Innovation Preannouncement and Entry in a Vertically Differentiated Industry

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Abstract

When considering the preannouncement of the market introduction of a newly developed, durable good, an innovative firm faces a trade-off. By announcing early, the firm can prevent the loss of potential demand before the launch of its product. At the same time, the incumbent firm learns about the market introduction and has the opportunity to take preemptive actions against the innovative firm. This analysis shows under which industry conditions an innovative firm can be expected to preannounce its product launch into a vertically differentiated industry. Welfare considerations indicate that consumers would not necessarily be better off if the information about future product generations would be common knowledge and that there might even be situations in which they would prefer product preannouncements to be banned completely.

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1 Introduction

In durable good industries with fast technological progress, consumers are faced with the intertemporal choice between subsequent product generations. Buying the presently available product entails the risk of early economic obsolescence due to an immediately afterwards upcoming innovation. This potential loss has to be traded off with the expected cost of waiting for a better technology.[1] Product preannouncements are an appropriate and widely observed strategy for innovating firms to increase the expected value of waiting for the consumers and prevent the loss of potential future demand. For example, Volkswagen announced the arrival of its new beetle car three years in advance and one year before its availability, they already had 70.000 orders from waiting customers.

Nevertheless, such advance communications may not always be entirely beneficial to the innovative firm. Although they are directed to inform potential customers, the message will obviously reach incumbent competitors, too. And as many markets with fast technological progress are dominated by firms with a certain degree of temporary market power, strategic interaction is most probable as the following examples from the video game market demonstrates.

In 1988, Sega introduced its 16-bit-Mega Drive home video system which was at that time a large innovation step beyond the existing 8-bit systems. They sold the console for $190 and games were priced between $40 and $70. Nintendo, Sega's closest competitor, reacted and gave its customers a reason to wait by preannouncing their own new 16-bit system. As an immediate response to this, Sega started offering their system in bundle with one game for $150. One year later, Nintendo entered the market and soon prices dropped under $100.[2]

The 32-bit generation of game consoles was announced by the new entrant Sony in 1994. The year before its actual launch in 1995 was the poorest in terms of sales figures of the whole industry history since consumers were waiting for the new technology to arrive.[3]

Finally, in the end of 1995, Nintendo preannounced the launch of its 64-bit console machine in autumn 1996. From the day of the announcement

[1] The same reasoning and all other arguments of this work can also be applied to products with some kind of switching costs or network externalities. In fact, the assumption of this work that consumers can buy a durable good only once in their lifetime is equivalent to prohibitively high switching costs.

[2] For more details see Brandenburger & Nalebuff (1995), p.237-242.

[3] see 'Power games', Marketing Week: London; May 19, 1995.

until its introduction the prices of Sega's and Sony's 32-bit systems dropped from \$299 to \$149.[4]

Another well-known and well-reported preannouncement story, the Control Data anti-trust case in 1967 is another example for the severity of strategic reactions. The sales of the computer manufacturer Control Data suffered tremendously when IBM announced the arrival of its new and largely superior System/360 model in 1964 which was finally not available before 1967. But the immense price cuts that Control Data had to offer to attract customers, induced them to bring an anti-trust charge against IBM.[5]

With the use of preannouncements, firms can retain customers from buying substitute products and thus preserve their own potential demand until the period of product introduction. At the same time, as the examples above show, this advance information spills over to the incumbent competitor and gives him the opportunity for an additional strategic move before the innovative firm's entry.

The aim of the present paper is to analyse the strategic role of innovation preannouncements in an imperfectly competitive market setting. It will be shown how the described trade-off affects the announcement behaviour of an innovative firm in the context of a vertically differentiated market with overlapping consumer generations. We analyse situations in which the preannouncement of a new, superior technology by an outside firm gives the incumbent monopolist incentives for preemptive price cuts in the pre-entry period in order to attract consumers before the availability of the new product. The main results can be summarised as follows. The probability that an innovating firm will preannounce its product is high, if

- the innovation step beyond the existing technology is sufficiently large,
- time between preannouncement and launch is short (or the consumers are impatient),
- the average consumers' valuation for quality is rather low and/or
- consumers are more heterogeneous with respect to their valuation of quality.

At a first glance, the welfare results of the model are somewhat surprising. From the consumers' point of view, the market can produce *too few* or *too*

[4] see 'Sony and Sega plan price cuts to torpedo Nintendo 64 launch', *Marketing Week*: London; July 26, 1996.

[5] Fisher & McGowan & Greenwood (1985) devote a whole book to the IBM/Control Data case taking place between 1960 and 1980.

many preannouncements. While the under-provision of information seems obvious given a preemptive reaction by an incumbent, the over-provision result stems from the consumers' trade-off between efficient *information transmission* and *market contestability*. Preannouncements of new products entail efficient information transmission and an efficient matching between consumers and product generations over time. By contrast, with the entrant's use of preannouncements, markets lose the threat of entry in periods where there is no innovation and the incumbent regains market power. We show that consumers would prefer a ban on preannouncements in situations in which the upcoming innovation step is of an intermediate size and ex ante expectations about its introduction are rather high.

The previous work dealing with preannouncements of strategies mainly analyses problems related to commitment effects. Henkel (1996) studies games in which in an announcement stage each player commits partly to a strategy. The degree of commitment is endogenous and individually chosen and later deviation from the announcement is costly. The author finds that in the case of strategic complements in the basic game the introduction of the announcement stage induces the players to commit partly and thus supports collusion. Caillaud et al. (1995) analyse precommitment effects through public announcements of contracts between principals and their agents, when contracts can be secretly renegotiated. Crawford & Sobel (1982) show that announcements without any direct influence on the payoffs ('cheap talk') can be relevant in games with private information. Farrell (1987) does the same for games in which there is a coordination problem.

The present paper departs from this strand of literature with the somewhat extreme assumption that the preannouncement of the innovation is fully credible, i.e. the innovative firm can perfectly commit to timing and quality of the new product. In other words, we completely abstract from any kind of untruthful preannouncement that might lead to 'vaporware'-products. We think that this is appropriate since it allows us to concentrate on the 'strategic reaction'-effect of preannouncements without affecting the qualitative nature of our results (see the last section for a further discussion).

With this assumption, our work is much closer to some other studies. Farrell & Saloner (1986) analyse the effect of preannouncements on the adoption of a new incompatible good in the presence of network externalities. In this context, preannouncements make the adoption of the new technology more likely which *can* be socially desirable. A major drawback of their model is that it does not consider strategic pricing but assumes a competitive supply of the old and the new technology. Yin (1995) presents a study, in which an innovating firm can announce the quality of its product early or late. Delaying the announcement means that the competitor has to set its own quality on the basis of the distribution of the possible innovation outcomes. In this model, the innovator has no incentive to announce early and the results are straightforward: Although the early announcement policy is socially desirable, it is not supported in the equilibrium. Gerlach (1999) analyses the preannouncement behaviour of a monopolist. Announcing a superior technology cannibalises the present sales of the old technology if consumers have some kind of switching costs. The author shows that monopolists may have an incentive not to preannounce in order to make consumers buy the old *and* switch to the new product afterwards. Furthermore, this work analyses the rationale behind 'vaporware', i.e. products that are announced although they will knowingly not be available at the promised date.

Our work also relates to the literature on information exchange among firms and their impact on competition. Kühn & Vives (1995) provide quite general conditions including the type of competition and the nature of uncertainty under which firms have an incentive to share information about cost or demand. The scenario that comes closest to our model is Bertrand competition with private value cost uncertainty in which firms typically have no incentives to share information. In this paper, however, innovations are preannounced in order to influence consumers' decisions.

The organisation of the paper is along the dynamic structure of the presented game-theoretical model starting from backwards. The following section presents the basic assumptions of the model. Section III is devoted to the second period market results with and without innovation while section IV looks at the first period pricing behaviour of the incumbent and the purchase decision of the consumers. The next two sections respectively analyse the preannouncement behaviour of the innovating firm and its welfare implications. Finally, section VII concludes with the discussion of the proposed framework, some robustness checks and possible extensions. Note that all proofs are delegated to the appendix.

