough to stop firms from making investment. The next section then explores the case when these effects are strong.

I will say that a state is "stable" if neither firm invests once that state is reached. Based on the set-up of the game, state (1,1;1,1) is obviously stable. We can use backward induction to determine which other states are stable.

Consider what happens at state $(1,0;1,1)$, at which the entrant is using both formats and the incumbent is only using the old format. At this point, as the incumbent is deciding whether to invest in the new format, it faces both the problem of cannibalizing its existing sales and the problem of potentially entering a format that the entrant is already using. I will assume that neither of these effects is strong enough to stop it from investing. In particular:

$$\left(\frac{1}{1-\delta}\right)\left[\pi^{A}_{(1,1;1,1)} - \pi^{A}_{(1,0;1,1)}\right] > \frac{1}{F'(0)} \tag{2}$$

This condition ensures that the discounted gains from entering the new format are at least enough to justify investing the first marginal dollar in this format. When this condition holds, condition $(1,0;1,1)$ is not stable because the incumbent will always make positive investment at this state, and therefore the game will eventually move to state $(1,1;1,1)$, with both firms using both formats.

I assume a similar condition holds for all possible states:

Assumption 1. *For any state in which a firm is not already using both formats, the incremental per-period profits to the firm from adopting an additional format (holding constant the competitor's state) is greater than* $\frac{1-\delta}{F'(0)}$.

Appendix A presents an example of a model of product market competition that generates a profit function for each firm at each possible state. It then derives conditions in which Assumption 1 holds for this particular model of product market competition. Intuitively, this assumption implies that cannibalization and preemption effects alone cannot be enough to prevent a firm from investing.

Assumption 1 immediately implies that, once one firm has implemented both formats, the other firm will keep investing until it also has implemented both formats. In other words, states $(1,0;1,1)$, $(1,1;0,1)$, and $(1,1;0,0)$ are not stable.

I also make the following fairly innocuous assumptions.

Assumption 2. *A firm that uses neither format earns zero profits.*

Assumption 3. *Holding its own state constant, a firm's profits cannot increase as a result of its competitor implementing a new format.*

Together, Assumptions 1, 2, and 3 guarantee that the entrant invests at the initial state $(1,0;0,0)$. To see why this is true, note that Assumptions 1 and 2 guarantee that $\left(\frac{1}{1-\delta}\right)\pi^B_{(1,1;0,1)} > \frac{1}{F'(0)}$. In other words, if the incumbent is already using both formats, the entrant is willing to invest the first marginal dollar to have a chance of gaining the stream of profits it will receive from implementing the new format. Also, Assumption 3 guarantees that $\pi^B_{(1,0;0,1)} \geq \pi^B_{(1,1;0,1)}$. In other words, implementing the new format generates higher profits for the entrant if the incumbent has not yet implemented it. This implies that it is strictly superior for the entrant immediately to begin investing in the new format at the initial state rather than waiting (and continuing to earn zero profits while it waits) for the incumbent to implement the new format first.

Thus, given these assumptions the only state that could possibly be stable is $(1, 0; 0, 1)$, the state at which each firm uses a different format.[3] At this state each firm must worry that implementing a new format will lead to retaliation by its competitor.

For example, to compute how quickly firm B (the entrant) is expected to retaliate against a successful attack by firm A (the incumbent), let e^* denote firm B's optimal investment level at state $(1, 1; 0, 1)$. Because firm A no longer has any reason to invest once the game reaches this state, firm B chooses e^* by solving a simple dynamic programming problem. Intuitively, Assumption 1 guarantees that $F'(0)$ is large enough that firm B will at least want to spend the first marginal dollar to try to implement the old format. However, if F'' is very negative, then each additional dollar spent has a rapidly decreasing impact on the probability of success. In such situations, in each period the firm will simply make a small "exploratory" investment that gives it a small chance of success. For example, the firm could assign a small internal team or division to work on a project for expanding its business into an additional format, knowing that such a team has a small chance of coming up with a large breakthrough. On the other hand, if F'' is not too negative, then each incremental dollar continues to have a large impact on the success probability, so the firm will invest enough to give it a large chance of success in any given period.[4]

Imagine firm A has a choice between staying at state $(1, 0; 0; 1)$ forever, or implementing the second format and moving to state $(1, 1; 0; 1)$. This will lead to a temporary increase in firm A's profits; however, once firm B successfully retaliates the game moves to state $(1, 1; 1; 1)$, at which point increased competition in each format

[3] I do not analyze state $(1, 0; 1, 0)$. Given the assumption of symmetric formats, under most reasonable models of competition the entrant would never want to begin by attacking the incumbent's existing area of expertise. I also do not analyze state $(1, 1; 1, 0)$, as it is analogous to state $(1, 1; 0, 1)$.

[4] As a mathematical example, let $F(e) = \frac{q}{r}\ln(re + 1)$ as long as this function is less than one, and $F(e) = 1$ otherwise. The first derivative when the function is less than one is $F'(e) = \frac{q}{re+1}$. Note that $F'(0) = q$, and for all $e > 0$, $F'(e)$ becomes smaller as r grows larger. Holding q constant, as $r \to \infty$, then $e^* \to 0$ and $F(e^*) \to 0$. On the other hand, again holding q constant, if $r \to 0$ from the right, then $e^* \to \frac{1}{q}$ and $F(e^*) \to 1$.

might cause firm A's profits might drop below their initial level. When deciding whether to launch such an attack, firm A must weigh the short-term increase in profits against lower long-term profits due to increased competition:[5]

