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Popularity and Debut

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Abstract: This paper focuses on the impact of brand popularity on two firms' optimal entry strategies into an emerging industry. Brand popularity shows the proportion of consumers holding an affinity towards one firm's product or the other. Word of mouth effects influence the distribution of preferences between periods, in turn expected profits. I show that differences in popularity give firms dissimilar incentives to lead or to follow, which affects their strategic choices of timing of entry when fast introduction is costly. I study the subgame perfect equilibria of the game to observe how they connect to popularity, strength of word of mouth communication, and consumer heterogeneity. The paper shows for which markets the asymmetry in the duopoly should be expected to increase or decrease. The model is extended to study how pre-ordering influences the efficiency of the industry.

JEL classification: D 83, L11, O33

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1 Introduction

> *"Even the most casual observer cannot escape noticing the invigorating effect rivalry commonly has on industrial firms' research and development efforts."*
>
> Opening sentence of Scherer (1967).

This paper studies the relationship between popularity of firms and their time to market strategies in an emerging market characterized by *word of mouth* effects. In many situations social interaction between consumers promotes the diffusion of product information, creating a dependency between the adoption choice of an early consumer onto a later buyer's preference. In this environment two competing firms of unequal popularity must simultaneously commit to a time to market strategy for a product line extension of their existing brand. Solving for the unique subgame perfect equilibria that exist in different markets, shows how the entry game influences industrial structure. Further, this leads to conclusions on whether one should expect firm dominance to be increasing or decreasing. The model also considers the welfare effects of pre-ordering slowly introduced products that are introduced to the market late.

Suppose that there exist two firms, A and B, both sponsoring a product for which each consumer type holds an affinity towards one or the other. A consumer can therefore be considered as being fan or nonfan of a product. Such taste differences can be attributed to branding as buyers will often identify with a brand's values and ideas, like the image, and feel a sense of loyalty towards the goods. In the larger picture this has to do with a brand's reputation, success of advertising campaign, and public perception. Alternatively, switching from a familiar to an unfamiliar product may be associated with learning costs, or the consumption value may be uncertain, in particular when considering experience goods. The fashion industry is a good example of the sort of market where this model applies. Major fashion houses such as Chanel, Dior, and Versace each have their own style and image, and have all branched out from production of clothes into other industries like perfume, luggage, and watches. Needless to say, the line extensions benefit from the association with the original brand; if this was not the case firms would have started production under a different brand name. Coca-Cola and Pepsi extending their product lines with diet and vanilla flavors is another example. It is therefore interesting to investigate how popularity of a brand affects product line extensions, and how strategic considerations between brands impact timing of product introduction.

Consumption externalities make the brand adopted in the first of the two stages of competition more likely to appeal to a later buyer. In other words, the adoption decision of the earlycomer feeds into the distribution from which consumer types are drawn at stage 2. In the marketing literature this is often referred to as word of mouth communication, while economists typically refer to such behavior as fashion or herding effects. Though I am an economist by trade, I will use the marketing term as it better fits the model's line of thought. Dye (2000) reports that approximately 67% of the U.S. economy is affected by word of mouth effects, speaking its clear language of the significance of this phenomenon. This highlights the importance of getting a thorough grasp on the impact of word of mouth communication on product introduction, as this will impact the structure of the industry and the performance of the market as a whole. Yet I do not know of any paper that has modelled this relationship in a formal way.

As suggested by the name, word of mouth effects typically refer to verbal communication from one person to another working as a social network effect, but apply to communication in general. As most of the literature considers only recommendation of goods I will adhere to this as well.[1] In addition, peer reviews are likely less biased than a producer's own advertising. Dye (2000) finds that among other industries, toys, broadcasting, amusement, and fashion are largely driven by buzz, while electronics, pharmaceuticals, and food and drink are less influenced. Oil, gas, and insurance are almost immune to word of mouth. Ellison and Fudenberg (1995) describe how people often rely on the experience of others in their own decision making, as it may be both costly and time consuming to acquire information, especially when decisions must be made frequently:

> "Economic agents must often make decisions without knowing the costs and benefits of the possible choices. Given the frequency with which such situations arise, it is understandable that agents often choose not to perform studies or experiments, but instead rely on whatever information they have obtained via casual word of mouth communication. Reliance on this

[1] Knowing where *not* to go is also valuable information. One can think of situations where a bad experience of one customer has a negative influence on a firm's future sales. Yelp.com is a site devoted to consumers' reviews of restaurants, shops, night life etc. whether good or bad.

> sort of easily obtained information appears to be common in circumstances ranging from consumers choosing restaurants or auto mechanics to business managers evaluating alternative organizational structures."

When Google introduced its web-based e-mail client Gmail in April 2004, promotion was almost exclusively driven by word of mouth communication. Google's tactic was to give Gmail accounts to a number of 'power users', who all had five invitations to give away at their own discretion. Each new account holder could give away five new accounts and so on. By limiting the supply Google managed to create a lot of buzz around Gmail.[2] The e-mail industry is also subject to another sort of word of mouth communication called *viral marketing*; small ads automatically attached to outgoing e-mails, among others used by Hotmail and Yahoo!, exploit users' social networks to increase brand awareness.

A multitude of articles have considered the question of whether firms with high market power have a tendency to increase their dominant position through new product development. Notable front-runners in this literature are Gilbert and Newbery (1982), who demonstrate how an incumbent can maintain its dominant position in a market with potential entry, and Budd, Harris, and Vickers (1993) providing conditions for which a dominant firm increases its lead in a duopoly. Common to this strand of literature is the *efficiency effect* illustrating how firms with high market power have greater incentives to maintain this power than smaller firms have to capture it. As a matter of course the industry structure moves in the direction of higher total industry profits, making dominant brands consolidate their positions further. This result has great implications for future competition and effectiveness of markets. The present model derives a similar conclusion on increasing firm dominance but with the important difference that total industry profits are independent of firm size. As such the model applies to emerging industries not presently explained by existing models, and I believe that this result offers new insight into the literature on endogenous timing of product introduction. This offers a new rationale for why it is usually Big Pharma that introduces novel product categories to the market, like erectile dysfunction drugs (Pfizer, Viagra) and antidepressants (Eli Lilly, Prozac), while smaller players often choose to invent around patents or produce generic versions of the drugs once patents

[2] In fact, interest in Gmail was so high that invitations were sold at around \$60 on eBay (see http://www.wired.com/culture/lifestyle/news/2004/05/63524). As of February 2007, it has been possible to create a Gmail account directly on the homepage without an invitation.

expire.

A related increasing dominance result is found by Cabral (2002), who focuses on firms' strategic choices of covariance in R&D strategies when playing an infinite horizon game of product improvement. Cabral shows that an inferior firm has an incentive to differentiate itself from a dominant opponent, even though this entails choosing a less promising R&D path. In expected terms the dominant firm moves the most up the quality ladder strengthening its position further.

Another issue tackled by the literature is the effect of pre-innovation rents on the incentives to do R&D. In general, a firm with high market power has less of an incentive to innovate due to the cannibalization of its existing profit streams. This is known as the *replacement effect* and it implies a decrease in market power of the dominant firm. This model identifies a similar effect but departs from a different standpoint. The asymmetry in the distribution of popularity creates a wedge in the two brands' strategic entry decisions, in which the inferior firm has more to gain from being first-mover while the dominant firm has more to loose from being second-mover. This affects strategies played and the way industry structure should be expected to develop. As markets are emerging by assumption there can be no preexisting rents to cannibalize, and for this reason decreasing dominance must be the result of something else. The model offers an explanation as to why several dominant firms, among those IBM, turned down the idea of developing the world's first commercial photocopier when approached by the technology's inventor. Instead a rather unknown firm, later renamed Xerox, seized the opportunity to become leader in this new industry. 10 years after IBM introduced its first photocopier.

Structurally, the paper most closely related to the present is Kristiansen (1998). Kristiansen considers R&D choices by two *ex ante* symmetric firms in a network market. Winning competition at stage 1 gives the sponsor a strategic advantage at stage 2, because its installed base makes its product more attractive to the latecomer. Kristiansen shows that firms' incentives are similar to those in the prisoners' dilemma, and derives the conditions for firms to engage in a costly, and socially inefficient, R&D race. Our models are concerned with the same question but model the dependencies in customers' valuations differently. Kristiansen assumes, as is typical for network markets, an interdependent two-way relationship between the adoption choice of early and late customers. This treatment of word of mouth communication on the other hand, involves a one-way externality only, in which the adoption choice of an early buyer influences the distribution of future consumer types. The present model is therefore not very demanding on a consumer's forward looking abilities. This simplification reduces the complexity of the model's dynamics, opening the door for analysis of asymmetries in firm characteristics.