2 The Model

We consider a simple two period model of a vertically differentiated industry in the spirit of Gabszewicz & Thisse (1979) and Shaked & Sutton (1982, 1983). In every period, $t = 1, 2$, a cohort of consumers who only differ in their taste for quality θ, will enter the market. Though the valuation of a consumer is only known to himself, it is common knowledge that the taste parameter is uniformly distributed on $[a - h, a + h]$. The parameter a can be interpreted as the average valuation of consumers for quality, while h reflects the degree of heterogeneity of the consumer population. We normalise the mass of consumers in each cohort to 1 and we will submit the distribution parameters to the following restriction:

$$a \geq 5h. \tag{1}$$

This condition states that consumers' tastes are not too heterogeneous with respect to the average valuation of the population and it ensures us covered market equilibria in both periods. In the considered time span, every consumer can afford to buy at most one unit of the durable good. This means for cohort 1 consumers that switching from a product they bought in the first period to another in period 2 is prohibitively costly.[6]

On the supply side, we consider two firms, an incumbent monopolist, referred to as firm 1, and a potentially innovating outside firm 2. While the incumbent offers in both periods product 1 of quality q_1, firm 2 conducts R&D to develop a superior technology. This innovation process is stochastic, though the R&D investment decision is not explicitly modelled. With probability ρ_0, the next step on an imaginary quality ladder is done and the resulting product is of a given quality $q_2 > q_1$. In the "no innovation" event (with probability $1 - \rho_0$), the only available quality is q_1, which prevents firm 2 from entering the market as there are entry cost of $\varepsilon > 0$. For simplicity, both firms are assumed to produce at zero marginal costs. Firms and consumers have rational expectations, are risk neutral and discount future revenues using discount factors $0 \leq \delta \leq 1$ per period. Finally, it will be convenient to use $\Delta := \frac{q_2 - q_1}{q_1}$ as a measure for the size of the upcoming innovation step.

The time structure of the model is as follows (cf. 1). Before period 0, nature moves and firm 2 succeeds with probability ρ_0 in developing the new product which can be introduced to the market as soon as period 2.[7] In the innovation case, firm 2 can decide whether to preannounce the product or not.[8] In period 1, the incumbent firm offering a product of quality q_1 and the first cohort consumers use the preannouncement signal to update their prior beliefs and form expectations about the market outcome in period 2. After the incumbent monopolist has set a price p, consumers can either purchase good q_1 in $t = 1$ or wait for the second period. If there is no new product

[6] We will relax this assumption in section 7.

[7] Think of the delay as the time for testing the product, preparing mass production and negotiate distribution channels.

[8] Notice that, this choice is only to be made in the innovation subgame since in this simple two period framework, untruthful preannouncements make no sense for firm 2. See section 7 for a discussion of this assumption.

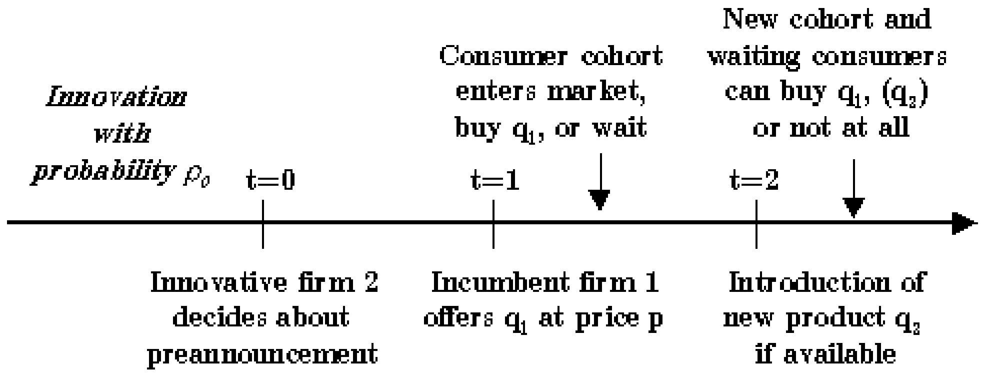

Figure 1: Time structure of the model

introduced in $t = 2$, firm 1 keeps on selling the old product at a price p_1^M, whereas the entry of firm 2 results in a duopoly in which firms set prices (p_1^D, p_2^D). The waiting first cohort and the entering second cohort consumers can buy product q_1, q_2 (if available) or not all (the value of the outside option is normalised to 0). In order to keep matters as simple as possible, we exclude transactions via a resale market and any depreciation of the durable good.

With these assumptions, a consumer θ, who buys product q_1 in period 1, derives an overall net utility of

$$U_{11}(\theta) = \theta q_1 - p + \delta\theta q_1, \tag{2}$$

where U_{ij} denotes the utility of consuming product i in period 1 and j in period 2. The expected net utility of waiting (this first period option is denoted by 0) and buying product q_j, $j = 1, 2$, in period 2 is

$$E[U_{0j}(\theta)] = \delta\theta q_j - \delta E[p_j]. \tag{3}$$

We will look for Perfect Bayesian equilibria of this game and start our analysis by looking at the second period market outcome taking into consideration the first cohort consumers that decided to wait. Then we turn to the first period and assume that the market participants rationally anticipate the future market constellations. In the case of an innovation announcement, priors are updated to one and there is complete certainty about the upcoming launch of a new product. If there is no announcement, beliefs can also be reconsidered since no communication can mean that either there is no innovation or that it is not profitable for the firm to preannounce it. Finally, we look at the announcement decision of the innovating firm who rationally expects the behaviour of her competitor and the consumers.

3 The Second Period

In the last period, the entering second cohort consumers join the waiting first cohort consumers which results in some aggregate (non-cumulative) distribution function. As it will turn out in the next section, we can confine ourselves to two possible outcomes. Either, low-valuation consumers in the interval $[a-h, x]$, with $a-h \leq x \leq a+h$, have decided to wait for the second period and the aggregate density function will be

$$f_I^{agg}(\theta, x) = \begin{cases} 2 & \text{if } a-h \leq \theta \leq x, \\ 1 & \text{if } x < \theta < a+h, \end{cases}$$

Or, high-valuation consumers in $[y, a+h]$, with $a-h \leq y < a+h$, stay in the market until period 2, yielding

$$f_{II}^{agg}(\theta, y) = \begin{cases} 1 & \text{if } a-h \leq \theta \leq y, \\ 2 & \text{if } y < \theta < a+h, \end{cases}$$

Together with these two possible consumer populations (x or y are endogenously determined in the first period), we have to consider two market structures, depending on the success of the R&D process. If the new product is not available, firm 1 keeps its monopolistic position and offers a product of quality q_1 at a price p_1. As the second period net utility of a consumer θ is given by $\theta q_1 - p_1$, the consumer who is indifferent between buying and the outside option of value 0 is at $\frac{p_1}{q_1}$. With $f_I^{agg}(\theta, x)$, the monopolist faces a second period demand

$$D_I^M(p_1, x) = \begin{cases} (x-(a-h)) + 2h & \text{if } p_1 \leq (a-h)q_1, \\ (x - \frac{p_1}{q_1}) + (a+h-\frac{p_1}{q_1}) & \text{if } (a-h)q_1 \leq p_1 \leq xq_1, \\ Min\{a+h-\frac{p_1}{q_1}, 0\} & \text{if } p_1 \geq xq_1. \end{cases}$$

For low prices the monopolist serves all or at least some of the waiting consumers. If $p_1 > xq_1$ he only sells to cohort 2 consumers with a high valuation. The demand function is continuous, piecewise linear and convex since its slope in $[(a-h)q_1, xq_1]$ is higher than in regime with $p_1 > xq_1$. These properties translate into a profit function $p_1 D_I^M(p_1, x)$ which may have two peaks. Nevertheless, it is straightforward to show that the slope of the profit function is negative for all $p_1 \geq (a-h)q_1$ as long as $a \geq 3h$ (see proof of Lemma 1 in the appendix). Thus, we have

Lemma 1 *Given demand $D_I^M(p_1, x)$ and for all $a \geq 3h$, a monopolist offering a product of quality q_1, optimally chooses $p_1^M = (a-h)q_1$ and serves all consumers in the market.*

If the consumer population is given by $f_{II}^{agg}(\theta, y)$, the demand function is

$$D_{II}^M(p_1, y) = \begin{cases} (a+h-y)+2h & \text{if } p_1 \leq (a-h)q_1, \\ (a+h-y)+(a+h-\frac{p_1}{q_1}) & \text{if } (a-h)q_1 \leq p_1 \leq yq_1, \\ Min\{2(a+h-\frac{p_1}{q_1}), 0\} & \text{if } p_1 \geq yq_1. \end{cases}$$

If the waiting consumers are on the upper end of the taste scale, the demand gets a concave shape and incentives to set low prices become weaker since they would have to be applied over a larger mass of high valuation consumers. The corresponding profits are single-peaked and it can be shown that

Lemma 2 *For all $a \geq 5h$, a monopolist that faces $D_{II}^M(p_1, y)$ sets $p_1^M = (a-h)q_1$ and serves all consumers in the market.*

The intuition for these two lemmas is straightforward. In Lemma 1, there is an additional mass of low valuation consumers that gives the monopolist a strong incentive to decrease the price in order to serve all consumers. On contrary, if the bulk of consumers is on the upper end of the taste scale, firm 1 is inclined to raise its price and give up some of the low-valuation consumers. But as Lemma 2 shows, this is not optimal as long as (1) holds.