Lemma 1. *There exists an equilibrium in which state* $(1,0;0,1)$ *is stable if and only if:*

$$\left(\frac{\pi^A_{(1,1;0,1)}\big[1+\delta(1-F(e^*))\big]+[\delta/(1-\delta)]F(e^*)\pi^A_{(1,1;1,1)}}{1-\delta^2(1-F(e^*))}\right)-\left(\frac{1}{1-\delta}\right)\pi^A_{(1,0;0,1)}\leq\frac{1}{F'(0)}$$

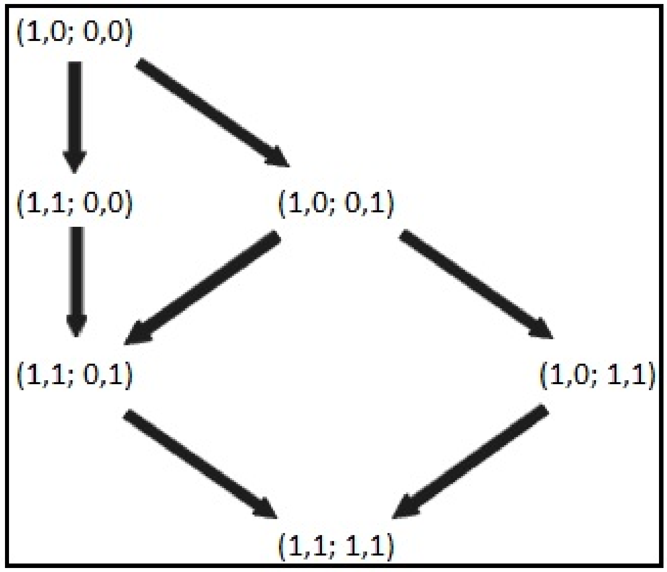
The first term on the left side of this inequality represents the expected discounted profits to firm A just after reaching state $(1,1;0,1)$, accounting for firm B's eventual retaliation; the second term represents the expected discounted profits to firm A of staying permanently at state $(1,0;0,1)$. As $F(e^*)\to 0$, the expected time required for successful retaliation grows without bound, and the left side of this inequality approaches $\frac{1}{1-\delta}\big(\pi^A_{(1,1;0,1)}-\pi^A_{(1,0;0,1)}\big)$. Intuitively, when implementing a format becomes sufficiently difficult (F'' is very negative), the expected time required to retaliate becomes so long that firms do not worry about retaliation. Rather, they each invest at least a small amount in the other format because Assumption 1 guarantees that the expected discounted profits of a successful attack are enough to justify investing the first marginal dollar.

Based on the preceding analysis, the following proposition characterizes conditions in which all states are unstable, so both firms eventually adopt both formats.

Proposition 1. *If implementing a format is sufficiently difficult that the condition in Lemma 1 does not hold, then in the long run both firms implement both formats.*

[5] The following lemma only guarantees *existence* of an equilibrium in which state $(1,0;0,1)$ is stable. There could also be another equilibrium in which both firms always attack each other.

Figure 1. When implementing a format is difficult, both firms implement both formats. (Arrows indicate possible paths the game state can follow.)[6]



Intuitively, if implementing a format is difficult, which is guaranteed by the condition that F'' is sufficiently negative, then any retaliation is expected to take a long time to succeed, so firms worry mostly about the immediate profit impact of implementing a new format. Assumption 1 guarantees that this immediate impact is enough to justify investing at least the first marginal dollar in any format the firm is not yet using, so firms make positive investment until they have both implemented both formats. Of course, it will take a long time for this to occur because the probability of successful implementation in any given period is low.

I now consider the case when implementing a format is easy, which is true when F'' is not very negative. As $F(e^*) \to 1$, retaliation for an attack is very likely to occur in the next period after the attack, and the condition in Lemma 1 becomes:

[6]Technically we have not guaranteed that the incumbent invests at the initial state (1,0;0,1); however, it is straightforward to show that if implementation is sufficiently difficult, Assumption 1 guarantees that the incumbent immediately invests at this initial state rather than waiting until the game reaches state (1,0;0,1). On the other hand, one of the extensions to the model derives conditions for which the incumbent *does* delay investment.

$$\left(\pi^A_{(1,1;0,1)} - \pi^A_{(1,0;0,1)}\right) - \left(\frac{\delta}{1-\delta}\right)\left(\pi^A_{(1,0;0,1)} - \pi^A_{(1,1;1,1)}\right) \leq \frac{1}{F'(0)} \tag{3}$$

Thus, unless firms have very low discount factors or the harm done by mutual attacks is very small, Lemma 1 will apply as long as implementation is easy enough.

If the condition in Lemma 1 holds, then there is an equilibrium in which state $(1,0;0,1)$ is stable. When this is true, in some cases the incumbent invests nothing at the initial state, guaranteeing that the entrant is the only one to implement the new format. To derive conditions in which this occurs, let Λ^A denote firm A's continuation value if the game reaches a given state after its investment decision is realized. Firm A's continuation value at state $(1,1;0,1)$ is the same as the first term in the condition of Lemma 1:

$$\Lambda^A_{(1,1;0,1)} = \left(\frac{\pi^A_{(1,1;0,1)}\left[1+\delta(1-F(e^*))\right] + [\delta/(1-\delta)]F(e^*)\pi^A_{(1,1;1,1)}}{1-\delta^2(1-F(e^*))}\right) \tag{4}$$

Let $\widehat{e}$ denote firm B's optimal investment at state $(1,1;0,0)$. Because firm A no longer has any reason to invest once the game reaches this state, firm B can find $\widehat{e}$ by solving a dynamic programming problem. Firm A's continuation value at state $(1,1;0,0)$ is then given by:

$$\Lambda^A_{(1,1;0,0)} = \left(\frac{\pi^A_{(1,1;0,0)}\left[1+\delta(1-F(\widehat{e}))\right] + \delta F(\widehat{e})[\pi^A_{(1,1;0,1)} + \delta\Lambda^A_{(1,1;0,1)}]}{1-\delta^2(1-F(\widehat{e}))}\right) \tag{5}$$