Doganoglu (2003) investigates how consumption externalities influence firms' pricing decisions and steady state market shares. Under the assumption that market shares in the previous period increase consumers' valuation for a product, it is shown that popular firms exploit periods of high demand by charging high prices, which, however, reduces future demand and thus prompts the firm to set a lower price in those periods. The conditions for the existence of a steady state in this market are derived, and under these conditions no firm grows too dominant. The setup of Doganoglu's model is quite different from mine, but even so the pricing behavior is similar sparking confidence in its robustness.

Ellison and Fudenberg (1993) study adoption in the presence of word of mouth effects, in a world where consumers are imperfectly informed on the options available to them, but may learn about better products other than the one currently used through communication with other users. Ellison and Fudenberg show that word of mouth effects improve efficiency in the long run by helping consumers find out about the good that is best suited for them.

Understanding the connection between popularity, word of mouth effects, and time to market strategies, provides new insight into how one should expect markets to develop given the characteristics applying to specific industries. The model does not strive to identify the ultimate winner of the market, which most often involves a collection of complex circumstances like advertising, upgrading, chance, etc. Rather the model is an attempt to better understand the incentives facing firms when deciding on time to market strategies.

2 The model

Two firms, A and B, sponsor competing brands, and must both choose when to introduce an extension to their product line. The timing of the model's three stages is as follows. At stage 0 the two firms simultaneously commit to a time to market strategy, determining whether firms introduce the new product at stage 1 (early to market) or stage 2 (late to market). Being early to market is associated with a fixed development cost C whereas late to market is costless. In the words of Scherer: *"Accelerating the pace of development is costly for three reasons. First, errors are made when one overlaps development steps instead of waiting for the information early experiments supply. Second, it may be necessary to support parallel experimental approaches to hedge against uncertainty. Third, there are conventional diminishing returns in the application of additional scientific and engineering manpower to a given technical assignment."* (Scherer 1980, pp. 426-427). Thus C has the interpretation of a time to market cost. To keep focus on the impact of popularity itself on firms' choice of entry strategies, it is assumed that C applies to both firms equally. The market is emerging in the sense that any rents from a firm's other activities are unaffected by the choice of timing for the introduction of this new good.

A consumer arrives in each of stages 1 and 2, referred to as the earlycomer and the latecomer respectively. Each customer can also be interpreted as being a generation of buyers with identical tastes. The earlycomer has the option to purchase an available product (if any) at stage 1 or postpone adoption to stage 2. Once a buyer has adopted a brand he stays loyal for the remainder of the game. Another interpretation of this assumption is that adoption choices are irreversible in the sense that switching between brands is very costly. See Farrell and Klemperer (2007) for a detailed discussion of switching costs. Though it is assumed that the earlycomer may adopt at stage 1, he only derives a single period of product use, and so is indifferent as far as adopting a given product at stage 1 or stage 2. Moreover, there is no discounting of time in the model for simplicity. These assumptions are consistent with thinking of time periods as being 'short'. Figure 1 illustrates the timing of the model.

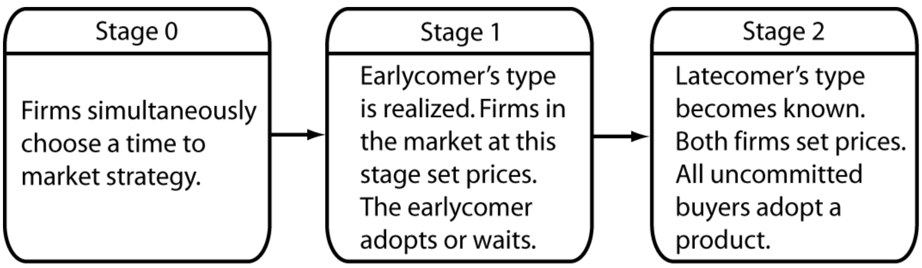

Figure 1

The realized qualities of firms' innovations are assumed to be stochastic, because firms cannot accurately predict the outcome of the development process at stage 0.[3] This

[3]Choi (1994) discusses the assumption of stochastically evolving technologies and finds that this assumption is particularly descriptive of economies where quality levels are difficult to foresee at early stages of research or when the availability of supporting goods is uncertain.

assumption seems descriptive of many situations in business, where a company realizes that it has an opportunity to enter an emerging industry, but may be unsure of factors such as actual production costs, how consumers will receive the idea, in addition to the uncertainty towards the final quality of the good. The latter interpretation is used in this model. Qualities of technologies A and B, denoted a and b respectively, are determined as independent draws from the distribution $G(-)$ with support $[0;1]$, the expectation of which is uncorrelated with the introduction strategy.

There are two types of consumers in the game; those who prefer brand A and those who prefer brand B, referred to as either 'fans' or 'nonfans' of a particular good. A buyer views brands as imperfect substitutes; the preferred brand is appreciated in its entirety, whereas the buyer only enjoys fraction z of the nonpreferred good, with $z \in [0, 1]$. Therefore, the parameter z can represent either the level of product differentiation between the brands, or the degree of heterogeneity in consumer tastes. Products are perfectly substitutable when $z = 1$ in that a nonfan experiences no loss of utility of consuming the 'wrong' brand. On the other hand, if $z = 0$ a buyer derives no utility from consumption of her least preferred brand. As an example an A-fan prefers the consumption of technology A if $a \geq bz$ (without taking prices into account). The popularity of firms determines the frequency of each buyer type occurring in the economy. Define the initial probability of meeting an A-fan as λ, where $\lambda \in [0;1]$, and the residual probability thus represents the probability of facing a B-fan. Without loss of generality assume that $\lambda \geq \frac{1}{2}$ such that player A is interpreted as being the more popular firm *ex ante*. One may also explain firm differences as the result of relative market shares or market power. Here, I choose the popularity interpretation as it better fits the picture of brand competition.

The zero-sum nature of popularity makes total industry profits, that is the sum of the two firms' profits, independent of the degree of asymmetry in popularity. One player's gain from an increase in popularity is exactly offset by the opponent's loss from its decrease in popularity. This fact is central when considering the increasing dominance results.

As discussed in the introduction, the brand adopted by the earlycomer benefits from increased likelihood of the latecomer being a fan through word of mouth communication. Let λ^A and λ^B represent the probability of encountering an A-fan at stage 2 given brands A and B respectively have been adopted at stage 1. The residual probabilities denote chances of meeting a B-fan. The stronger word of mouth communication, represented by η, with $\eta \geq 0$, the greater is an early winner's chance of meeting a fan later. However, great initial popularity limits the scope of further increase. In the extreme case where $\lambda = 1$, brand A gains nothing from winning early. To model the word of mouth effect explicitly I use a modified version of the Polya urn best known from probability theory. Imagine a bag with λ red balls and $(1 - \lambda)$ white balls. A random draw from this distribution, with replacement, determines the earlycomer's type. If A wins at stage 1, then add η additional red balls to the bag, such that the probability of realizing a red ball in the next draw equals $\frac{\lambda+\eta}{1+\eta}\left(= \lambda^A\right)$.[4] In this case the probability of a white ball equals $\frac{1-\lambda}{1+\eta}\left(= \left[1 - \lambda^A\right]\right)$ the probability of drawing one of the original white balls in a pool of $1 + \eta$ colored balls. Likewise, when firm B wins competition at stage 1, an additional number of η white balls is added to the bag, such that the new probabilities of drawing a red ball, respectively a white ball, in the next period become $\frac{\lambda}{1+\eta}\left(= \lambda^B\right)$ and $\frac{1-\lambda+\eta}{1+\eta}\left(= \left[1 - \lambda^B\right]\right)$. Lastly, if no adoption occurs at stage 1, there is nothing for consumers to talk about, and so the distribution from which the latecomer's type is drawn remains unaffected.

Normalize the quantity bought by the latecomer to unity and let the earlycomer buy a fraction ϕ hereof. To focus on how the distribution of tastes influences firms' R&D strategies, it is assumed that firms are able to distinguish between consumer types, and therefore can price discriminate between users. Firms produce at zero marginal costs and engage in price competition. Consumers and firms make rational expectations on future play as well as realization of qualities. Buyers have a reservation level of utility of zero. The paper only considers pure strategies. The equilibrium concept is subgame perfection.