Let us now turn to the case in which the outside firm introduces the new product of quality q_2 in the second period and both firms play a simultaneous Nash equilibrium in prices. As long as all consumers derive a positive net utility, the indifferent consumer between buying q_1 at p_1 and q_2 at p_2 is at $\frac{p_2-p_1}{q_2-q_1}$. Consider first a population $f_I^{agg}(\theta, x)$ and the demand for the low-quality product $D_{I1}^D(p_1, p_2, x)$. For sufficiently low prices p_1, firm 1 attracts all cohort 1 consumers and high valuation consumer of cohort 2. For higher prices some waiting cohort 1 consumers start to switch to the high quality product. Define $\Delta q := (q_2 - q_1)$ and $\Delta p =: (p_2 - p_1)$, then

$$D_{I1}^D(p_1, p_2, x) = \begin{cases} (x-a+h)+2h & \text{if } \Delta p > (a+h)\Delta q, \\ (x-a+h)+(\frac{\Delta p}{\Delta q}-a) & \text{if } x\Delta q \leq \Delta p \leq (a+h)\Delta q, \\ Min\{2(\frac{\Delta p}{\Delta q}-a+h), 0\} & \text{if } \Delta p < x\Delta q. \end{cases}$$

Note again that this demand schedule is piecewise linear and concave because firm 1 serves with a relatively high price the high-density segment of the consumer distribution. The corresponding profits are therefore single-peaked and one gets five candidate solutions to the profit maximisation problem given a price p_2 of the high-quality firm, three corner solutions and two interior solutions. Accordingly, the best response function for firm 1 consists of five parts

$$R^D_{I1}(p_2, x) = \begin{cases} 0 & \textit{if } p_2 \le \widetilde{p}_1, \\ \frac{1}{2}[p_2 - (a-h)\Delta q] & \textit{if } \widetilde{p}_1 \le p_2 \le \widetilde{p}_2, \\ p_2 - x\Delta q & \textit{if } \widetilde{p}_2 \le p_2 \le \widetilde{p}_3, \\ \frac{1}{2}[p_2 - (2a - 2h - x)\Delta q] & \textit{if } \widetilde{p}_3 \le p_2 \le \widetilde{p}_4, \\ p_2 - (a+h)\Delta q & \textit{if } p_2 > \widetilde{p}_4, \end{cases}$$

with $\widetilde{p}_1 := (a-h)\Delta q, \widetilde{p}_2 := (2x - a + h)\Delta q$, $\widetilde{p}_3 := (2a - 2h - 3x)\Delta q$ and $\widetilde{p}_4 := (4h + x)\Delta q$. This reaction functions is continuous, piecewise linear and monotonically increasing in p_2.

The demand of the high-quality firm faced with a consumer distribution $f^{agg}_I(\theta, x)$ is

$$D^D_{I2}(p_1, p_2, x) = \begin{cases} Min\{(a + h - \frac{\Delta p}{\Delta q}), 0\} & \textit{if } \Delta p > x\Delta q, \\ (x - \frac{\Delta p}{\Delta q}) + (a + h - \frac{\Delta p}{\Delta q}) & \textit{if } (a-h)\Delta q \le \Delta p \le x\Delta q, \\ (x - a + h) + 2h & \textit{if } \Delta p < (a-h)\Delta q. \end{cases}$$

This function is convex and the corresponding profit function can have two peaks. Nevertheless, as long as $a \ge 3h$, the marginal profits are negative for all $p_2 \ge p_1 + (a-h)(q_2 - q_1)$. Thus, the best response function is simply

$$R^D_{I2}(p_1, x) = p_1 + (a-h)(q_2 - q_1).$$

Solving for the Nash equilibrium, we get

Lemma 3 *Consider a simultaneous price setting duopoly with a high quality firm q_2, a low quality firm q_1 and the consumer population $f^{agg}_I(\theta, x)$ given above. For $a \ge 3h$, the unique Nash equilibrium in prices is given by $p^*_1 = 0$ and $p^*_2 = (a-h)(q_2 - q_1)$. The high-quality firm serves all consumers in the market.*

This equilibrium with one active firm is mainly due to the assumption that the consumers are not too heterogeneous with respect to the taste parameter. Additionally, if the mass of low-valuation consumers is large, the firm with the high quality good has an even stronger incentive to serve all consumers by driving the low-quality supplier out of the market.

If firms are confronted with a $f_{II}^{agg}(\theta, y)$ population, the respective demand function of firm 1 is

$$D_{II1}^{D}(p_1, p_2, y) = \begin{cases} (a+h-y)+2h & \textit{if } \Delta p > (a+h)\Delta q, \\ (\frac{\Delta p}{\Delta q} - y) + (\frac{\Delta p}{\Delta q} - a + h) & \textit{if } (a+h)\Delta q \geq \Delta p \geq y\Delta q, \\ Min\{(\frac{\Delta p}{\Delta q} - a + h), 0\} & \textit{if } \Delta p < y\Delta q. \end{cases}$$

This convex demand schedule leads to a profit function that has two peaks for some values of p_2. And this is reflected in a discontinuity in the best response pattern of firm 1:

$$R_{II1}^{D}(p_2, y) = \begin{cases} 0 & \textit{if } p_2 < \widetilde{p}_1 \\ \frac{1}{2}[p_2 - (a-h)\Delta q] & \textit{if } \widetilde{p}_1 \leq p_2 \leq \widetilde{p}_5, \\ \frac{p_2}{2} - \frac{y+a-h}{4}\Delta q & \textit{if } \widetilde{p}_5 \leq p_2 \leq \widetilde{p}_6, \\ p_2 - (a+h)\Delta q & \textit{if } p_2 > \widetilde{p}_6, \end{cases}$$

with $\widetilde{p}_5 := (y + \frac{y-a}{\sqrt{2}})\Delta q$ and $\widetilde{p}_6 := \frac{1}{2}(3a + 5h - y)\Delta q$. This best response has a discontinuity at $p_2 = \widetilde{p}_6$, where the low-quality firm is indifferent between serving some of the bigger mass of high-valuation consumers at a low price and serving only low-valuation consumers from cohort 2 at a rather high price.

If high-valuation consumers wait for the second period, the demand of firm 2 is

$$D_{II2}^{D}(p_1, p_2, y) = \begin{cases} Min\{2(a+h-\frac{\Delta p}{\Delta q}), 0\} & \textit{if } \Delta p > y\Delta q, \\ (a+h-y) + (a+h-\frac{\Delta p}{\Delta q}) & \textit{if } y\Delta q \geq \Delta p \geq (a-h)\Delta q, \\ (a+h-y)+2h & \textit{if } \Delta p < (a-h)\Delta q. \end{cases}$$

Equivalently to a monopolist, the high-quality firm has less of an incentive to serve all consumers when the bulk of waiting cohort 1 customers is on the upper end of the taste scale. Nevertheless, it is shown in the appendix that

Lemma 4 *Consider a simultaneous price setting duopoly with the consumer population $f_{II}^{agg}(\theta, y)$ given above. For $a \geq 5h$, the unique Nash equilibrium in prices is given by $p_1^* = 0$ and $p_2^* = (a-h)(q_2 - q_1)$. The high-quality firm serves all consumers in the market.*

As for the monopolist, the duopolist has an incentive to serve even the consumer with the lowest valuation as long as average valuation is sufficiently large relative to consumer heterogeneity. Therefore, condition (1) ensures us that in the second period only one firm will be active in the market, the monopolist in the no innovation event or the innovator otherwise. Furthermore, all waiting consumers will be served in equilibrium at a price that equals the valuation (differential valuation) of the consumer with the lowest θ.