Finally, let $\overline{e}$ denote the entrant's optimal investment in the new format at the initial state $(1,0;0,0)$ assuming the incumbent invests nothing at this state. Assuming firms are in an equilibrium in which neither invests at state $(1,0;0,1)$, the value $\overline{e}$ is again the solution to a simple dynamic program. In this case, if there is an equilibrium in which the incumbent invests nothing at the initial state, its expected discounted profits if it stays at this state are given by:

$$\Lambda^A_{(1,0;0,0)} = \left(\frac{\pi^A_{(1,0;0,0)} \left[1 + \delta(1 - F(\bar{e}))\right] + [\delta/(1-\delta)] F(\bar{e}) \pi^A_{(1,0;0,1)}}{1 - \delta^2(1 - F(\bar{e}))} \right) \tag{6}$$

The following lemma states conditions guaranteeing there is an equilibrium in which the incumbent lets the entrant win the new format.

Lemma 2. *If the condition in Lemma 1 holds, there exists an equilibrium in which firm A invests nothing at state* $(1, 0; 0, 0)$ *if and only if:*

$$\Lambda^A_{(1,1;0,0)} - \Lambda^A_{(1,0;0,0)} \leq \frac{1}{F'(0)} \tag{7}$$

As implementation becomes easier, so that $F(e^*)$, $F(\widehat{e})$, and $F(\bar{e})$ all converge to one, the condition in this lemma approaches:

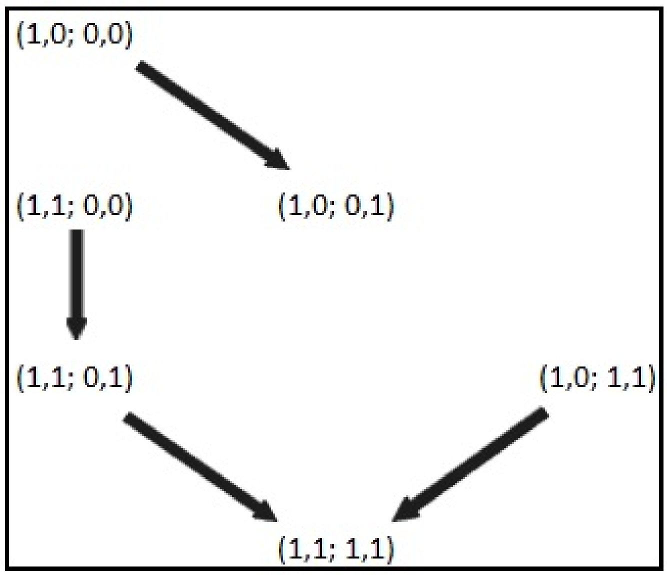
$$\left[\pi^A_{(1,1;0,0)} + \delta \pi^A_{(1,1;0,1)} + \delta^2 \pi^A_{(1,1;0,1)} + \left(\frac{\delta^3}{1-\delta}\right) \pi^A_{(1,1;1,1)}\right] - \left[\pi^A_{(1,0;0,0)} + \left(\frac{\delta}{1-\delta}\right) \pi^A_{(1,0;0,1)}\right] \leq \frac{1}{F'(0)} \tag{8}$$

Thus, if attacks are harmful $\left(\pi^A_{(1,1;1,1)} \text{ is smaller than } \pi^A_{(1,0;0,1)}\right)$ and firms are not too short-sighted (δ is not too small), the condition in Lemma 2 holds as long as implementation is sufficiently easy.

I can now state conditions in which the incumbent allows the entrant to win the new format, and threats of retaliation prevent either firm from adopting a second format.

Proposition 2. *If implementing a new format is easy enough that the conditions of Lemma 1 and 2 hold, then there is an equilibrium in which firm B is the only one that invests in the new format. Once it successfully implements this format, neither firm makes further investment.*

Figure 2. When implementing a format is easy, a firm will not implement a second format because this would lead to swift retaliation. (Arrows indicate possible paths the game state can follow.)



This proposition states that when implementing a format is easy, the entrant is guaranteed to win the new format. The intuition is that if the incumbent implemented the new format, it would give up its only mechanism for punishing the entrant, which would then lead the entrant to implement both formats. To avoid this outcome, the incumbent allows the entrant to win the new format, thus retaining the threat of retaliation as a way to prevent the entrant from adopting the old format.

To summarize, I have shown that an increase in the probability of successfully implementing a format can make an incumbent less likely to invest in the new format. This result was driven by the assumption that both formats are attractive enough that, in the absence of concerns over retaliation, each firm always wants to invest at least a small amount in any format it has not yet implemented. In fact, if the probability of successful implementation in any given period is low, in the long run both firms inevitably adopt both formats. However, if the probability of successful implementation in any given period is high, the incumbent allows the entrant to win the new format, and threats of retaliation then prevent the firms from avoid attacking each other's format.

3.2 Strong preemption and cannibalization effects

Whereas the previous section assumed cannibalization and preemption effects were too weak to prevent investment, this section focuses on the case when both of these effects are strong. I show that this reverses the impact of investment difficulty on the incumbent's investment choice. In particular, under these new assumptions, the incumbent is *less* likely to invest in the new format when implementing a new format is difficult.

This section continues to assume Assumptions 2 and 3 hold, but it replaces Assumption 1 with the following:

Assumption 4. *The incremental per-period profits from adding a new format (holding the competitor's state constant) are greater than* $\frac{1-\delta}{F'(0)}$ *if the competitor is not using this format and the focal firm is not using the other format, but less than* $\frac{1-\delta}{F'(0)}$ *in all other cases.*

This assumption implies that cannibalization and preemption effects are strong enough that investing in a format is profitable for the entrant if it adds the new format at the initial state, but is unprofitable (holding the competitor's state constant) in all other cases. The model of product market competition in Appendix A presents conditions in which this assumption holds for that particular model of competition.