3 Analysis

Based on expected profits at stage 0 resulting from competition at stages 1 and 2, firms choose their time to market strategies. Since both firms have two strategies the game has four possible subgames; simultaneous entry at stage 2, simultaneous entry at stage 1, sequential entry with firm A leading the market, sequential entry with firm B leading the market. Figure 2 reports expected profits as a function of firms' entry strategies, net of their individual payoff in subgame (2,2). The derivations are contained in Appendix A. Player A's profits are reported in the upper left hand side of

[4] I would like to emphasize that it is the identity of the brand adopted at stage 1 that influences the distribution *not* the earlycomer's type in itself.

each entry, while player B's profits are the lower right hand elements. As is discussed below, these profits can be represented by a firm's gain for leading the market and its loss for being second-mover.

A \ B	1	2
1	$-\Omega^B-C$ $-\Omega^A-C$	Ω^A-C $-\Psi^B-\Omega^A$
2	$-\Psi^A-\Omega^B$ Ω^B-C	0 0

Figure 2

Before moving on, consider some aspects of pricing. Expected fan and nonfan profits are derived in Appendix A and are denoted F and N respectively. F and N are functions of z exclusively, with $F \geq N$ for all $z \leq 1$. Strong differences between brands make a customer's option value of adopting her least preferred brand low. This puts the favored producer in position to charge a relatively high price. As is well-known at this point, the greater the popularity enjoyed by a brand the more frequently does it face a fan. Likewise, Doganoglu (2003) finds that a producer with a high market share in a horizontally differentiated duopoly charges higher prices than its smaller competitor. In equilibrium, the firm that can offer a consumer the highest value sets its price just shy of the best profitable offer made by the lower value firm.

Let me just briefly describe some of the more interesting elements of competition in the different subgames. In subgame (1,1) prices are driven down to the point, possibly below costs, where the expected gain at stage 2 from winning rather than loosing the earlycomer's business is completely dissipated. As shifting popularity is of zero-sum nature, firms are willing to give out identical discounts implying that the winner of stage 1 competition is the one offering the higher value (just as it would have done without the discounts). As there are no brands introduced early in subgame (2,2) word of mouth communication does not influence popularity. In either of the two sequential equilibria, the earlycomer will adopt the first-mover's brand, disregarding his own type, as the first-mover can always match the buyer's expected surplus from postponing adoption. This result is due the second-mover's inability to commit itself to offering the earlycomer a certain level of surplus if he postpones adoption. The section on pre-ordering studies the effects of removing this assumption.

Figure 3 shows the mathematical expressions behind first-mover gains and second-mover losses.

$$\begin{aligned}
\Omega^A &= (1-\lambda)\left(\tfrac{\eta}{1+\eta}\right)(F-N) \\
\Omega^B &= \lambda\left(\tfrac{\eta}{1+\eta}\right)(F-N) \\
\Psi^A &= \lambda\phi F + (1-\lambda)\,\phi N \\
\Psi^B &= (1-\lambda)\,\phi F + \lambda\phi N
\end{aligned}$$

Figure 3

The term Ω^i is the first-mover gain of firm i, $i = A, B$. Since the earlycomer always adopts the first-mover's brand it will benefit from word of mouth communication amongst consumers between stages 1 and 2. This increases the first-mover's popularity associated with higher payoffs as the firm more likely earns F rather than N.[5] Since A is the more popular firm by assumption, B has the most to gain from leading the industry in terms of increases to popularity via word of mouth communication. Thus first-mover benefits can be ordered as $\Omega^A \leq \Omega^B$. In general, the benefits of market leadership may include technological leadership, patenting of R&D, learning effects, and consumers' switching costs as discussed by Lieberman and Montgomery (1988). Whereas the benefit of being first-mover pertains to profits earned on the latecomer, the second-mover loss originates from a firm's opportunity cost of not being able to do business with the earlycomer who adopts the first-mover's brand. Let the second-mover loss of firm i be represented by Ψ^i. Take brand A for an example; the earlycomer is an A-fan with probability λ, and a B-fan with probability $(1-\lambda)$, associated with opportunity costs of ϕF and ϕN respectively. Moreover, the greater the popularity of a firm, the more frequently does it face a fan, and the higher does its second-mover loss become. We can therefore rank second-mover losses as $\Psi^B \leq \Psi^A$. Assuming that firms are equally popular, $\lambda = \frac{1}{2}$, first-mover benefits and second-mover losses coincide, such that $\Omega^A = \Omega^B$ and $\Psi^A = \Psi^B$.

Consider how the $\Omega^A, \Omega^B, \Psi^A$, and Ψ^B, are influenced by changes in the parameters. Stronger word of mouth effects generally increase first-mover gains, by benefiting an early winner with a more favorable probability distribution of customer types at stage 2. Absent word of mouth communication early to market carries no gains in expected

[5] This is comparable to the *weakened-rival effect* demonstrating the business stealing incentive of firms in network markets to introduce their products more quickly to appropriate a greater share of late users' surpluses, by increasing the relative size of their own private installed base. See Katz and Shapiro (1986).

profits. The greater consumer heterogeneity, the bigger is the difference in a buyer's willingness to pay for the two brands. This increases the importance of holding a favorable probability distribution, in turn raising first-mover gains. On the other hand perfect substitutability completely eliminates the first-mover advantage, as fans and nonfans place the same valuation on a brand, in which case firm popularity looses its importance. The effect of heterogeneity on second-mover losses is less straightforward: Calculus shows that as consumers become increasingly homogeneous, the second-mover loss of firm A becomes less severe only as long as $(1-\lambda)\frac{\partial N}{\partial z} < -\lambda\frac{\partial F}{\partial z}$ holds, respectively $\lambda\frac{\partial N}{\partial z} < -(1-\lambda)\frac{\partial F}{\partial z}$ for firm B. These conditions state that the weighted increase in nonfan profits must be smaller than the decrease in fan profits for second-mover losses to be decreasing as consumers become more homogeneous. Now turn to the effect of popularity on firms' incentives.

> **Proposition 1.** Greater popularity reduces the firm's first-mover benefit, while increasing its second-mover loss.

The proposition can be verified by taking the derivatives of Ω^A, Ω^B, Ψ^A, and Ψ^B with respect to λ. As discussed previously, a popular brand in general has less to gain from leading an industry than its rival, owning to a smaller scope of further increases. On the other hand, popular brands will, by definition, more often face a fan, leading to greater losses if being second-mover. Greater asymmetry in firm dominance strengthens these effects and makes for a poorer alignment of firms' incentives in general.

Now let's derive the equilibria of the model. The time to market cost in comparison to firms' first-mover advantages and second-mover losses determines the equilibrium of the game. Figure 4 illustrates how C may fall into nine areas consisting of different combinations of producers' first-mover gains and second-mover losses. These areas are useful in the analysis below as they govern which strategies firms play by.

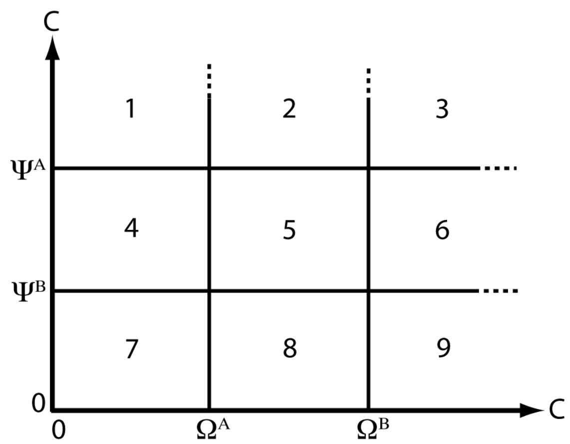

Figure 4

Different industries support different entry combinations as the unique (pure strategy) subgame perfect equilibrium of the game. Below I discuss these equilibria and relate to real-life examples.

> **Proposition 2.** The popular firm leads the market in a sequential equilibrium for $C < \Omega^A$ and $\Psi^B < C < \Psi^A$, making (1,2) the unique subgame perfect equilibrium.

The proof of this proposition, as well as those of propositions 3, 4, and 5, is derived from direct comparison of firms' profit levels as reported in figure 2, and are not included in the paper for this reason.

Proposition 2 characterizes industries where only the second-mover loss of the dominant firm exceeds the cost of being early, the latter being low enough for even the dominant firm to seek first-mover status. This makes it a dominant strategy for A to enter at stage 1. While firm B would like to become first-mover, knowing the action that A is going to take, the best-response is to become second-mover. Fearing a 'Stackelberg war' B rather forgoes the expected profits that could have been made on the earlycomer (that is Ψ^B) than wasting the time to market cost. As a matter of course, the dominant firm strengthens its position (in expected terms), while the inferior firm is further weakened. The effect emerges because the dominant firm has more to loose from being second, even though the inferior rival has the greatest incentive to be first. In Scherer's words:

> "The theory predicts then that profit-maximizing dominant firms will be potent imitators when their market shares are endangered. They may

> even accelerate their development efforts so strongly in response to a challenge that they induce the challenger to relax its development pace and settle for the smaller market share associated with being second." (Scherer 1980, p. 428).