4 First Period

After firm 2 had the opportunity to preannounce the new product in t=0, the incumbent firm and the cohort 1 consumers update their initial belief ρ_0 to $\widetilde{\rho}$. With this information consumers weight the second period results of Lemma 1 to 4 and decide whether to buy product q_1 and leave the market or to wait for the last period. The net utility of the first alternative is given by $U_{11}(\theta)$ from Eq. (2). The expected utility of waiting $E[U_0(\theta)]$ depends on the expected second period purchase and amounts to

$$\begin{aligned} E[U_0(\theta)] &= \widetilde{\rho}E[U_{02}(\theta)] + (1-\widetilde{\rho})E[U_{01}(\theta)] \\ &= \widetilde{\rho}[\delta\theta q_2 - \delta p_2^D] + (1-\widetilde{\rho})[\delta\theta q_1 - \delta p_1^M] \\ &= \widetilde{\rho}\delta[\theta q_2 - (a-h)(q_2-q_1)] + (1-\widetilde{\rho})\delta[\theta q_1 - (a-h)q_1]. \end{aligned} \tag{4}$$

Note that both in the innovation and the no innovation event, all consumers expect a positive net utility in the second period. Further, although the duopoly price of the high quality good increases with the quality difference $(q_2 - q_1)$, every consumer benefits from a larger innovation step.Figure

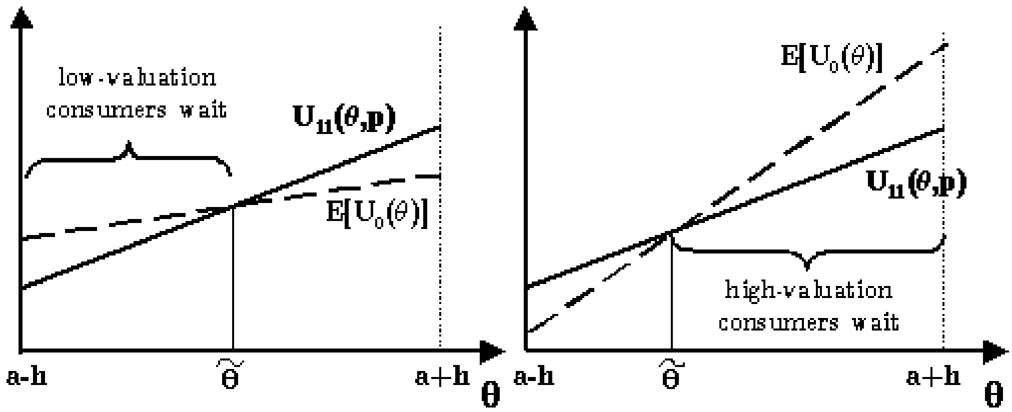

Figure 2: (Indirect) utility functions for $\Delta \leq \frac{1}{\widetilde{\rho}\delta}$ (left) and for $\Delta > \frac{1}{\widetilde{\rho}\delta}$ (right)

2 depicts the indirect utility of the two alternatives as a function of the consumers' taste parameter θ. Two parameter regimes have to be distinguished. If $\Delta \leq \frac{1}{\widetilde{\rho}\delta}$, the slope of $U_{11}(\theta)$ is larger than the slope of $E[U_0(\theta)]$, implying that high-valuation consumers are more inclined to buy in the first period than low-valuation consumers. If $\Delta > \frac{1}{\widetilde{\rho}\delta}$, the expected quality of the second period purchase is sufficiently high to make the high-valuation consumers more patient than the low-valuation consumers.

In both cases, one gets the position of the consumer who is just indifferent between buying q_1 in period 1 and waiting for the second period, by setting equal (2) and (4). This yields

$$\widetilde{\theta}(p) = \frac{p - (a-h)\widetilde{\rho}\delta(q_2 - q_1) - (1-\widetilde{\rho})(a-h)\delta q_1}{q_1 - \widetilde{\rho}\delta(q_2 - q_1)}. \quad (5)$$

This threshold value determines the composition of the demand for the incumbent's product. If $\Delta \leq \frac{1}{\widetilde{\rho}\delta}$, all consumers in $[\widetilde{\theta}(p), a+h]$ will buy q_1 in the first period and leave the market. The remaining first cohort consumers wait for the second period, generating a consumer population $f_I^{agg}(\theta, x = \widetilde{\theta}(p))$. Thus, the incumbent's demand from cohort 1 consumers is split into a certain first period demand and an expected second period demand that depends on the launch of the new technology. Hence, the incumbent's profit function for this parameter regime (referred to as regime I) takes the following form

$$\Pi_1^I(p, \widetilde{\rho}) = p[a + h - \widetilde{\theta}(p)] + \delta(1-\widetilde{\rho})(a-h)q_1[(\widetilde{\theta}(p) - (a-h)) + 2h],$$

which he maximises for given (updated) expectations $\widetilde{\rho}$ with respect to the first period price p. Note that the incumbent serves the whole market in the first period if and only if $(1+\delta)(a-h)q_1 - p \geq E[U_0(a-h)]$ or

$$p \leq (1 + \delta - \widetilde{\rho}\delta)(a-h)q_1. \quad (6)$$

For $\Delta > \frac{1}{\widetilde{\rho}\delta}$, the discounted, expected value of the new product is higher than the 'buy and keep' value of the incumbent's product. For this reason, consumers with a higher marginal utility of quality are more willing to wait for the second period. This also means that for a given first period price p, all consumers in $[a-h, \widetilde{\theta}(p)]$ will buy q_1 and leave the market, while the upper part of the cohort will wait for the second period and generate a $F_{II}^{agg}(\theta, y = \widetilde{\theta}(p)])$ population. In this parameter regime (II), the incumbent maximises

$$\Pi_1^{II}(p, \widetilde{\rho}) = p[\widetilde{\theta}(p) - (a-h)] + \delta(1-\widetilde{\rho})(a-h)q_1[(a + h - \widetilde{\theta}(p)) + 2h], \quad (7)$$

and serves all cohort 1 consumers in the first period if and only if $(1+\delta)(a+h)q_1 - p \geq E[U_0(a+h)]$ or

$$p \leq (a + h + (a-h)\delta(1-\widetilde{\rho})q_1 - \widetilde{\rho}\delta 2h(q_2 - q_1). \quad (8)$$

Proposition 1 summarises the solution to the maximisation problem of the incumbent in both parameter regimes. Define

$$\widehat{\Delta} := \frac{a + 3h}{4h\widetilde{\rho}\delta},$$

then

Proposition 1 *For given expectations $\widetilde{\rho}$, the incumbent's optimal price in the first period is:*

$$p^* = \begin{cases} (1+\delta-\widetilde{\rho}\delta)(a-h)q_1 & \textit{if } 0 \le \Delta \le \frac{1}{\widetilde{\rho}\delta}, \\ (1+\delta-\widetilde{\rho}\delta)(a-h)q_1 - 2h(\widetilde{\rho}\delta(q_2-q_1)-q_1) & \textit{if } \frac{1}{\widetilde{\rho}\delta} \le \Delta \le \widehat{\Delta}, \\ (1+\delta-\widetilde{\rho}\delta)(a-h)q_1 - \frac{(a-h)q_1}{2} & \textit{if } \Delta > \widehat{\Delta}. \end{cases}$$

For innovation steps $\Delta \le \frac{1}{\widetilde{\rho}\delta}$, the incumbent's product has a higher expected quality than the new technology which makes it optimal for firm 1 to preempt the market with the price that makes the consumer with the lowest valuation indifferent between buying and waiting. For intermediate values of Δ (later referred to as parameter regime *II.1*), the expected value of the new technology is higher than the quality of the existing one but they are still close substitutes which implies that the incumbent has relatively low costs (in terms of a relatively high first period price p) to attract the whole market. However, if Δ exceeds the threshold value $\widehat{\Delta}$ (region *II.2*), it is no longer optimal to serve the highest valuation consumers with a lower price and the incumbent only sells to low-valuation consumers, while all consumers θ in $[\widetilde{\theta}(p^*), a+h]$ wait for the second period. The optimal price p^* decreases with a higher quality q_2 and higher expectations $\widetilde{\rho}$ since these variables make the consumers more patient and require stronger price cuts from the incumbent in order to retain demand.

