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A Dynamic Monopoly with Experience Goods and Risk-Averse Consumers

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Abstract

I analyze the dynamic problem of a monopolist facing different masses of risk-averse consumers in two periods. All qualities are equally costly and the true quality is uncertain for all the agents in the first period. I find that a semi-separating equilibrium is sustainable in the second period if the first-period market share is strictly positive due to social learning. Increasing patterns of prices may arise when low qualities are revealed, but this outcome is less likely with less risk-averse consumers. The welfare analysis suggests that the authority could only help when the consumers were not very risk averse.

Keywords: asymmetric information, risk aversion, price pattern.
JEL classification: L12, L15

1 Introduction

From time to time, a truly innovative product appears into the market: the Walkman was the first portable cassette player that consumers could actually buy,[1] the Virtual Boy was the first portable video game console capable of displaying true 3D graphics out of the box, and several prototypes of wearable technology with an optical head-mounted display are currently in progress.[2] When the products have such innovative nature, both the firm

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[1] In fact, the first portable cassette player was the Stereobelt, invented by Andreas Pavel. Even though he filed a patent in 1977, at that time there was no major vendor interested in manufacturing the device. Sony began to commercialize the Walkman in 1979, with the subsequent legal battles that lasted until 2004.

[2] The reader could be familiar with the Google Glass, although the idea does not belong to Google; instead, the original device is the EyeTap, developed in the eighties by the father of wearable computing Steve Mann.

and the consumers ignore how well they will fit the consumers' taste at the moment of being introduced.

In this context of incomplete information, the monopolist may have incentives to set a price low enough to induce experimentation, so that the parties involved in the transaction learn how well the product fits the consumers' taste. But observe that the aforesaid price might not be an introductory price: if consumers would find that they dislike the product, the monopolist could be forced to decrease the price in the period next to the experimentation, depending on the severity of the dislike.

I study the dynamically optimal pricing strategy of a forward-looking monopolist that introduces a novel product, when facing consumers who are risk-averse and non-strategic. The product can be seen as an experience good[3] at the moment of the introduction, whilst signaling is possible afterwards due to non-idiosyncratic tastes if the monopolist induced experimentation. The cost of inducing experimentation increases as the risk aversion increases, but the subsequent positive effect of removing the uncertainty could offset the effect derived from learning that the product does not fit well the consumers' taste.

The rest of the paper is organized as follows: Section 2 explains the model; the Bayesian-Nash equilibrium is characterized in Sections 3 and 4; Section 5 discusses the problem of the social planner; and Section 6 concludes.

■ Literature Review:

Dynamic pricing in the presence of uncertainty is an old question. A first research line considers forward-looking consumers and ignores signaling. Shapiro (1983) studies the dynamic pricing problem of a monopolist aware of its quality but unable to signal it; thus, consumers only learn through experience. Introductory prices occur when consumers underestimate quality, whereas in my model introductory prices may also happen when consumers find that they overestimated how well the product will fit their taste, due to the subsequent positive effect on utility of removing the initial uncertainty.

Another example is **?**. The authors study the dynamic monopoly pricing when all the agents are initially uncertain about the number of high-type consumers, which in turn determines the extent of the network externality. The first-period price is below the expected second-period price in order to induce the high-type consumers to buy in the first period, and so the externality becomes observable in the second period. In my framework the monopolist also sets a low price oriented to remove the initial uncertainty, although it is due to the risk aversion of the consumers.

Bergemann and Valimaki (2006) and Villas-Boas (2006) consider frameworks in which the perception of the quality is subjective. The former examine a monopoly who dynamically changes her pricing policy depending on the relative sizes of the segments of informed and uninformed consumers, and find that introductory prices happen in niche markets. The latter examines a dynamic duopoly in which consumers have a relative preference for

[3] According to Nelson (1970), an experience good is a product such that some of its characteristics cannot be observed in advance by the consumers, but instead are ascertained upon consumption.

the variety they learn about in first place, and concludes that the anti-competitive effect of exploiting the informational advantage dominates the pro-competitive effects.

Empirical studies support the hypothesis that, for some goods, consumers can only learn through experience.[4] For instance, Crawford and Shum (2005) use anti-ulcer drugs data and conclude that, while there is substantial heterogeneity in the effectiveness across patients, they and their doctors gradually reduce the costs of uncertainty through direct trial of the different drugs. Israel (2005) uses car insurance data and finds that consumers overestimate the quality when contracting the service, but that the impact of learning is mitigated as the quality is discovered only after a road accident.

A second research line deals with signaling considerations. Milgrom and Roberts (1986) consider a dynamic monopoly in which introductory prices and dissipative advertising are signals of the type, defined as the probability that a random consumer finds the product satisfactory.[5] In equilibrium, introductory prices are used if the good is not perceived as surely satisfactory. Bagwell and Riordan (1991) study the signaling problem of a static monopoly when some consumers are informed, finding that the price distortion necessary to signal a high type decreases as the number of informed consumers increases.