The novelty of this result is that increasing dominance arises in markets where total industry profits are independent of firms' sizes. This model uses a different set of assumptions than the existing literature on product introduction to reach this conclusion. In particular it does not require existence of the efficiency effect, and therefore applies to other markets than those previously described.

The analysis can help understand why Big Pharma usually leads the introduction of new product categories: Published research, say from universities, can open up new markets for medical companies to exploit commercially. This information is available to big as well as small firms, and without entry of the other, each firm would like to become leader as the scope of monopoly rents as long as the patent is running is quite high. However, if both firms individually choose to undertake research to develop the new drug, a small brand will find its market share too small to justify the R&D expenditure, as competition will drive down prices. The end result is that one should expect the big medical companies to be first to explore new opportunities, while their smaller competitors are better off saving development costs and introducing a generic equivalent of the original product once the patent expires. Alternatively, the smaller brand could choose to invent around the first-mover's patent, which would be less costly that having to do all research from scratch. As an example, Viagra, a drug for erectile dysfunction, was introduced by Pfizer in 1998. 5 years later Eli Lilly (Cialis) and GlaxoSmithKline/Bayer (Levitra) entered the market once they managed to invent around Pfizer's patent.

I am aware of two other papers, Cabral (2002, 2003), exhibiting increasing dominance without reliance on the efficiency effect. These models study the related issue of improvements to existing products. I will return to these papers later.

Proposition 3. The inferior firm will lead the market and the superior firm will follow if the time to market cost satisfies $\Omega^A < C < \Omega^B$ and $\Psi^A < C$. This makes the outcome (2,1) the unique subgame perfect equilibrium.

Proposition 3 demonstrates a situation where duopolists are sufficiently asymmetric in popularity such that late to market is a dominant strategy for the superior firm only. By the same token, the inferior firm has a great incentive to lead the market. Assuming that the quantity bought by the earlycomer relative to the latecomer is small (that is ϕ low), if for example consumers are hesitant to adopt the new product because of uncertainty, the second-mover losses remain small. In this case it seems plausible that a dominant firm is best off postponing entry thereby ceding the market to its smaller rival to avoid the expense of development costs. Similar behavior is found in general classification bicycle racing, where the ultimate winner is the rider with the fastest total time over a multi-stage race. However, there is also considerable prestige associated with winning individual stages of the race making riders frequently attempt to break away from the peloton. Low-ranking riders are usually allowed to escape, as teams with a promising classification rider are better off preserving energy to be able to handle other riders posing more imminent threats to the overall classification.

The inferior firm leading the market closes the gap between the duopolists, implying a *decrease* in firm dominance.[6] This result is comparable to the replacement effect demonstrating that a company with high market power has less to gain from the introduction of a never version of an existing good than their rival has, because it suffers more from cannibalization of current rents. In contrast I show how decreasing dominance can arise without having to assume anything about other activities. This result relies only on an asymmetry in brand popularity, and as the market is emerging by assumption, decreasing dominance is not caused by the cannibalization of rents, but by the cannibalization of brand popularity. This I believe is a novel effect.

In 1938 Patent attorney Chester Carlson invented electrophotography, the technology behind the world's first plain-paper photocopier. Before then duplicators and carbon paper were used for copying. Carlson tried to sell his idea to several major companies including IBM but without luck. It was only when the Haloid Company, later renamed Xerox, picked up the idea that the technology began developing into a commercial product. In 1959 the Xerox 914 hit the market. In 1970 IBM introduced its first photocopy machine, the IBM Copier. This example illustrates how a dominant player could have entered the market but declined.[7] Instead a smaller firm chose to

[6] If the word of mouth effect is sufficiently strong, the inferior firm may even leapfrog its rival's dominance and create the reverse situation.

[7] In fact, Chester Carlson's original patent had already expired when the Xerox 914 was introduced.

seize leadership and gain market power. See Owen (2005) for background story, the birth and history of, the photocopier.

To investigate the relationship between popularity and consumer heterogeneity further for this specific equilibrium, fix the parameters $\eta = 1, \phi = \frac{3}{10}, C = \frac{1}{16}$, let the distribution function $G(-)$ be uniform, and plot the combinations of λ and z that make each of the three constraints in proposition 3 bind with equality. The (z, λ)-area containing the dot satisfies all three conditions simultaneously. The parameter values are chosen to replicate the photocopy machine industry. According to Dye (2000) electronics, such as photocopiers, are moderately influenced by word of mouth effects. Consistent with Dye, choosing $\eta = 1$ makes the effect of word of mouth communication on firms' first-mover gains produced by the Polya urn equal to $\frac{1}{2}$. In general this effect is given by $\left(\frac{\eta}{1+\eta}\right)$ and belongs to $[0; 1)\, \forall \eta \geq 0$. Further, it seems reasonable that the cost of developing the electrophotography technology into a commercial product is higher than what a firm could hope to earn through early sales. One can therefore argue that the relationship between ϕ and C is relatively low in this market. Figure 5 illustrates the 'iso-incentive' curves of the relevant constraints.

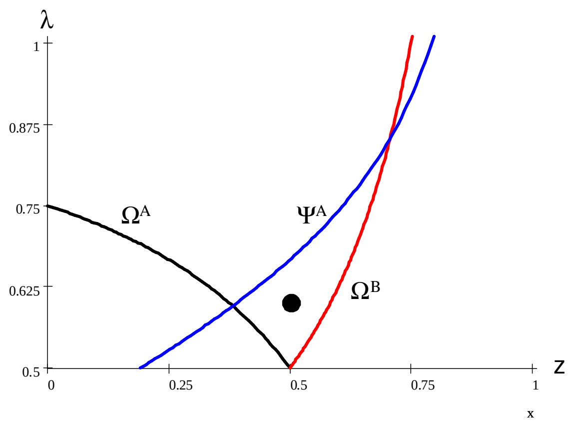

Figure 5

As products become increasingly substitutable (that is as $z \uparrow$) the difference between expected fan and nonfan profits decreases, and so does the gain from being first to market. To preserve status quo in terms of first-mover gains, both firms need to experience a lower level of popularity. For the dominant (inferior) firm this implies a negative (positive) relationship between z and λ. The connection between z and λ in Ψ^A depends on their mutual level as can be seen from the comparative statics above. For this particular parameterization, an increase in z (within the unit interval) always raises the loss firm A experiences for being second-mover, as the weighted increase in forgone nonfan profits exceeds the reduced loss on fans. To restore balance, λ must be shifted upwards to place more weight on fan profits relative to nonfan profits. Clearly, moving away from a point within the triangle ultimately leads to violation of one or more of the constraints set forth in proposition 3 needed for (2,1) to be equilibrium, in which case equilibrium may change or may simply no longer exist.

The next industry has both firms racing into the new market.

> **Proposition 4.** Given that $C < \Omega^B$ and $C < \Psi^B$ hold, both firms optimally play the early to market strategy. In this case (1,1) is unique subgame perfect equilibrium.

If early to market is an inexpensive strategy such that $C < \Omega^A$ and $C < \Psi^B$ hold (area 7), it is a dominant strategy for both players to introduce products quickly, since first-mover benefits and second-mover losses exceed the time to market cost. If the time to market cost satisfies the conditions $\Omega^A < C < \Omega^B$ and $C < \Psi^B$ (area 8), it is a dominant strategy for brand B to be early to market. Firm A is not interested in leading the market, but at the same time it sinks the time to market cost rather than becoming second-mover. Accordingly, the best strategy is simply to imitate whatever action taken by B. As a matter of course both companies introduce their brands quickly. Scherer finds that:

> *"There is abundant evidence from case studies to support the view that actual and potential new entrants play a crucial role in stimulating technical progress, both as direct sources of innovation and as spurs to existing industry members."* (Scherer, 1980, pp. 437-438).

When Westinghouse-supported research into gas-discharge lamps (later to evolve into the fluorescent lamp) turned out to provide high quality lighting as well as have a long life time, General Electric responded by increasing its research efforts into the improvement of filaments for the incandescent lamp, invented by the founder Thomas A. Edison. After losing the AC/DC standards war to the arch rival Westinghouse, allowing the gas-discharged lamp to become the predominant design in lighting over the incandescent lamp would be another serious blow to General Electric. See Reich (1992) for further details on General Electric and the electric industry, and McNichol (2006) for the dramatic history of the battle between General Electric and Westinghouse in the early days of electricity.