It immediately follows from this assumption that all states except the initial state are stable. Also, Assumptions 2 and 4 imply that the entrant makes positive investment at the initial state since the alternative would be to earn zero dollars forever. The only remaining question is whether the incumbent invests at the initial state.

The incumbent faces a choice between investing in the new format in the hope of preventing the entrant from investing there, or alternatively, just staying at the initial state until the entrant finally does succeed in implementing the new format. I derive conditions in which the latter strategy is optimal in equilibrium.

The discounted value of the incumbent's profits if it adopts the new format and reaches state $(1,1;0,0)$ is given by $\left(\frac{1}{1-\delta}\right)\pi^A_{(1,1;0,0)}$. The next step is to compute the incumbent's expected discounted profits if it stays at the initial state $(1,0;0,0)$. As in the previous section, let $\bar{e}$ denote the entrant's optimal investment in the new format at the initial state if there is an equilibrium in which the incumbent invests nothing at this state. Since Assumption 4 guarantees that neither firm will invest at state $(1,0;0,1)$, the entrant finds $\bar{e}$ by solving the same dynamic program it used to find this value in the previous section. Assuming there is an equilibrium in which the incumbent invests nothing at the initial state, its expected discounted profits if it stays at this state are given by the same expression for $\Lambda^A_{(1,0;0,0)}$ in equation (6).

We can now state a necessary and sufficient condition for existence of an equilibrium in which the incumbent does not invest in the new format at the initial state.

Lemma 3. *If cannibalization and preemption effects are strong enough that Assumption 4 holds, there exists an equilibrium in which the incumbent makes zero investment at the initial state* $(1, 0; 0, 0)$ *if and only if:*

$$\left(\frac{1}{1-\delta}\right)\pi^A_{(1,1;0,0)} - \Lambda^A_{(1,0;0,0)} \leq \frac{1}{F'(0)}$$

The first term on the left side of this inequality represents the discounted value of the incumbent's profits if it wins the new format. The second term represents its expected discounted profits if it just stays at the initial state; in this case, it will continue to earn monopoly profits until the entrant successfully implements the new format, at which point both firms will perpetually earn the profits from being one member of a duopoly that uses different formats.

As implementing a format becomes very difficult (F'' becomes very negative), $F(\bar{e})$ converges to zero. The inequality in Lemma 3 then becomes:

$$\left(\frac{1}{1-\delta}\right)\left(\pi^A_{(1,1;0,0)} - \pi^A_{(1,0;0,0)}\right) \leq \frac{1}{F'(0)} \tag{9}$$

Recall that Assumption 4 guarantees that this inequality holds. Intuitively, if implementing a new format is very difficult, the incumbent prefers to remain at the initial state and milk profits from the old format during the very long expected period of time it takes before the incumbent adopts the new format. The benefits of trying the preempt the entrant in this difficult-to-implement format are not enough to outweigh the incumbent's concerns over cannibalization from the old format.

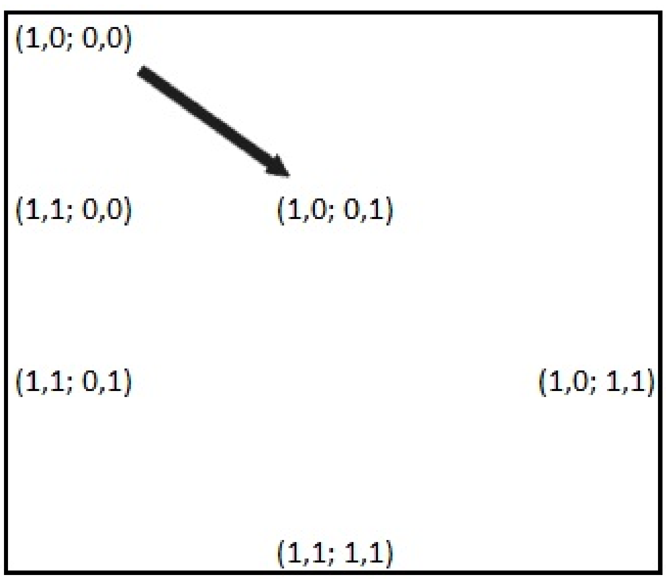
On the other hand, as implementing a format becomes very easy (F'' becomes close to zero) $F(\bar{e})$ converges to one. The inequality in Lemma 3 then becomes:

$$\left(\frac{1}{1-\delta}\right)\left(\pi^A_{(1,1;0,0)} - \pi^A_{(1,0;0,1)}\right) - \left(\pi^A_{(1,0;0,0)} - \pi^A_{(1,0;0,1)}\right) \leq \frac{1}{F'(0)} \tag{10}$$

Intuitively, when implementing a format is easy and the benefits to the incumbent of keeping the entrant out of the new format are large, the incumbent is willing to invest in this format and cannibalize heavily from its existing sales because otherwise the entrant will quickly adopt the new format.