To conclude this section, we will look at the impact of the incumbent's pricing strategy on the residual demand RD from cohort 1 in period 2. Plugging the optimal price from Proposition 1 into (5), one obtains

Corollary 1 *The residual demand from cohort 1 consumers is given by*

$$RD^*(\widetilde{\rho}, .) = \begin{cases} 0 & \textit{if } 0 \le \Delta \le \widehat{\Delta}, \\ 2h - \frac{(a-h)q_1}{2[\widetilde{\rho}\delta(q_2-q_1)-q_1]} & \textit{if } \Delta > \widehat{\Delta}. \end{cases}$$

In fact, in the present model, firm 2 is solely interested in the mass of cohort 1 consumers that is waiting since the price in the second period is independent of the composition of the consumer population. Corollary 1 shows that the incumbent prefers to preempt the market as long as the upcoming innovation step is not too large. For sufficiently high Δ, the mass of waiting cohort 1 consumers increases with a higher q_2, $\widetilde{\rho}$, h and δ. It decreases with a higher a.

5 The Preannouncement Decision

When considering the preannouncement decision, the innovating entrant rationally anticipates the behaviour of the incumbent in the pre-entry period and knows that his signal is used by the market participants to update their priors. In this section, we will look for Perfect Bayesian equilibria of this game, in which firm 2 chooses a cohort 1 demand maximising announcement strategy for beliefs that are updated according to Bayes' rule. Let us denote β as the probability that firm 2 preannounces an innovation. Two types of equilibria can be distinguished: no announcement ('pooling') equilibria and announcement equilibria.

In an *announcement equilibrium* (β^*=1)[9], consumers and the incumbent know that it is profitable for an entrant to preannounce its new product, i.e. they can infer from the absence of an announcement that there has been no innovation, i.e.

$$\widetilde{\rho} = E[\text{innovation} \mid \text{no announcement}] = 0. \tag{9}$$

This Bayesian updating is anticipated by the entrant who has an incentive to preannounce whenever the following condition holds

$$RD^*(\rho = 1, .) > RD^*(\rho = 0, .). \tag{10}$$

In a *pooling equilibrium* ($\beta^* = 0$), the entrant prefers not to announce the innovation. Thus, consumers and firm 1 can interpret the absence of an announcement either with the possibility that there is no innovation or with the event that the innovation is not preannounced. Their priors remain unchanged,

$$\widetilde{\rho} = E[\text{innovation} \mid \text{no announcement}] = \rho_0. \tag{11}$$

This argument yields the following necessary and sufficient condition for pooling equilibria:

$$D_2^*(\rho = \rho_0, .) \geq D_2^*(\rho = 1, .). \tag{12}$$

Proposition 2 gives the different equilibria regimes.

Proposition 2 *Depending on the size of the innovation step Δ, we get the following two types of Perfect Bayesian equilibria:*

[9] Since we do not consider the case of untruthful preannouncements, any preannouncement changes the priors to $\widetilde{\rho} = 1$.

1. $0 \leq \Delta \leq \Delta^A := \frac{a+3h}{4\delta h}$*: The innovating firm does not preannounce* (β^*=0) *and market participants hold the belief given in (11).*

2. $\Delta > \Delta^A$*: It is always profitable for the innovating firm to preannounce* (β^*=1)*; belief updating follows (9).*

Figure 4 in the next section shows the graph of the preannouncement probability β^* as a function of the new product's quality. The main comparative statics of these equilibria are summarised in the next corollary.

Corollary 2 *Comparative statics of the equilibria described in Proposition 2 yield:*

$$\frac{\partial \Delta^A(.)}{\partial a} > 0, \frac{\partial \Delta^A(.)}{\partial h} < 0, \frac{\partial \Delta^A(.)}{\partial \delta} < 0.$$

The rationale behind Corollary 2 is rather simple. Preannouncements will take place for parameter constellations at which preemption is most expensive for the incumbent. Ceteris paribus, this is true whenever the upcoming innovation step is sufficiently large or if the discount rate is high, which is equivalent to saying that time between launch and preannouncement is short for a given discount rate. Furthermore, there are more preannouncements in industries with a more heterogenous population of consumers. This holds because inframarginal rents for consumers are higher when tastes are more dispersed and this increases the value of waiting for higher quality. In the limiting case, where $h \to 0$, the incentive to preannounce disappears completely because consumers foresee that the innovating firm can appropriate all the innovation rents and this makes it easy for the incumbent to preempt the market in the pre-entry period.

By contrast, the average consumer valuation has a negative impact on the occurrence of an announcement because it raises disproportionately the value of today's purchase option compared to any expected value of future product generations. Interestingly, the initial innovation probability ρ_0 has no impact on the preannouncement behaviour of an entrant. On the one hand, a higher innovation probability increases the incentives for consumers to wait, but on the other, it makes the incumbent more aggressive in the pre-entry period. Taken together, these effects cancel out.

6 Welfare Implications

Obviously, there are two potential welfare distortions in this model. First, we have imperfect competition in both periods and second, there is an asymmetric information constellation between the potentially innovating firm and the other market participants. This section will show that in some sense a welfare maximising social planner has to trade off these two imperfections.

In order to analyse the welfare effects of the preannouncement behaviour in this second-best world, we will take the market structure as given and concentrate on the efficiency of the information transmission in the economy. Our welfare measure will be the *ex ante* expected total consumer surplus of cohort 1 which is the sum of the expected net utility of the consumers who buy product q_1 in period 1 and the expected net utility of cohort 1 consumers who buy a product of quality $q_i, i = 1, 2$, in period 2. For the computations of these measures, we have to return to the parameter regimes of Proposition 1, since each of them corresponds to a different allocation of consumers to products and periods and to a different first period price of the incumbent. Denote $E[CS_r^k(\widetilde{\rho})]$ the interim consumer surplus with $k = Inno$ $(NoIn)$ in case of an (no) innovation and $r = I, II.1$ or $II.2$ standing for the respective parameter regime.

If $0 \leq \Delta \leq \frac{1}{\widetilde{\rho}\delta}$,all consumers in $[a-h, a+h]$ buy the incumbent's product in the first period. Therefore, for given (updated) expectations $\widetilde{\rho}$, the *interim* consumer surplus for cohort 1 is the same whether there is an innovation or not, i.e.

$$E[CS_I^{Inno}(\widetilde{\rho})] = E[CS_I^{NoIn}(\widetilde{\rho})] = \frac{1}{2h}\int_a^b ((1+\delta)\theta q_1 - (1+\delta-\widetilde{\rho}\delta)(a-h)q_1)d\theta.$$

For $\frac{1}{\widetilde{\rho}\delta} < \Delta \leq \widehat{\Delta}$, all consumers of cohort 1 buy product q_1 and pay $p^* = (1 + \delta - \widetilde{\rho}\delta)(a-h)q_1 - 2h(\widetilde{\rho}\delta(q_2 - q_1) - q_1)$, this yields

$$E[CS_{II.1}^{Inno}(\widetilde{\rho})] = E[CS_{II.1}^{NoIn}(\widetilde{\rho})] = \frac{1}{2h}\int_a^b ((1+\delta)\theta q_1 - p^*)d\theta.$$

Finally, in the second part of parameter region II the incumbent's optimal first period price is $(1 + \delta - \widetilde{\rho}\delta)(a-h)q_1 - \frac{(a-h)q_1}{2}$ and consumers with a valuation in $[\widetilde{\theta}(p^*), a+h]$ decide to wait for the second period. Thus, the launch of a new product generates a consumer surplus of

$$E[CS_{II.2}^{Inno}(\widetilde{\rho})] = \frac{1}{2h}\int_{a-h}^{\widetilde{\theta}(p^*)} ((1+\delta)\theta q_1 - p^*)d\theta + \frac{1}{2h}\int_{\widetilde{\theta}(p^*)}^{a+h} \delta(\theta q_2 - (a-h)(q_2 - q_1))d\theta.$$

If the innovation is not introduced, we have

$$E[CS_{II.2}^{NoIn}(\widetilde{\rho})] = \frac{1}{2h}\int_{a-h}^{\widetilde{\theta}(p^*)} ((1+\delta)\theta q_1 - p^*)d\theta + \frac{1}{2h}\int_{\widetilde{\theta}(p^*)}^{a+h} \delta(\theta q_1 - (a-h)q_1)d\theta.$$

Before proceeding to the *ex ante* measures, some comments on the *interim* surplus functions are in order. First, it is straightforward to show that if there is a new product, more certainty about it is always beneficial to the consumers, i.e. $E[CS^{Inno}(\rho'')] > E[CS^{Inno}(\rho')]$ for $\rho'' > \rho'$. Higher innovation expectations entail a higher threat of entry and thus a lower first period price of the incumbent, an effect that in the following will be referred to as the *contestability effect*. Moreover, in the innovation event a higher $\widetilde{\rho}$ means that the purchase decision is based on better information (since the true probability of the launch of a new product is 1) and there is less scope for a mismatch between consumers and products.