This racing equilibrium implies decreasing dominance even though entry choices are symmetric: Symmetric entry gives the earlycomer the opportunity to evaluate brands against each other knowing their realized qualities, and he may end up adopting the least preferred product due to the stochastic nature of the development process. By virtue of being less popular, brand B has a greater chance of winning over a nonfan than it has of loosing a fan. As a result, firm B faces a fan with relatively higher probability at stage 2, and so the industry sees a decrease in dominance.

Lastly, consider an industry where both brands are introduced slowly.

> **Proposition 5.** If $\Omega^B < C$ and $C > \Psi^B$ hold then (2,2) is the unique subgame perfect equilibrium.

Whenever $\Omega^B < C$ and $\Psi^A < C$ hold (areas 3 and 6) then late to market is a dominant strategy for both firms. For $\Omega^B < C$ and $\Psi^B < C < \Psi^A$ late to market remains a dominant strategy for B only. Knowing this, the best-response of player A is to mimic this decision for the same reasons as discussed in connection to proposition 4, and both firms end up as late entrants. No entry at stage 1 creates no word of mouth effects, leaving firms' positions unchanged.

Beyond unique subgame perfect equilibrium

We have now considered the unique subgame perfect equilibria of the game that exist everywhere except in areas 1, 5, 9, where equilibria are either not unique, not subgame perfect, or simply do not exist in the simultaneous move game. In a companion paper, Winther (2008), I derive the unique subgame perfect equilibria arising in the same basic game with the exception of sequential decision making at stage 0. Under sequential moves firms' problem of incomplete information on the opponent's action is eliminated, and the game is shown to have a unique subgame perfect equilibrium in all areas. I will now briefly discuss the players' incentives in areas 1, 5, 9.

■ In area 1 both brands prefer to play an asymmetric equilibrium; first-mover benefits of both players are greater than the time to market cost which at the same time exceeds second-mover losses. Consequently, both firms would like to assume leadership of the industry, but are better off being follower given that their opponent enters early. This leaves two possible pure-strategy equilibria, namely (1,2) and (2,1). This incentive structure resembles the 'Chicken game'. Sequential commitment to entry strategies would make the Stackelberg leader seek first-mover status in the industry, knowing that the Stackelberg follower's best-response is to differentiate itself, and so would choose to become second-mover in the market.

■ In area 5 the time to market cost is greater than brand A's benefit of being first-mover, but still lower than its loss of being second-mover. For firm B the exact opposite holds true. Hence, firm A would like for firms to play the same strategy, while B is better off when firms play by different strategies. Such incentives correspond to those found in 'Matching pennies', where one player always wants to deviate given the other's action. For the same reasons this game has no equilibrium in pure-strategies in this area. Winther (2008) shows that (1,2) is the unique subgame perfect equilibrium when A leads the decision game, while (2,2) follows with B as Stackelberg leader. The asymmetry of the outcomes is rooted in the fact that firms play by different best-response function to their opponent's strategy. When the inferior firm is Stackelberg leader it knows that the dominant firm best imitates whatever strategy it plays, and so safely chooses the late to market strategy. On the other hand, the inferior firm optimally differentiates itself, forcing the dominant firm to seize first-mover status when being Stackelberg leader to avoid suffering the loss of being second-mover.

The incentives in area 5 are similar to those derived by Cabral (2002) in a game of product improvements. In a duopoly where firms have products of different qualities, the lower value firm has an incentive to differentiate itself from its rival by choosing a different research path in order to avoid correlation of payoffs from product improvements. Cabral shows that this holds even though the alternative research path is less likely to be successful, as the firm would remain behind on the quality ladder had it chosen the same research path as the rival. A related result is found in Cabral (2003) showing that the lower value firm optimally chooses to pursue a more risky R&D strategy than the opponent does, in an attempt to get ahead in competition. In connection to the previous discussion of increasing dominance, the lower value firm will therefore fall further behind its dominant rival in expected terms.

■ In area 9 neither firm is interested in leading the market nor becoming follower, leaving two possible pure-strategy equilibria (1,1) and (2,2), with the Pareto preferred outcome being (2,2) as it yields higher expected profits than (1,1) for both brands. Therefore it is reasonable that (2,2) is the subgame-perfect equilibrium of the game. This corresponds to the 'Driving game', in which motorists must decide on driving on the left or right.

Assuming firms choose the Pareto preferred outcome in area 9, consider how the private outcome matches the socially optimal one.

> **Proposition 6.** The industry is efficient when both firms choose to be late to market. This occurs if and only if $\Omega^B < C$.

The proposition can be verified by comparison of the expected welfare levels of the different outcomes as derived in Appendix B. Fast entry is associated with two types of inefficiencies. First, there is the waste of time to market costs under fast introduction. Second, under sequential entry the earlycomer is shown to adopt whatever brand introduced by the first-mover. In expected terms there is a loss of welfare as the earlycomer might have chosen to adopt the second-mover's product had he waited. Under simultaneous entry a buyer knows the actual values of both brands, alleviating this potential inefficiency.

From a policy point-of-view the key to efficient industries is to manage the first-mover advantage of the inferior brand. The greater the asymmetry in brand popularity, the greater is the inferior brand's gain from market leadership, and the more likely is an inefficient equilibrium. Also, greater substitutability between brands, or weaker word of mouth effects, reduces the benefit of leading the market, as additional expected profits from winning the earlycomer become less significant. Taking this idea one step further, one can think of a situation where firms would want to reduce the level of product differentiation to avoid a mutually costly race for market leadership. This move demands that firms are appropriately suited for coordinating such changes. By controlling the size of first-mover, the firms may reach (2,2) as equilibrium and thereby save time to markets and any discounts given to the earlycomer. Less differentiated products, however, mean less revenue to firms, but provided that only a small change in z is needed to achieve efficiency, revenues will remain largely unaffected. This contradicts economic intuition suggesting that firms prefer their products to be highly differentiated in order to reduce the severity of price competition. From a social point of view the 'collusive' efforts of firms are welcomed. Higher z not only reduces the loss of welfare when buyers adopt their least preferred product, but also prevents the economy from loosing development costs. This type of collusion is comparable to the one described in Rotemberg and Saloner (1986) showing how firms in a cartel may want to limit the price they charge (during booms) in order to reduce the incentives to deviate from the current cartel.

Multiple periods of product use make faster introduction more attractive, as the earlycomer's willingness to pay increases. Likewise, introducing discounting into the model only makes the earlycomer more inclined to adopt a product at stage 1, raising firms' incentives for fast introduction.

4 Pre-ordering

This section investigates how pre-ordering impacts firms' entry strategies, and the ensuing effect on welfare for the industry as a whole. Pre-ordering is basically a forward contract signed at stage 1 by the earlycomer and a firm introducing its brand at stage 2. The contract commits the firm to deliver, and the buyer to adopt, the good at stage 2 at a specified price. Forward contracts are frequently used in utilities markets e.g. for oil, gas, electricity. Pre-ordering of books, electronics, or video games is also quite common.

Appendix C describes and derives prices and expected profit levels under pre-ordering. The resulting payoff matrix is shown in figure 6, with the entries adjusted for players' individual subgame (2,2) profits.

A \ B	1	2
1	$\phi N-\Omega^B-C$; $\phi N-\Omega^A-C$	$\phi N-C$; $\phi N-\Omega^A$
2	$\phi N-\Omega^B$; $\phi N-C$	0 ; 0

Figure 6

By assumption, pre-ordering does not increase the popularity of the good; even though the contract is signed at stage 1 the product is not introduced until stage 2, making word of mouth effects remain absent as no one gets to try the product before then. In a sequential equilibrium, the first-mover is interested in capturing the earlycomer to improve its position, and will offer a discount to avoid that the consumer pre-orders its rival, which would leave popularity at status quo. At the same time, the second-mover will pay a discount to avoid decreased popularity should the first-mover be adopted. This behavior is consistent with the observation that pre-ordered goods are commonly sold at a discounted price. As can be seen from Appendix C, firms offer identical discounts as shifts in popularity has a symmetric impact on expected profits. The ultimate winner of competition is therefore the firm that can offer the earlycomer the higher value in expected terms.