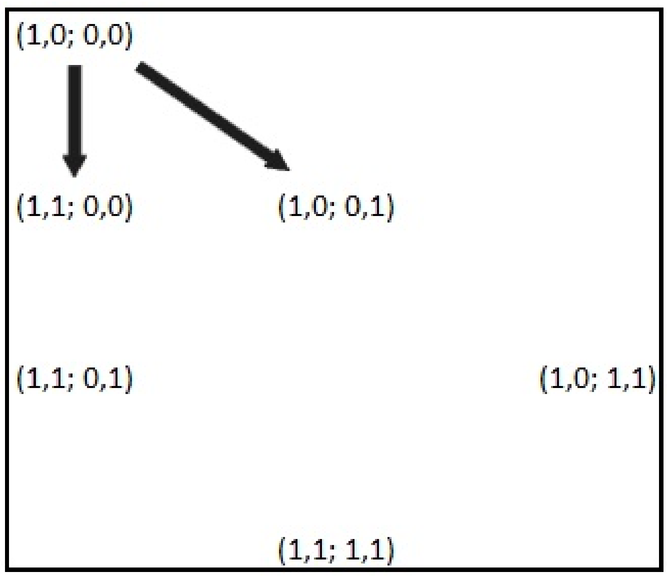
Proposition 3. *Assume cannibalization and preemption effects are strong enough that Assumption 4 holds. If implementing a new format is difficult enough that the condition in Lemma 3 holds, there exists an equilibrium in which the incumbent makes zero investment and the entrant is guaranteed to win the new format in the long run. However, if implementing a new format is easy enough and successful investment by the entrant is harmful enough to the incumbent that the condition in Lemma 3 does not hold, then in any equilibrium both firms make positive investment in the new format at the initial state. In both cases, once one firm adopts the new format, neither firm makes any further investment.*

Figure 3. When cannibalization and preemption effects are strong and implementing a format is *difficult*, the incumbent allows the entrant to win the new format.



Survey data show that high tech firms vary substantially in how much their managers say they are willing to cannibalizes existing sales (Chandy and Tellis 1998). In cases where a new technology has a winner-take-all property (preemption effects are strong), this model implies that incumbents should be willing to cannibalize existing sales when there is a high probability that an entrant can quickly implement the new technology, but incumbents should not be willing to cannibalize existing sales when this probability is low.

Figure 4. When cannibalization and preemption effects are strong and implementing a format is *easy*, the incumbent is willing to cannibalize its sales to try to preempt investment by the entrant.



In this section, the impact of investment uncertainty on the incumbent's investment decision contrasts with results from the previous section. The key distinction is that in the current section the incumbent faces a trade-off between cannibalization and preemption, and investment uncertainty makes the relative benefits of preemption more distant, which makes the incumbent *less* willing to cannibalize its existing sales by investing in the new format. By contrast, the previous section assumed both of these effects were not strong enough to prevent investment, and the incumbent primarily faced a trade-off between the short-term gains from adopting the new format and the long-term loss due to retaliation. In this case, investment uncertainty made the cost of retaliation more distant, which made the incumbent *more* willing to invest in the new format in order to increase its short-term profits.

3.3 Other regions of the parameter space

I have focused on cases in which preemption and cannibalization effects are either both weak or both strong. These cases are particularly interesting because the difficulty of implementing a format determines the equilibrium outcome. I do not present detailed results for the other possible combinations of these parameter values because the results are more straightforward and less interesting. In particular, if preemption effects are weak and cannibalization effects are strong, the incumbent allows the entrant to win the new format; and if preemption effects are strong and cannibalization effects are weak, the two firms race to enter the new format. In contrast with the results presented in previous sections, these results hold regardless of the difficulty of implementing a format. Technically, these results do not depend on the second derivative of the function F that maps investment into success probability.

4 Extensions: Asymmetric formats

Until now I have assumed that each firm's profit function is symmetric across formats. I now present two extensions in which there are asymmetries across formats. The first extension shows that a large fixed expense in the old format allows the incumbent to attack the new format without fear of retaliation. The second extension assumes either firm's use of the new format severely damages profits in the old format; I then derive conditions in which the incumbent adopts a delayed response strategy, avoiding investment in the new format until the entrant has successfully adopted it.

4.1 Fixed expense in the old format

A major appeal of many Internet-based business models is that they allow firms to avoid fixed expenses such as physical retail locations that are associated with traditional business models. I now present a model extension showing that, even when implementing a format is easy, such fixed expenses in the old format can allow the incumbent to attack the new format without fear of retaliation.

To illustrate this effect, I assume there is a recurring fixed expense f to operating the old format, which is avoided in the new format. For example, at state $(1,0;0,1)$, firm A's profits are now $(\pi^A_{(1,0;0,1)} - f)$, whereas firm B's profits are still $\pi^B_{(1,0;0,1)}$. Assumptions 2 and 3 still apply to this modified profit function. I also assume cannibalization and preemption effects are too weak to prevent investment, so Assumption 1 holds for investment in the new format, although it may not hold for investment in the old format due to the fixed expense.

If the fixed expense is high enough, the entrant will never invest in the old format:

Lemma 4. *The entrant never invests in the old format if:*

$$f > \left(\frac{1}{1-\delta}\right)\left[\pi^B_{(1,0;1,1)} - \pi^B_{(1,1;0,1)}\right] - \frac{1}{F'(0)} \tag{11}$$

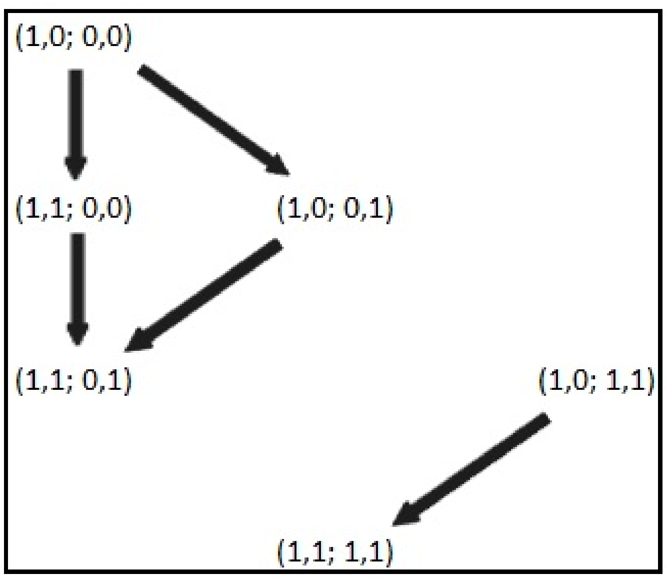
Intuitively, this condition guarantees that the entrant does not want to invest in the *old* format at state (1,0;0,1) even if implementing this format generates preemption effects that cause the incumbent to drastically reduce its investment in the *new* format. This condition is typically stronger than necessary, but it is a notationally succinct way to guarantee that at both states $(1,0;0,1)$ and $(1,1;0,1)$, the entrant does not want to invest in the old format due to the high recurring fixed expenses that it would incur if it successfully implemented this format.