Nevertheless, in the no innovation event, better information (a lower $\widetilde{\rho}$) is not always beneficial. Figure 3 below depicts the interim consumer surplus in the innovation and in the no innovation event. High expectations in the no innovation event lead to a mismatch of consumers to periods and a loss of consumer rent due to waiting. But once this mismatch is eliminated (which is the case in the regimes I and $II.1$ since the incumbent preempts the market), the negative effect of the decreasing threat of entry (implying a higher first period price) is dominating and the consumer surplus decreases for lower $\widetilde{\rho}$.

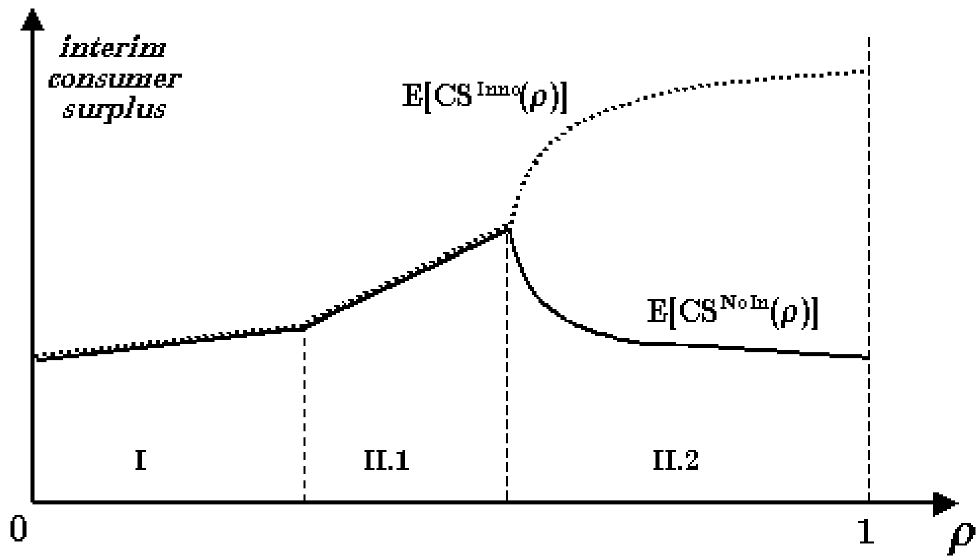

Figure 3: Expected (interim) consumer surplus

With this in mind, let us now turn to the calculation of the optimal preannouncement probability β^{opt}. Assume β^{opt} can be implemented exogenously by a social planner that is maximising the *ex ante* expected consumer surplus. To compute this measure, one has to take into account three different events and the respective beliefs held by the incumbent and the consumers. First, with probability $\rho_0\beta$, there will be an innovation that is preannounced in period 0. Secondly, with probability $\rho_0(1-\beta)$, a new product is introduced but not preannounced and finally, with the remaining probability $(1-\rho_0)$ there will be no innovation. The absence of a preannouncement given any β leads to the following Bayesian' belief updating

$$\begin{aligned}\widetilde{\rho}(\beta) &= \frac{prob(innovation/no\ announcement)}{prob(innovation/no\ announcement) + prob(no\ innovation)} \\ &= \frac{\rho_0(1-\beta)}{\rho_0(1-\beta)+1-\rho_0} = \frac{\rho_0(1-\beta)}{1-\rho_0\beta}.\end{aligned}$$

Thus, the *ex ante* expected consumer surplus can be written as follows

$$\begin{aligned}E[CS(\beta)] &= \rho_0\beta E[CS^{Inno}(1)] + \\ &\quad \rho_0(1-\beta)E[CS^{Inno}(\frac{\rho_0(1-\beta)}{1-\rho_0\beta})] + \\ &\quad (1-\rho_0)E[CS^{NoIn}(\frac{\rho_0(1-\beta)}{1-\rho_0\beta})].\end{aligned} \tag{13}$$

The announcement probability β enters this surplus function in two ways. In case of an innovation, it influences the relative weight of preannouncement versus pooling equilibria. In this respect, the effect of increasing β is - ceteris paribus - always positive. But it also appears as a measure of the contestability of the market if no preannouncement occurs, since it determines the belief updating. A higher β implies that consumers and the incumbent ascribe the absence of an announcement more to the possibility that there is no innovation since $\widetilde{\rho}(\beta)$ decreases in β. And - as discussed above - lower innovation expectations might have a negative impact on $E[CS^{NoIn}]$.

We demonstrate in the appendix that these two opposed effects generate a surplus function that has two local maxima over a large range of parameters. One at $\beta = 1$ which takes advantage of the benefits of an announced innovation and one at a lower level of β which relies on keeping up the threat of entry and thus reducing the market power of the incumbent in the case of no innovation. The result of the social planner solving the programme $max_\beta E[CS(\beta)]$ is explicitly derived in the appendix and given in the following proposition. Define

$$\begin{aligned}\Delta_0 &: = \frac{1}{\delta}, \\ \Delta_1 &: = \frac{4h + \sqrt{\rho_0^2(a-h) + 16h^2(1-\rho_0)^2}}{4\rho_0\delta h} \text{ and}\end{aligned}$$

$$\Delta_2 \ : \ = \frac{a+3h}{4\rho_0 \delta h}.$$

Then,

Proposition 3 *If $\Delta \leq \Delta_0$, consumers are indifferent between all β in [0,1]. Otherwise, the preannouncement probability that maximises the expected consumer surplus (13), is given by*

$$\beta^{opt} = \begin{cases} 1 & \text{if } \Delta_0 \leq \Delta \leq \Delta_1, \\ 0 & \text{if } \Delta_1 < \Delta \leq \Delta_2, \\ 1 - \frac{(1-\rho_0)(a+3h)q_1}{\rho_0[4\delta h(q_2-q_1)-(a+3h)q_1]} & \text{if } \Delta > \Delta_2. \end{cases}$$

Figure 4 below sketches the graph of the efficient preannouncement probability β^{opt} as a function of the innovation step size Δ. For $\Delta \leq \Delta_0$, the overall value of the new technology is too small to make a difference. Consumers will choose the old product independently of their beliefs about an innovation. By contrast, for larger innovation steps, the result of Proposition 3 reflects the trade-off between information transmission leading to a better match between consumers and products and the contestability of the market implying low first period prices in the no innovation event. For rather low values of Δ, the threat of entry is not sufficient to force the incumbent to set a low first period price. On the other hand, a high Δ increases the value of a good match between products and consumers. For intermediate values it is optimal to choose a low announcement probability β in order to make the consumers benefit from a contestable market.

Now, we are in the position to compare the efficient preannouncement with the market outcome described in Proposition 2. Since it turns out that $\Delta_0 \leq \Delta^A \leq \Delta_1$ one obtains

Corollary 3 *The market outcome, as described by Proposition 2, can yield efficient preannouncement, excessive announcement and excessive pooling.*

This overprovision result is due to the fact that from an *ex ante* point of view, the innovative firm only considers the impact of the preannouncement on the market outcome if the new product can actually be launched. She does not take into account the effect of her preannouncement behaviour if there is no innovation, i.e. the potential entrant is not concerned about the contestability of the market. In a situation, in which a preannouncement is

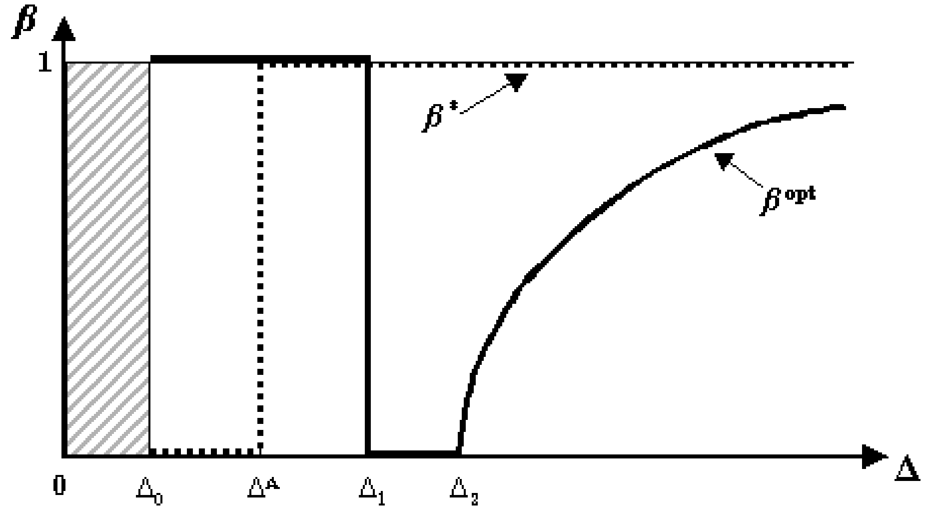

Figure 4: Equilibrium (β^*) and efficient (β^{opt}) announcement probability

optimal, its absence generates the certainty that there is no upcoming innovation and without the threat of entry, the incumbent firm regains market power and can extract more consumer surplus. Thus, the innovating firm confers a negative externality to the consumers and tends to produce too many preannouncements.