The socially efficient outcome (2,2) arises as a unique subgame perfect equilibrium under pre-ordering for $\phi N < C$, where ϕN is the gain from leading the industry under pre-ordering. The combinations of C and z resulting in an efficient market under pre-ordering are given by those in regions II and III in figure 7.[8] This result should be compared to the original game where efficiency was achieved whenever $\Omega^B < C$, corresponding to regions I and II.

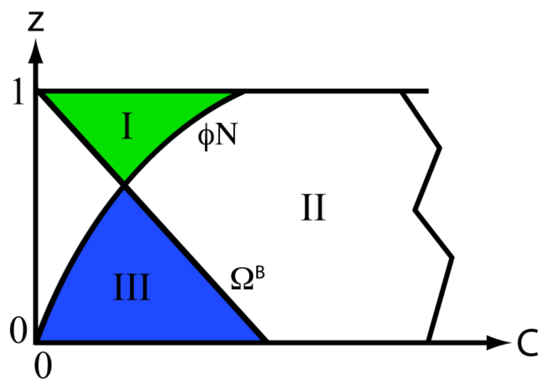

Figure 7

When substitutability between brands is low (that is when is z low) pre-ordering improves welfare over the original game as represented by region III. Without pre-ordering low substitutability makes the additional popularity to be gained through word of mouth communication a more important component of stage 2 profits, inducing firms to introduce their products early. However, the gain for being first-mover under pre-ordering, ϕN, is small when substitutability is low. By the reverse arguments, pre-ordering may lead to a reduction in efficiency in a regime of high substitutability as can be seen from region I.

From a policy perspective it is only advisable to 'allow for' pre-ordering of goods, should it be possible, in situations where homogeneity is low. Also, pre-ordering is likely to be welfare improving in markets with strong word of mouth effects. If forward contracts are not binding in their own right, a social planner should want to set up an institution to enforce or mediate such contracts. This could be an institution like the Danish *Consumers' Ombudsman*, who protects consumers by supervising and enforcing the 'Marketing Practices Act'. New York City Department of Consumer Affairs helps "mediate and resolve consumer complaints" and as such can help consumers take legal

[8]Figure 6 is pictured with the distribution function $G(-)$ being uniform.

action to halt deceptive trade practices under the Consumer Protection Law. However, dealing with brands suggests that firms are active players in other markets as well, which would give them more of an incentive to make good on their commitments in the interest of credibility.

If firms could choose research efforts endogenously, pre-ordering could give firms adverse incentive effects once the contract has been signed; as contracts are signed before the actual quality becomes known, specifying a price for the good, the firms would be tempted to reduce quality.

5 Conclusions

This paper studies the connection between brand popularity and time to market strategies under the presence of word of mouth effects. I have shown how popular brands have less incentive than unpopular brands to enter into new industries, while having more to loose from being second-mover at the same time, and depending on the industry considered, such asymmetries in incentives can support different outcomes of the entry game as unique subgame perfect equilibrium. The paper takes a novel approach to the study of product introduction as the results are driven by differences in popularity rather than by the efficiency and replacement effects, adding a new dimension to the study of increasing or decreasing industry dominance. Moreover, the model can help explain firm behavior in markets that are not presently covered by the literature.

From a welfare point of view, efficiency generally suffers the greater the asymmetry in brand popularity. Lastly, its was shown that pre-ordering improves welfare only when consumers view brands as poor substitutes.

Appendix A

This Appendix derives the expected profits in each of the four possible subgames. Price competition establishes that, for a given buyer type, the lower value firm will reduce its price to the point where it is indifferent between winning or loosing. In equilibrium the higher value firm wins competition with a price equal to the excess value it offers over the loosing firm. Before considering the four subgames, it is useful to derive the expected profits of firms when facing a fan or a nonfan with certainty. Firm A wins a nonfan whenever $az \geq b$ holds. The corresponding expected profit level is

$$E\left[\pi^A_{nonfan}\right] = \int_0^1 \int_0^{az} (az - b)\, dG(b)\, dG(a)$$
$$= \int_0^1 \int_0^{bz} (bz - a)\, dG(a)\, dG(b) = E\left[\pi^B_{nonfan}\right] \equiv N$$

By symmetry of the game firm B makes the same expected profit when it meets a nonfan. Let N denote the expected profit made on a nonfan in general. N is a continuous and monotonically increasing function of z, because higher z expands not only the integrand (this is the markup) but also the range of integration. Next, consider firm A's expected profits when facing a fan, which happens if $a \geq bz$

$$E\left[\pi^A_{fan}\right] = \int_0^1 \int_{bz}^1 (a - bz)\, dG(a)\, dG(b)$$
$$= \int_0^1 \int_{az}^1 (b - az)\, dG(b)\, dG(a) = E\left[\pi^B_{fan}\right] \equiv F$$

Symmetry of the game implies that firm B makes the same level of expected profits should the buyer be a B-fan. Let F denote the expected profits made on a fan. F is a continuous and monotonically decreasing function of z for the same reasons as above. If the goods are perfect substitutes, $z = 1$, it is quite intuitive, and can be shown formally, that a firm's expected profit is the same whether or not it meets a fan or a nonfan. For all $z \in [0;1]$ it holds that $F \geq N$, showing that a firm always makes higher expected profits when meeting a fan rather than a nonfan. These results are useful in the derivation of the expected profits in the four subgames below.

■ **Subgame (2,2)** When products are introduced in period 2, word of mouth does not play a role in competition, because the earlycomer does not adopt a brand in period 1. Joint probability of both users being A-fans equals λ^2, both being B-fans equals $(1-\lambda)^2$ and one buyer of each type equals (2 times) $\lambda(1-\lambda)$. These probabilities are associated with the frequency of which a firm realizes either N or F, and so lead to the expected profits of this subgame

$$E\left[\pi^A_{22}\right] = \lambda(1+\phi)F + (1-\lambda)(1+\phi)N$$

$$E\left[\pi^B_{22}\right] = (1-\lambda)(1+\phi)F + \lambda(1+\phi)N$$

$E\left[\pi^A_{22}\right]$ and $E\left[\pi^B_{22}\right]$ are used as benchmarks in the other subgames.

■ **Subgame (1,1)** Competition for the earlycomer's business drives prices in the early stage down. Firms are willing to give a discount corresponding to the profit value in stage 2 of the additional popularity when achieving the earlycomer's business above the popularity when the rival wins. Formally $\left(\lambda^A - \lambda^B\right)[F] + \left(\lambda^B - \lambda^A\right)[N] \iff \left(\frac{\eta}{1+\eta}\right)(F - N)$. This makes the two firms' discount choices symmetric, as it relates to the difference in popularity levels and not the actual levels. A nice property of this result is that the higher value firm remains the winner of competition at stage 1. Whether the price is positive or negative is a function of the realized qualities and the discount size. Consider the adoption decision of a consumer of type j, where $j = A, B$. Let j hold valuations V^A_j and V^B_j for the two products. If player A, for example, is the higher value firm it wins competition and the equilibrium price $p^A_j = V^A_j - V^B_j - \left(\frac{1}{\phi}\right)\left(\frac{\eta}{1+\eta}\right)(F - N)$. Any price higher than p^A_j puts B in a position to make a profitable undercut, while all lower prices still make A the winner, but with a smaller markup. A similar price holds if B is worth more to the earlycomer. Note that the discount is given in proportion to the relative generation size. At stage 1 firm A makes an expected profit of:

$$E\left[\pi^A_{stage\_1}\right] = \phi \left\{ \begin{array}{c} \lambda \int_0^1 \int_{bz}^1 \left(a - bz - \left(\frac{1}{\phi}\right)\left(\frac{\eta}{1+\eta}\right)(F - N)\right) dG(a)\, dG(b) \\ + (1-\lambda) \int_0^1 \int_0^{az} \left(az - b - \left(\frac{1}{\phi}\right)\left(\frac{\eta}{1+\eta}\right)(F - N)\right) dG(b)\, dG(a) \end{array} \right\}$$

Let θ represent the probability of a firm winning stage 1 competition given the earlycomer is a nonfan. In other words θ expresses the probability of $bz > a$ (likewise θ is the probability of $az > b$). Since $a, b, z \in [0,1]$ then $\theta \in [0,1]$ as well. Rewrite the expected stage 1 profit as

$$E\left[\pi^A_{stage\_1}\right] = \lambda\phi F + (1-\lambda)\phi N - \lambda(1-\theta)\left(\tfrac{\eta}{1+\eta}\right)(F-N)$$
$$-(1-\lambda)\theta\left(\tfrac{\eta}{1+\eta}\right)(F-N)$$