When the condition in Lemma 4 holds, the incumbent can invest in the new format without worrying about retaliation. This implies that, even if implementing a format is easy, the state $(1,0;0,1)$ cannot be stable because the incumbent always attacks the new format from this state.

Proposition 4. *If the fixed expense in the old format is large enough to satisfy the condition in Lemma 4, in equilibrium both firms eventually adopt the new format, but the entrant never invests in the old format.*

As an example, following E-trade's early success with new online trading technology, Charles Schwab invested in its own online trading platform (Lal 1996). E-trade never seriously considered a retaliatory move of investing in the bricks-and-mortar locations necessary for in-person investment advice.[7] Schwab now offers both the in-person and online investment formats, while E-trade focuses on the online format.

Figure 5. Large fixed expenses in the old format allow the incumbent to invest in the new format without fear of retaliation. (Arrows indicate possible paths the game state can follow.)



Under the conditions of Proposition 3, the incumbent is guaranteed to make positive investment at the initial state (1,0;0,0). To see why this is true, recall that

[7]Based on a personal interview with E-trade founder Bill Porter.

Assumption 1 implies that, by implementing the new format, the incumbent increases its profits in all subsequent periods (conditional on the entrant's state) by at least $\frac{1-\delta}{F'(0)}$. In the absence of any impact on the entrant's investment decisions, this would guarantee that the incumbent makes positive investment at the initial state. In fact, Assumptions 2 and 3 guarantee that when the incumbent implements the new format, this causes the entrant to *reduce* its investment in this format, further reinforcing the incumbent's desire to invest at the initial state. Thus, the incumbent is guaranteed to make positive investment at the initial state. By contrast, the next extension derives conditions in which the incumbent does *not* invest at the initial state.

4.2 Delayed entry response

In some cases successful implementation of the new format by either firm severely reduces profits from the old format. For example, an online retailing format might free-ride on customer service provided by traditional stores, making it much less profitable to continue operating this old format. This type of channel conflict can occur both between firms and within a single firm (Anderson et al. 2009). Alternatively, the new format might be what Reinganum (1983) calls a "drastic innovation," meaning that it totally replaces the old format. In such cases, if implementing the new format is difficult enough, the incumbent might want to continue to milk profits from the old format until the entrant successfully implements the new format, at which point the incumbent starts investing in the new format as well.

The key feature of the profit function needed to ensure that this type of delayed entry response occurs is that, when the entrant implements the new format, this *increases* the incumbent's incremental profits from implementing this format.

To illustrate why this might happen, I make the extreme assumption that either firm's use of the new format eliminates profits from the old format, for example, due to the free-riding effect described above. For convenience of exposition, I also assume that either firm's use of the old format does *not* affect the profits from using the new format, although this is not crucial for my results to hold. These assumptions imply, for example, that $\pi^A_{(1,0;0,1)} = 0$ and $\pi^B_{(1,0;0,1)} = \pi^B_{(0,0;0,1)}$.[8]

Under these new assumptions, once the entrant implements the new format, it will never invest in the old format. As was the case in the previous model extension, this in turn implies that at state $(1,0;0,1)$ the incumbent can attack the new format without fear of retaliation.

The only remaining question is how firms behave at the initial state $(1,0;0,0)$. Assumptions 1 to 3 (which I assume still apply to the new format) still guarantee that the entrant makes positive investment in the new format at this state. However, in contrast with the previous model extension, the incumbent might not invest at this state.

To understand why, note that the new assumptions about the profit function imply that when the entrant uses neither format, the incumbent cannot increase its profits by using both formats ($\pi^A_{(1,1;0,0)} = \pi^A_{(1,0;0,0)}$). On the other hand, once the entrant implements the new format, the incumbent's profits from using the old format drop to zero, and the incumbent can increase profits by adding the new format ($\pi^A_{(1,1;0,1)} > \pi^A_{(1,0;0,1)} = 0$). Intuitively, at first the entrant cannot increase profits by adding the new format since the resulting damage to the old format would offset any additional profits generated; however, once the entrant has started using the new format (so the damage to the old format is already done), the incumbent might as well implement the new format too.

Nonetheless, at the initial state the incumbent might still want to invest in the

[8]In the case of free-riding, the new format might actually benefit from the existence of the old format. To allow this benefit to occur, we could make the alternative assumption that use of the new format leaves the old format just barely profitable enough that the incumbent will continue to use the old format.

new format as a preemptive measure to reduce the entrant's investment there. To rule this out, I derive conditions in which, even if these preemption effects are very strong, the incumbent prefers to delay its investment.

Note that, even with strong preemption effects, an *upper* bound on the discounted value of the incumbent's profits at state $(1,1;0,0)$ is given by $\left(\frac{1}{1-\delta}\right)\pi^A_{(1,1;0,0)}$. The next step is to find a *lower* bound on the incumbent's expected discounted profits if it stays at the initial state $(1,0;0,0)$. If there is an equilibrium in which the incumbent makes zero investment at this state, then $\overline{e}$ as defined in section 3.1 and 3.2 is an upper bound on the amount the entrant invests in this state (it will actually invest less than this because it knows the incumbent will later adopt the new format, making this format less attractive).