Finally, let us compare the market outcome with two scenarios that are somehow more realistic than the randomising choice of a social planner considered above. First, consider a full information scenario (FIS), in which the result of the R&D process is common knowledge in the economy. One might think, for example, of a law that forces innovating firms to preannounce their new product at least a minimum time before the actual launch. Or perhaps of an omniscient innovation agency that is able to gather and spread all information about upcoming product launches. Formally, this means that the incumbent and the consumers can update their priors correctly and we get

$$E[CS^{FIS}] = E[CS(1)] = \rho_0 E[CS^{Inno}(1)] + (1 - \rho_0)E[CS^{NoIn}(0)]. \quad (14)$$

Further, consider the scenario, in which a law prohibits preannouncements of any kind. In such a no information scenario (NIS), consumers would derive a surplus of

$$E[CS^{NIS}] = E[CS(0)] = \rho_0 E[CS^{Inno}(\rho_0)] + (1 - \rho_0)E[CS^{NoIn}(\rho_0)]. \quad (15)$$

The next corollary compares the consumers' surplus in the full information

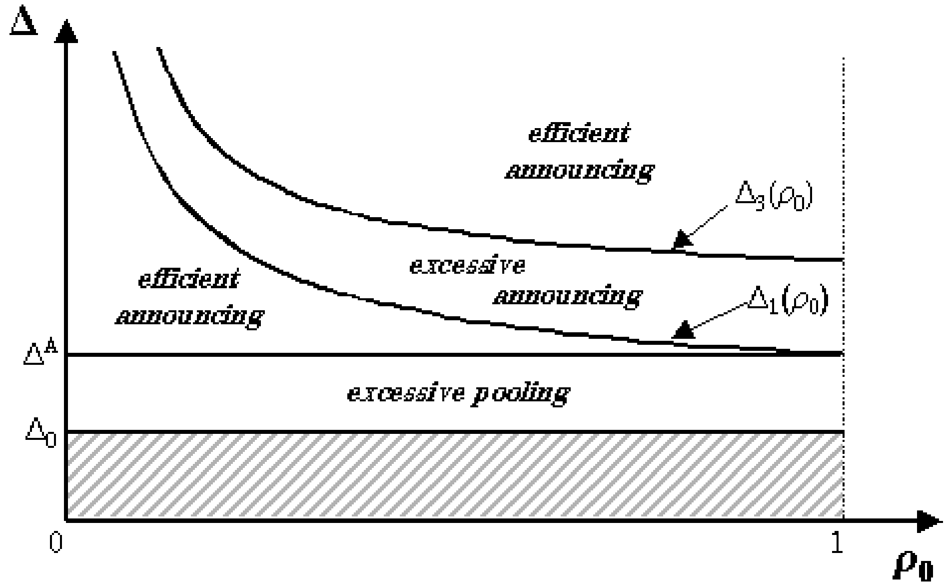

Figure 5: Excessive announcing and pooling in the $\Delta - \rho_0$-space

and the no information scenario. Define

$$\Delta_3 := \frac{2\sqrt{(a-h)^2 + 16h^2}}{\delta(1+\rho_0)\sqrt{(a-h)^2 + 16h^2} - \delta\sqrt{(1+\rho_0)^2(a-h)^2 + 16h^2(1-\rho_0)^2}},$$

then

Corollary 4 *If* $\Delta_1 < \Delta < \Delta_3$*, then* $E[CS^{NIS}] > E[CS^{FIS}]$*, else* $E[CS^{NIS}] \leq E[CS^{FIS}]$*.*

Figure 5 illustrates this result in the $\Delta - \rho_0-$parameter space and relates the efficient consumer policy to the market outcome of Proposition 2. Consumers would be best off if product announcements were banned for all Δ in $[\Delta_1, \Delta_3]$, that means if the upcoming innovation step is intermediate but the innovation probability is rather high. By contrast, if Δ is in $[\Delta_0, \Delta^A]$ the best consumer policy is to enforce preannouncements in order to prevent excessive pooling of the innovating firm. Eventually, in the remaining parameter space, the market outcome coincides with the consumers' optimal choice between FIS and NIS.

7 Concluding remarks

This paper analyses the role of innovation preannouncements in markets with imperfect competition and rational, forward looking consumers. For innovative firms, preannouncements are a way to induce potential customers to wait for the innovation instead of buying the presently available technology. But in the presence of an incumbent firm with market power, this advantage has to be traded off with the possibility of a strategic reaction of the latter in the form of preemptive pricing in the pre-entry period. Our model incorporates the intertemporal product choice of consumers under uncertainty into the framework of a vertically differentiated industry and enables us to rationalise some of the findings of an empirical study on product preannouncements by Eliahsberg/Robertson (1988). In analysing interview data of 75 firms, they concluded that preannouncements are more likely if the measure for competitive environment is low, if the upcoming innovation step is large and if consumers are sufficiently forward-looking.

More surprisingly, the welfare analysis of our model shows that, from the *ex ante* point of view of the consumers, the signalling equilibria of the market can lead to under- *and* overprovision of preannouncements. This result is due to the fact that a policymaker has to trade off transmission of information in the economy and the contestability of the pre-innovation market. In this vein, a ban on preannouncements is the best consumer policy in constellations in which the industry is expected to grow fast and the next innovation step is neither too large nor too small. Innovation preannouncements have to be enforced when the new technology is not much better than the old one.

To conclude, let us discuss some limitations of this work that could serve as possible starting point for extensions of the framework. First, we confined our analysis to the case in which the incumbent can not introduce the new technology. This extension would enrich the possible strategic interaction of the model, in particular it would allow for the use of product preannouncements as a means to deter entry into the industry, a strategy that is often mentioned in relation with Microsoft's product introductions.

A second issue is the exclusion of untruthful preannouncement which enabled us to concentrate on the 'strategic reaction' argument. In the absence of a contract between consumer and preannouncing firm, the costs of waiting for any new technology will be sunk as soon as the firm is not able to introduce the innovation at the promised date. Thus, the innovating firm could be tempted to preannounce the product too early with the opportunity to postpone the launch afterwards and anticipating consumers would no longer believe in the announcement without any commitments. Nevertheless, it seems that although untruthful preannouncements would somehow dilute the communication process between innovative firm and the market, they would not change the qualitative nature of the strategic effects discussed in this work.