The first two terms represent expected stage 1 profits. The third term shows that with probability $(1-\theta)$ firm A meets a fan and wins, in which case it gives out the discount $\left(\frac{\eta}{1+\eta}\right)(F-N)$. The fourth term has a similar interpretation. Turning to player A's expected stage 2 profits:

$$E\left[\pi^A_{stage\_2}\right] = \left\{\begin{array}{c} [\lambda]\left\{(1-\theta)\left[\lambda^A F + \left(1-\lambda^A\right)N(z)\right] + \theta\left[\lambda^B F + \left(1-\lambda^B\right)N(z)\right]\right\} \\ +[1-\lambda]\left\{\theta\left[\lambda^A F + \left(1-\lambda^A\right)N(z)\right] + (1-\theta)\left[\lambda^B F + \left(1-\lambda^B\right)N(z)\right]\right\} \end{array}\right\}$$

Rewrite as

$$E\left[\pi^A_{stage\_2}\right] = \lambda F + (1-\lambda)N + \theta[1-2\lambda]\left(\tfrac{\eta}{1+\eta}\right)(F-N)$$

Adding the two stage profits, using the benchmark profits and defining $\lambda\left(\frac{\eta}{1+\eta}\right)(F-N) \equiv \Omega^B$ gives

$$E\left[\pi^A_{11}\right] = E\left[\pi^A_{22}\right] - \Omega^B - C$$

Similar calculations and the definition $(1-\lambda)\left(\frac{\eta}{1+\eta}\right)(F-N) \equiv \Omega^A$ lead to

$$E\left[\pi^B_{11}\right] = E\left[\pi^B_{22}\right] - \Omega^A - C$$

■ **Subgame (1,2)** In this subgame brand A is first-mover and brand B is second-mover. First, assume that the earlycomer is a B-fan. This buyer compares the utility $az - p^A_B$ of adopting A immediately, versus the expected utility $\int_0^{az}(b)\,dG(b) + \int_{az}^1(az)\,dG(b)$ of postponing adoption until stage 2. In equilibrium, firm A induces the B-fan to adopt its brand immediately by charging the price $p^A_B = \int_0^{az}(az-b)\,dG(b)$. Note that p^A_B is nonnegative, indicating that the first-mover always can, and always will, attract the earlycomer and still make a nonnegative markup for all possible parameters of the model. Integrating this markup over all possible realizations of a shows that the associated profit equals N. In a similar fashion it can be shown that the price needed to attract an A-fan is nonnegative as well. In this case the first-mover makes a profit of F. The reason for the first-mover always attracting the earlycomer, no matter buyer types or realized quality of its good, is the second-mover's inability to commit to a certain price. So even for very low realizations of a, the earlycomer's option value of postponing adoption becomes accordingly small.

It has now been established that the first-mover always wins the earlycomer. The resulting expected profit level becomes $E\left[\pi^A_{stage\_1}\right] = \lambda\phi F + (1-\lambda)\phi N$. At stage 2, firm A's probability of meeting a fan equals λ^A, and the expected profit becomes $E\left[\pi^A_{stage\_2}\right] = \lambda^A F + \left(1-\lambda^A\right)N$. In sum, the total expected profit becomes

$$E\left[\pi^A_{12}\right] = E\left[\pi^A_{22}\right] + \Omega^A - C$$

The expected profit of the second-mover equals $E\left[\pi^B_{12}\right] = \left(1-\lambda^A\right)F + \lambda^A N$. Defining $(1-\lambda)\phi F + \lambda\phi N \equiv \Psi^B$ gives

$$E\left[\pi^B_{12}\right] = E\left[\pi^B_{22}\right] - \Psi^B - \Omega^A$$

■ **Subgame (2,1)** By symmetry, expected profits in subgame (2,1) become

$$E\left[\pi_{21}^{A}\right]=E\left[\pi_{22}^{A}\right]-\Psi^{A}-\Omega^{B}$$

where $\lambda\phi F+(1-\lambda)\,\phi N\equiv\Psi^{A}$

$$E\left[\pi_{21}^{B}\right]=E\left[\pi_{22}^{B}\right]+\Omega^{B}-C$$

Appendix B

To assess the efficiency of the actions taken by the private firms, this section derives the welfare levels resulting from each subgame. Welfare equals the value of the good adopted by the consumer. The social planner is assumed to care about the economy as a whole, not whether welfare comes as firms' profits or consumers' surpluses. One should expect that the social planner always prefers that both firms enter at the market late as this equilibrium not only involves no wasted time to market costs, no time to market costs are wasted. In fact, late entry of firms not only saves the cost of R&D but also reduces the potential loss if the earlycomer adopts an inferior product at stage 1.

■ **Subgame (2,2)** Consider the welfare created through the consumption by a B-fan who adopts product B if $b>az$; otherwise he prefers technology A. Let W^{j} represent welfare conditional on realizing a buyer of type j.

$W^{B}=\int_{0}^{1}\int_{0}^{az}(az)\,dG(b)\,dG(a)+\int_{0}^{1}\int_{az}^{1}(b)\,dG(b)\,dG(a)=\int_{0}^{1}bdG(b)+N$

Likewise, the adoption decision of an A-fan leads to an expected welfare of size

$W^{A}=\int_{0}^{1}\int_{0}^{bz}(bz)\,dG(a)\,dG(b)+\int_{0}^{1}\int_{bz}^{1}(a)\,dG(a)\,dG(b)=\int_{0}^{1}adG(a)+N$

Weighting these welfare levels with the probabilities of which they occur and the quantities bought by generations, reduction leads to

$W_{22}=(1+\phi)\left\{N+\lambda\int_{0}^{1}adG(a)+(1-\lambda)\int_{0}^{1}bdG(b)\right\}$

Define $\int_{0}^{1}adG(a)=\int_{0}^{1}bdG(b)\equiv\Gamma$ being the expected quality of both products, to get

$$W_{22}=(1+\phi)(N+\Gamma)$$

■ **Subgame (1,1)** Since the expected welfare is independent of the timing of purchase, and because consumers have access to the same information on realized qualities of products, expected welfare in subgame (1,1) is similar to welfare in (2,2) except for the loss of development costs

$$W_{11}=(1+\phi)(N+\Gamma)-2C$$

■ **Subgame (1,2)** As shown in Appendix A, the earlycomer always adopts the first-mover's brand in a sequential equilibrium, making producer A face a more favorable probability distribution of fans. The resulting stage 1 welfare level becomes

$\phi\left\{\lambda\left(\int_{0}^{1}\int_{0}^{1}(a)\,dG(b)\,dG(a)\right)+(1-\lambda)\left(\int_{0}^{1}\int_{0}^{1}(az)\,dG(b)\,dG(a)\right)\right\}\Longleftrightarrow\phi\left\{\lambda\Gamma+(1-\lambda)\,z\Gamma\right\}$

The latecomer joins the network offering the higher utility, so expected welfare from stage 2 is

$\lambda^{A}\left(\int_{0}^{1}\int_{bz}^{1}(a)\,dG(a)\,dG(b)+\int_{0}^{1}\int_{0}^{bz}(bz)\,dG(a)\,dG(b)\right)$

$+ \left(1-\lambda^A\right)\left(\int_0^1 \int_0^{az} (az)\, dG(b)\, dG(a) + \int_0^1 \int_{az}^1 (b)\, dG(b)\, dG(a)\right)$
$\Leftrightarrow \lambda^A (\Gamma + N) + \left(1-\lambda^A\right)(\Gamma + N) \Longleftrightarrow \Gamma + N$
The sum of the expected welfare levels from the two stages becomes

$$W_{12} = \phi \{\lambda\Gamma + (1-\lambda) z\Gamma\} + \Gamma + N - C$$

Observe that η cancels from the welfare expression because one player's gain is exactly offset by the other player's loss. Closer substitutability between products increases welfare since the loss of consumers joining their least preferred product decreases.

■ **Subgame (2,1)** By symmetry of the problem

$$W_{21} = \phi \{(1-\lambda)(\Gamma) + \lambda z\Gamma\} + \Gamma + N - C$$

Comparison of welfare levels confirms intuition that the social planner prefers subgame (2,2) to any other subgame.

Appendix C

This Appendix contains the derivations of expected profit levels under pre-ordering. The terms F, N, Ω^A, Ω^B are defined in Appendix A.

■ **Subgame (2,2)** By assumption, word of mouth communication does not improve the popularity of brands when they are pre-ordered. For this reason no firm wants to give the earlycomer a discount in addition to the price given by the difference in (expected) brand qualities.