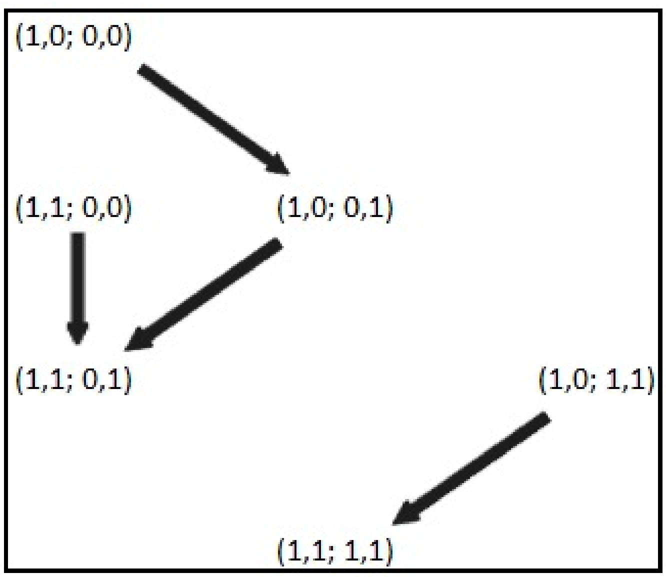
Thus, the left-side of the inequality in Lemma 3 (from section 3.2) is an *upper* bound on the benefits to the incumbent of adopting the new format at the initial state. As long as this condition holds, there is an equilibrium in which the incumbent does not invest at this state.

Recall that as implementing a format becomes very difficult (F'' becomes very negative), $F(\overline{e})$ converges to zero. Given that $\pi^A_{(1,1;0,0)} = \pi^A_{(1,0;0,0)}$, this implies that the left-side of the condition in Lemma 3 also converges to zero. Intuitively, if implementing a format is difficult enough, the incumbent might as well just continue to generate profits from the old format because the expected time for the entrant to implement the new format becomes very long.

Proposition 5. *If either firm's use of the new format eliminates profits in the old format, and implementing a format is sufficiently difficult that the condition in Lemma 3 holds, then the incumbent initially makes no investment; after the entrant successfully implements the new format, the incumbent begins investing in the new format until it also implements this format.*

As an example, wedding dress shops face the potential threat that a bride could spend several hours trying on dresses in their store and using their customer service until she finds a dress she likes, and then buy a similar dress online at a much lower price.[9] Currently most new brides are reluctant to buy a dress online, so for now the best strategy for the traditional shops may be to stick with their current format; however, if an online retailer ever builds a strong enough reputation that free-riding on customer service becomes a major problem in this market, traditional wedding shops might want to start selling online too.

Figure 6. If either firm's use of the new format eliminates profits in the old format, and implementing a format is difficult, the incumbent does not invest in the new format until the entrant has successfully adopted this format. (Arrows indicate possible paths the game state can follow.)



[9]My wife visited a wedding shop and found a dress she liked priced at $4,000. She then bought a very similar dress online for $600. She gave me permission to reveal this information.

5 Conclusion

This paper has developed a model in which an incumbent and an entrant compete in a market where a new business format has become available. If implementing a format is easy, the incumbent allows the entrant to win the new format, and firms then reach a collusive equilibrium in which they stay focused on different formats. By contrast, if implementing a format is difficult, firms can attack each other without worrying about swift punishment, since it will take many periods before the competitor successfully retaliates. In the latter case, each firm continually invests a small amount in the other's format until they both successfully implement both formats.

These results depend on Assumption 1, which guarantees that, in the absence of competitive reaction, a firm would always be willing to make at least a small investment in any format it is not yet using. On the other hand, when preemption and cannibalization effects are both strong, these results are reversed, and an increase in the probability of successful implementation increases the incumbent's willingness to cannibalize it sales by investing in the new format.

The extensions with asymmetric formats showed that the model is flexible enough to analyze a wide variety of competitive scenarios. Future research could further extend the modeling framework developed in this paper, for example, to allow for customer preferences that change over time, or to allow each firm to have private information about the ease of implementing a format.

This paper has derived its results using a model with two firms, two formats, and two possible states (zero or one) for each firm in a given format. Allowing more states might lead to interesting new results. For example, if the observable state of the game included many small incremental steps toward successful implementation of a format, collusion would be easier to sustain because a firm could quickly observe an attempted attack on its format. In some cases, a firm might want to make observable incremental steps toward implementing a new format without actually starting to use it, so that its competitor knows that the threat of retaliation can happen more quickly.

Another key assumption is that the number of firms in the market is fixed. If entry were easy, then each format would be implemented by new entrants until entry was no longer profitable. Thus, this model only applies if there is a fixed expense to operating in the market, or other entry barriers.

Future research could empirically investigate the predictions of the model, looking for systematic evidence that incumbents tend to avoid investing in new business formats in industries where all of the following hold: (1) entry barriers keep the number of firms small; (2) conditional on entry, implementing a format is relatively easy; and (3) both firms could profitably implement both formats (preemption and cannibalization effects are not too strong). In such industries, this model implies it is important to retain the threat of implementing the new format later as a form of retaliation.

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Appendix A: Product Market Competition Model

This appendix presents an example of a model of product market competition that gives rise to a profit function for each firm at each possible state. I then derive conditions that guarantee Assumption 1 holds (or alternatively that Assumption 4 holds) in this product market competition model. Assumptions 2 and 3 always hold in this model. The particular model of product market competition does not matter for the results in the main body of the paper. The only important elements of this model are that one parameter represents the strength of preemption effects, and another parameter represents the strength of cannibalization effects.