8 Appendix

Proof of Lemma 1

The profit function of the monopolist is piecewise concave and continuous. For Lemma 1 to hold it suffices to show that the marginal profit is negative for all $p_1 \geq (a-h)q_1$. For $(a-h)q_1 \leq p_1 \leq xq_1$, the marginal profit is $a+h+x-\frac{4p_1}{q_1}$, which is negative for all $p_1 > \frac{q_1}{4}(a+h+x)$. This threshold is smaller than $(a-h)q_1$ for all x in $[a-h, a+h]$ if and only if $a > 3h$. For $xq_1 \leq p_1 \leq (a+h)q_1$, the marginal profit is $a+h-\frac{2p_1}{q_1}$, which is negative for all $p_1 > \frac{q_1}{2}(a+h)$. This threshold is smaller than xq_1 for all x in $[a-h, a+h]$ if and only if $a > 3h$. Thus, $p_1^* = (a-h)q_1$.■

Proof of Lemma 2

For $(a-h)q_1 \leq p_1 \leq yq_1$, the marginal profit is $2(a+h)-x-\frac{2p_1}{q_1}$, which is negative for all $p_1 > \frac{q_1}{2}(2a+2h-x)$. This threshold is smaller than $(a-h)q_1$ for all y in $[a-h, a+h]$ if and only if $a > 5h$. For $p_1 > yq_1$, the marginal profit is $2(a+h)-\frac{4p_1}{q_1}$, which is negative for all $p_1 > \frac{q_1}{2}(a+h)$. This threshold is smaller than yq_1 for all y in $[a-h, a+h]$ if and only if $a > 3h$. Thus, if $a > 5h$, $p_1^* = (a-h)q_1$.■

Proof of Lemma 3

Given the piecewise linear and globally concave demand schedule, the profit function of firm 1 is always single-peaked. The interior maximum for $x\Delta q \leq \Delta p \leq (a+h)\Delta q$ is then defined by $\partial[p_1((x-a+h)+(\frac{\Delta p}{\Delta q}-a))]/\partial p_1 := 0$, which yields

$$p_1 = \frac{1}{2}[p_2 - (2a-2h-x)\Delta q].$$

It is straightforward to check that this value is in the regime range whenever $\widetilde{p}_3 \leq p_2 \leq \widetilde{p}_4$,with $\widetilde{p}_2, \widetilde{p}_3$ defined in the text. Equivalently, the interior solution for $\Delta p < x\Delta q$ is given by $\partial[p_1 2(\frac{\Delta p}{\Delta q} - a + h)]/\partial p_1 := 0$, thus

$$p_1 = \frac{1}{2}[p_2 - (a-h)\Delta q].$$

This solution holds for all p_2 in $[\widetilde{p}_1, \widetilde{p}_2]$. Finally, taking into account the three possible corner solutions, one can compose the reaction function $R_{I1}^D(p_2, x)$.

Firm 2's profit function is continuous. In order to show that $R_{I2}^D(p_1, x) = p_1 + (a-h)\Delta q$, it suffices to show that the marginal profit is negative for $p_2 \geq p_1 + (a-h)\Delta q$. For $(a-h)\Delta q \leq \Delta p \leq x\Delta q$ the marginal revenue is negative if $p_1 > \frac{1}{2}[5h-3a+x]\Delta q$, which is negative and holds for all non-negative p_1 and all x whenever $a > 3h$. For $\Delta p > x\Delta q$ the marginal revenue is negative if $p_1 > \frac{1}{2}[a+h-2x]\Delta q$, which is negative and holds for all non-negative p_1 and all x whenever $a > 3h$.

Hence, for $a > 3h$, it is easy to see that $(p_1^* = 0, p_2^* = a\Delta q)$ is the unique solution to the equation system

$$p_1 = R_{I1}^D(p_2, x) \text{ and } p_2 = R_{I2}^D(p_1, x)$$

and the unique Nash equilibrium.■

Proof of Lemma 4

Consider firm 1's maximisation problem. The interior maximum for $(a+h)\Delta q \geq \Delta p \geq y\Delta q$ is given by

$$p_1 = \frac{p_2}{2} - \frac{y+a-h}{4}\Delta q$$

and the interior maximum for $\Delta p < y\Delta q$ by

$$p_1 = \frac{1}{2}[p_2 - (a-h)\Delta q].$$

Both of them are interior, i.e. the profit function has two peaks for p_2 in $[\frac{1}{2}(3x-a-h)\Delta q, (2x-a-h)\Delta q]$. The local maximum value of the former is larger than the local maximum of the latter whenever $p_2 > \widetilde{p}_6$, with $\widetilde{p}_6$ given in the text.

Consider the maximisation problem of firm 2. For $y\Delta q \geq \Delta p \geq (a-h)\Delta q$, its marginal revenue is negative whenever $p_1 > (4h-y)\Delta q$, which is negative and holds for all non-negative p_1 and all y whenever $a > 5h$. For $\Delta p > y\Delta q$ the marginal revenue is negative if $p_1 > [3h-a]\Delta q$, which is negative and holds for all non-negative p_1 and all x whenever $a > 3h$.

Hence, for $a > 5h$, the reaction functions in the text hold and it is straightforward to check that $(p_1^* = 0, p_2^* = a\Delta q)$ is the unique Nash equilibrium.■

Proof of Proposition 3

The analysis of the consumer surplus $E[CS(\beta)]$ is rather tedious because dependent on beliefs and other parameters the economy can fall in one of the three regimes identified in Section 3. We will proceed in two steps. First, we will identify local maxima over the whole parameter range. And then, for all regions where there are more than one, we will pick the global maximiser.

Given a preannouncement probability β, the economy is in region $II.2$ whenever $0 \leq \beta \leq \beta_1 := \frac{\rho_0\delta(q_2-q_1)-q_1}{\rho_0[\delta q_2-(1+\delta)q_1]}$, it is in region $II.1$ if $\beta_1 < \beta \leq \beta_2 := 1 - \frac{(1-\rho_0)(a+3h)q_1}{\rho_0[4\delta h(q_2-q_1)-(a+3h)q_1]}$ and in region I for $\beta_2 < \beta \leq 1$. Note that $\beta_1 > 0$ if $\Delta > \Delta_2$ and $\beta_2 > 0$ if $\Delta > \widehat{\Delta} > \Delta_0$ (Δ_0, $\Delta_2, \widehat{\Delta}$ are defined in the text). Some tedious calculations give the slopes of the ex ante consumer surplus in these three parameter ranges. For region I, one gets

$$\frac{\partial E[CS_I(\beta)]}{\partial\beta} = \begin{cases} 0 & \text{if } 0 \leq \Delta \leq \Delta_0 \\ 2h[\rho_0[\delta q_2 - (1+\delta)q_1] > 0 & \text{if } \Delta_0 \leq \Delta \leq \Delta^A \\ \frac{16h^2(\delta\Delta q - q_1)+(a-h)^2}{16h(\delta\Delta q - q_1)} > 0 & \text{if } \Delta > \Delta^A. \end{cases}$$

Region $II.1$ only exists if $\Delta > \widehat{\Delta}$ thus,

$$\frac{\partial E[CS_{II.1}(\beta)]}{\partial \beta} = \begin{cases} 0 & \textit{if } \widehat{\Delta} \leq \Delta \leq \Delta^A \\ \frac{[4h\delta\Delta q+(a-3h)q_1][(a+3h)q_1-4h\delta\Delta q]\rho_0}{16h(\delta\Delta q-q_1)} < 0 & \textit{if } \Delta > \Delta^A. \end{cases}$$

Finally, in region $II.2$ which exists for $\Delta > \Delta_2$,

$$\frac{\partial E[CS_{II.1}(\beta)]}{\partial \beta} = \frac{\delta^2(a-h)^2(\Delta q)^2 q_1^2(1-\rho_0)^2\rho_0}{16h(\delta\Delta q - q_1)[q_1(1+\rho_0\delta-(1+\delta)\rho_0\beta)-(1-\beta)\rho_0\delta q_2]^2} > 0.$$

At least four conclusions can be drawn from this. First, for $0 \leq \Delta \leq \Delta_0$, the only relevant region is I and in this region the slope is 0, i.e. consumers are indifferent. Second, for $\Delta_0 \leq \Delta \leq \Delta^A$, there is only local maximum at $\beta = 1$ since the slope in region $II.1$ is 0 and positive for higher β in region I. Third, for $\Delta^A \leq \Delta \leq \Delta_2$, two local maxima exist, one at $\beta = 0$ and one at $\beta = 1$. Finally, if region $II.2$ exists for $\Delta > \Delta_2$, the two local maxima are $\beta = \beta_2$ and $\beta = 1$ because $\frac{\partial E[CS(\beta)]}{\partial \beta} > 0$ for all β in $[0, \beta_2]$.

As second step we now look for the global maximiser. For $\Delta^A \leq \Delta \leq \Delta_2$, the choice is between $\beta = 0$ and $\beta = 1$. Some calculations yield that $E[CS(1)] \geq E[CS(0)]$ if $\Delta \leq \Delta_1$ with Δ_1 given in the text. For $\Delta > \Delta_2$ we get that $E[CS(\beta_2)] \geq E[CS(1)]$. This completes Proposition 3.■

Proof of Corollary 3

The only change to the previous proof of Proposition 3 it that for $\Delta > \Delta_2$ we have to compare the local maxima at $\beta = 0$ and $\beta = 1$. Standard analysis shows that $E[CS(1)] \geq E[CS(0)]$ if and only if $\Delta > \Delta_3 (> \Delta_2)$.■

9 References

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