Assuming that the earlycomer is of type A, there are three alternatives to choose from at stage 1: 1) Pre-order brand A gives expected utility $\int_0^1 (a)\, dG(a)$. Rewrite as $\int_0^1 \int_0^1 (a)\, dG(a)\, dG(b)$. 2) Pre-order brand B gives expected utility $\int_0^1 (bz)\, dG(b)$ which can be written as $\int_0^1 \int_0^1 (bz)\, dG(b)\, dG(a)$. 3) Postpone adoption to stage 2 gives expected utility of $\int_0^1 \int_{bz}^1 (bz)\, dG(a)\, dG(b) + \int_0^1 \int_0^{bz} (a)\, dG(a)\, dG(b)$. Direct comparison shows that 3) is inferior to 1) and 2) indicating that the consumer will always choose to pre-order one of the goods. As the expected values of a and b are identical, the earlycomer values the contract of her preferred brand more highly. In this case it is an equilibrium in prices for brand B to offer the A-fan its product at cost, while firm A charges a price that soaks up the excess value it offers over brand B. Formally, this price p_A^A equals
$\int_0^1 \int_0^1 (a)\, dG(a)\, dG(b) - p_A^A \geq \int_0^1 \int_0^1 (bz)\, dG(b)\, dG(a)$
$\Leftrightarrow \int_0^1 \int_0^1 (a)\, dG(a)\, dG(b) - p_A^A \geq \int_0^1 \int_0^1 (bz)\, dG(a)\, dG(b)$
$\Leftrightarrow \int_0^1 \int_0^1 (a - bz)\, dG(a)\, dG(b) \geq p_A^A \Longleftrightarrow F - N \geq p_A^A$

In equilibrium, the inequality becomes an equality. As $F \geq N$ for all $z \leq 1$ the left hand side is nonnegative, suggesting that a firm can always profitably attract a fan. I would like to point out that this fact contrasts the original formulation of the model, in which a firm wins a fan if and only if it offer the higher surplus. Symmetry of the game implies that firm B is pre-ordered by a B-fan at a price of $p_B^B = F - N$. Prices charged to the latecomer at stage 2 are the same as in the original game. The resulting expected profit levels in subgame (2,2) with pre-ordering become

$$E\left[\pi_{22}^A\right] = \lambda\phi(F - N) + \lambda F + (1-\lambda) N$$

$$E\left[\pi_{22}^{B}\right]=(1-\lambda)\,\phi\,(F-N)+(1-\lambda)\,F+\lambda N$$

■ **Subgame (1,1)** Payoffs in this subgame are the same as in the original game as it does not involve pre-ordering because both products are available at stage 1. Expected profit levels of the firms

$$E\left[\pi_{11}^{A}\right]=\lambda\,(1+\phi)\,F+(1-\lambda)\,(1+\phi)\,N-\Omega^{B}-C$$

$$E\left[\pi_{11}^{B}\right]=(1-\lambda)\,(1+\phi)\,F+\lambda\,(1+\phi)\,N-\Omega^{A}-C$$

■ **Subgame (1,2)** The zero-sum nature of popularity, in much the same way as in Appendix A, that the discount given by firm A for increasing its popularity, is identical to the discount given by firm B to avoid becoming less popular. As both firms are willing to offer the same discount, the winning firm remains the one valued more highly by the earlycomer, but price competition forces the winning firm to give the full discount to the earlycomer, as the rival could make a profitable undercut. In equilibrium, the price charged by the winning firm equals the excess in value offered minus the full discount. For subgame (1,2) the discount equals $\left(\lambda^{A}-\lambda\right)F+\left(1-\lambda^{A}-1+\lambda\right)N\Longleftrightarrow\Omega^{A}$. Discounts given by the winning firm are included in the expected profit equations, but will be ignored in the following derivations for the sake of clarity.

Assume that the earlycomer is a B-fan. He has the following three choices at stage 1: 1) Buying brand A now has a value of az. 2) Pre-order brand B has value $\int_{0}^{1}(b)\,dG(b)$. 3) Postpone adoption gives $\int_{az}^{1}(az)\,dG(b)+\int_{0}^{az}(b)\,dG(b)$. Direct comparison shows that 3 is inferior to both 1 and 2, suggesting that the buyer never postpones adoption. Comparison of 1 and 2 reveals that the B-fan will adopt brand A immediately if and only if $\int_{0}^{1}(az-b)\,dG(b)>0$. The inequality holds whenever $az>b$. In Appendix A the probability of this event was defined as θ. The B-fan pre-orders brand B with the residual probability, $(1-\theta)$. Provided that $az>b$ holds, the expected price earned by firm A on the B-type earlycomer equals $\int_{0}^{az}(az-b)\,dG(b)$. The resulting expected profit is $\int_{0}^{1}\int_{0}^{az}(az-b)\,dG(b)\,dG(a)$. This is identical to the expected profit of meeting a nonfan, N. Whenever $az<b$ then the B-fan prefers to pre-order brand B, and in a similar manner it can be shown that the expected profit made by firm B becomes $\int_{0}^{1}\int_{az}^{1}(b-az)\,dG(b)\,dG(a)$. This equals fan profit, F. Symmetric arguments imply that firm A makes an expected profit of F when the earlycomer is a fan, in which case firm B should expect to earn N. Now use the expected profits made on the earlycomer alone (without discounts) to construct profits equations for the subgame as a whole. For firm A the expected profit earned in subgame (1,2) equals

$$\begin{aligned}E\left[\pi_{12}^{A}\right]=&\ \lambda\phi\left\{\int_{0}^{1}\int_{bz}^{1}\left[a-bz-\tfrac{1}{\phi}(1-\lambda)\left(\tfrac{\eta}{1+\eta}\right)(F-N)\right]dG(a)\,dG(b)\right\}\\&+(1-\lambda)\,\phi\left\{\int_{0}^{1}\int_{0}^{az}\left[az-b-\tfrac{1}{\phi}(1-\lambda)\left(\tfrac{\eta}{1+\eta}\right)(F-N)\right]dG(b)\,dG(a)\right\}\\&+\lambda\,(1-\theta)\left\{\lambda^{A}F+\left(1-\lambda^{A}\right)N\right\}+\lambda\theta\left\{\lambda F+(1-\lambda)\,N\right\}\\&+(1-\lambda)\,(1-\theta)\left\{\lambda F+(1-\lambda)\,N\right\}+(1-\lambda)\,\theta\left\{\lambda^{A}F+\left(1-\lambda^{A}\right)N\right\}-C\end{aligned}$$

This reduces to

$$E\left[\pi_{12}^{A}\right]=\lambda\,(1+\phi)\,F+(1-\lambda)\,(1+\phi)\,N-C$$

For firm B the expected profit can be expressed as

$$
\begin{aligned}
E\left[\pi_{12}^{B}\right] = {} & (1-\lambda)\,\phi\left\{\int_0^1\int_{az}^1\left[b-az-\tfrac{1}{\phi}(1-\lambda)\left(\tfrac{\eta}{1+\eta}\right)(F-N)\right]dG(b)\,dG(a)\right\} \\
& +\lambda\phi\left\{\int_0^1\int_0^{bz}\left[bz-a-\tfrac{1}{\phi}(1-\lambda)\left(\tfrac{\eta}{1+\eta}\right)(F-N)\right]dG(a)\,dG(b)\right\} \\
& +\lambda(1-\theta)\left\{\left(1-\lambda^{A}\right)F+\lambda^{A}N\right\}+\lambda\theta\left\{(1-\lambda)F+\lambda N\right\} \\
& +(1-\lambda)(1-\theta)\left\{(1-\lambda)F+\lambda N\right\}+(1-\lambda)\theta\left\{\left(1-\lambda^{A}\right)F+\lambda^{A}N\right\}
\end{aligned}
$$

This reduces to

$$E\left[\pi_{12}^{B}\right]=(1-\lambda)(1+\phi)F+\lambda(1+\phi)N-\Omega^{A}$$

■ **Subgame (2,1)** Symmetry of the game implies

$$E\left[\pi_{21}^{A}\right]=\lambda(1+\phi)F+(1-\lambda)(1+\phi)N-\Omega^{B}$$

$$E\left[\pi_{21}^{B}\right]=(1-\lambda)(1+\phi)F+\lambda(1+\phi)N-C$$

Where the discount given by the winning firm in this subgame equals Ω^{B}.

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- http://www.forbrug.dk/english/ - Homepage of the Danish Consumers' Ombudsman.
- http://www-03.ibm.com/ibm/history/history/year_1970.html - An overview of IBM's business history.
- http://www.nyc.gov/html/dca/html/about/about.shtml - New York City Department of Consumer Affairs.
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