Assume there is a unit mass of customers, who vary along two dimensions. First, their brand preferences are represented by a Hotelling line of length β, with firm A fixed at the left side of the line and firm B fixed at the right side. The second dimension of customer heterogeneity is format preferences. A fraction α of customers will only buy using format 1, another α will only use format 2, and the remaining $1 - 2\alpha$ are indifferent between the two formats, where $\alpha \in [0, \frac{1}{2}]$. Note that a large value of β indicates that customers tend to have strong preferences for one brand or the other, while a large value of α indicates they have strong preferences for one format or the other.

In each period, a customer purchases at most one product, and the utility derived from a product is computed as follows. Suppose a customer is located a distance d from the left side of the line. If this customer has either a preference for format 1 or no format preference, he would derive utility $V - d - P_{A,1}$ if he purchases from firm A using format 1 at price $P_{A,1}$. Similarly, if he has either a preference for format 2 or no format preference, he would derive utility $V - d - P_{A,2}$ if he purchases from firm A using format 2 at price $P_{A,2}$. However, if he has a preference for format 1, he would derive utility $-\infty$ from using format 2.

I assume $2\beta < V < 3\beta$, which ensures that the market is always covered in equilibrium, and that the pricing subgame always has a pure strategy equilibrium. If the Hotelling line is too short ($V > 3\beta$), then in some cases there is only a mixed strategy price equilibrium in which each firm randomizes between setting a high price to serve customers "loyal" to its format and setting a low price to capture the format "switchers." However, assuming the Hotelling line is sufficiently long ($V < 3\beta$) guarantees that firms always want to capture some of the switchers in equilibrium, and there is always a unique *pure strategy* equilibrium.

I also assume, without loss of generality, that marginal costs are zero, so that a firm's profits equal price times demand.

Given the assumption that $V > 2\beta$, it can be shown that the market is always covered in equilibrium, that is, if either firm uses a format that a customer is willing to consider, then that customer makes a purchase in equilibrium. For most states of the game, it can also be shown that, if a firm is the only one that uses a format, it will set the monopoly price for that format in order to maximize profits from its "loyal" customers. On the other hand, when both firms use a format, equilibrium prices in that format are the same as they would be in a standard Hotelling model. The only exception to this rule is state $(1, 0; 0, 1)$. In this case, equilibrium prices depend on whether the following holds:

Condition 1. $\beta\left(1 + \frac{2\alpha}{1-\alpha}\right) > V - \beta$

This condition ensures there are enough customers with strong format preferences that, when each firm uses a different format, they still want to set the monopoly price for that format. On the other hand, when this condition does not hold, prices are set competitively, in a similar manner to the Hotelling model.

To be precise, when Condition 1 holds, equilibrium prices and purchase decisions are as follows: If only one firm uses a format, its price for that format is $V - \beta$.

If both firms use a format, they each set price β for that format. In equilibrium, customers with a format preference purchase from the nearest firm that uses their preferred format. Customers who do not have a format preference purchase using a format served by both firms, if one is available, and otherwise they purchase from the nearest firm that offers either format. When Condition 1 fails, equilibrium prices and demand are the same as in the previous case, with the following exception: When each firm uses a different format, they each set price $\beta\left(1+\frac{2\alpha}{1-\alpha}\right)$

Equilibrium profits for each firm in each possible state are reported in Table 2. The first set of numbers for state $(1,0;0,1)$ are for the case when Condition 1 holds; the second set are for the case when this condition does not hold. I do not report profits or analyze state $(1,0;1,0)$, in which both firms use the old format. The entrant will generally not start by investing in the old format, so this state will not occur. I also do not analyze state $(1,1;1,0)$, as it is analogous to state $(1,1;0,1)$.

Table 2. Equilibrium Profits

State	Firm A's profits	Firm B's profits
$(1,0;0,0)$	$(V-\beta)(1-\alpha)$	0
$(1,1;0,0)$	$(V-\beta)$	0
$(1,0;0,1)$	$(V-\beta)\frac{1}{2}$	$(V-\beta)\frac{1}{2}$
$(1,0;0,1)$	$\beta\left(1+\frac{2\alpha}{1-\alpha}\right)\frac{1}{2}$	$\beta\left(1+\frac{2\alpha}{1-\alpha}\right)\frac{1}{2}$
$(1,1;0,1)$	$(V-\beta)\alpha+\beta(1-\alpha)\frac{1}{2}$	$\beta(1-\alpha)\frac{1}{2}$
$(1,0;1,1)$	$\beta(1-\alpha)\frac{1}{2}$	$(V-\beta)\alpha+\beta(1-\alpha)\frac{1}{2}$
$(1,1;1,1)$	$\beta\frac{1}{2}$	$\beta\frac{1}{2}$

Assumption 1 from the main body of the paper holds in this model of competition as long as:

$$\left(\frac{1}{1-\delta}\right)\beta\alpha\frac{1}{2} > \frac{1}{F'(0)} \tag{12}$$

Intuitively, brand and format preferences must both be strong enough that a firm is willing to invest the first marginal dollar in a format even if its competitor is already using that format and the focal firm is already using the other format. In other words, this condition holds if cannibalization and preemption effects alone are not strong enough to prevent investment.

Assumption 4 from the main body of the paper holds in this model of competition as long all of the following are true:

$$(V - \beta)\frac{1}{2} > \frac{1}{F'(0)} \tag{13}$$

$$(V - \beta)\alpha < \frac{1}{F'(0)} \tag{14}$$

$$\beta(1 - \alpha)\frac{1}{2} < \frac{1}{F'(0)} \tag{15}$$

Intuitively, consumers' valuations of the product must be high enough that capturing half the market justifies investing the first marginal dollar; however, format preferences must be weak enough that a monopoly extending its reach to those with preferences for the other format does not justify investing the first marginal dollar, and brand preferences must be weak enough that a firm will not add a format that its competitor is already using.