In my model, the problem of the second period is very similar to the one analyzed in Bagwell and Riordan (1991), although the amount of informed consumers was strategically determined by the monopolist in the first period. In contrast to Milgrom and Roberts (1986), the price plays no signaling role when introducing the product, and to spend money in dissipative advertising is not allowed.

Judd and Riordan (1994) analyze a dynamic monopoly in which both the buyers and the seller acquire private, noisy information about the quality of the good after the first purchase. Higher prices signal higher qualities in the equilibrium of the second period, and the equilibrium expected[6] second-period price exceeds the first-period price. On the contrary, I allow for the possibility of not buying in the first period, so some consumers may not get information. Also, I consider that the information derived from the first purchase is accurate instead of noisy.

It is possible to consider signals other than price and advertising. For instance, in Bar-Isaac (2003) the signal is the decision of the monopolist of producing or not; in Bose et al. (2006) the signal for a consumer at a certain period is the history of previous purchases by other buyers. In the duopoly market considered by Caminal and Vives (1996), the previous market share also plays a crucial signaling role, leading to the use of introductory prices.

[4] Although not focused on the learning process, Farina (2012) studies a typical case of subjective quality: the market of ready-to-drink orange juice. Using data from Brazil, concludes that the firms should give their juices for free to convince the uninformed consumers to taste them.

[5] Ackerberg (2003) tests the effect of advertising in the introduction of a low-fat yogurt in the American market, and finds that it only has a signaling effect on inexperienced consumers.

[6] The realized second-period price is proportional to the private signal of the seller, so it can be below the first-period price if the signal is low enough.

2 The Model

A monopolist sells a non-storable experience good in a game of two periods ($t = 1, 2$). He is located at the point 0 of the unit interval and his discount factor is equal to 1. It is possible to charge different prices in each period, but discrimination across consumers who live in the same period is not allowed. Price commitment across periods is not allowed either.

In period 1, it is uncertain how well the product will fit the consumers' needs (in a wide sense, this concept would be identified with the quality). Since sometimes it is reasonable to think that this adjustment depends more on some unobservable characteristics of the population than on the intrinsic characteristics of the product, I will assume that all the types are equally costly —without loss of generality, I normalize all the production costs to zero. Therefore, in the first period, all the agents assume that the quality is a random variable such that[2] $q \sim \mathcal{N}(\mu, \sigma)$, with $\mu > 0$. In any period the consumers buy either one unit or zero. In the first period, only the consumers who acquire the product learn the quality after consumption. The monopolist can undertake some market research after the first-period consumption choices at a negligible cost, so he also observes the quality.

There is a mass 1 of risk-averse consumers uniformly distributed in each period. The consumers have a unitary demand (they can buy either one unit or zero) and, since they only live for one period, they maximize their instantaneous utility conditional on their information sets. Although the consumers in each period are different, the information is disseminated from the first period to the second period in the following way: each consumer i located at x_i in the first period truthfully communicates his gathered information about the quality to the consumer located at x_i in the second period. This can be interpreted as if consumers would only have access to the information gathered by someone with the same horizontal preferences: in most cases, individuals make friends among other individuals with similar tastes, or they may join specialized clubs in which they meet other people with criteria and preferences which are alike. In any case, this communication structure captures two facts supported by evidence: the consumers learn from the experience of others and they cannot access every single piece of information available in the market. In a broad sense, it can be viewed as a very specific type of social learning. I also assume that, in the first period, the monopolist launches an extensive advertising campaign at a negligible cost to announce the existence of his product to the consumers. This campaign cannot be taken as a signal, since the monopolist also ignores how well the product that he supplies will fit the necessities of the consumers. However, the campaign affects the consumers' utility (for instance, it may be offensive for the local standards) but the monopolist cannot observe this before the first-period purchases. In the second period, no campaign is needed because the consumers are already aware of the existence of the product. Then, the demand of the first period will be random for the monopolist whereas the demand of the second period will be deterministic.

The timing is graphically explained in Figure 1. In words, is as follows: in the first

[2] A minimum degree of uncertainty $\sigma \geq 0.01$ is necessary for the model to work.

period, no agent knows the quality. The monopolist launches the campaign and sets the first-period price, the consumers make their consumption choices and the first-period payoffs are realized. Those who acquired the product observe the quality after consumption, and so does the monopolist. In the second period, the information dissemination takes place: this divides the market into informed (those consumers who learn the quality from the previous experience of the others) and uninformed consumers. All the second-period consumers observe the market share of the first period. The monopolist sets the second-period price, and the uninformed consumers use the first-period market share and the second-period price to update their beliefs. Since the informed consumers already know the true quality, they do not make any inference process. Finally, the consumption choices are made, the second-period payoffs are realized and the game ends.

I consider that the consumers exhibit a CARA (Constant Absolute Risk Aversion) utility

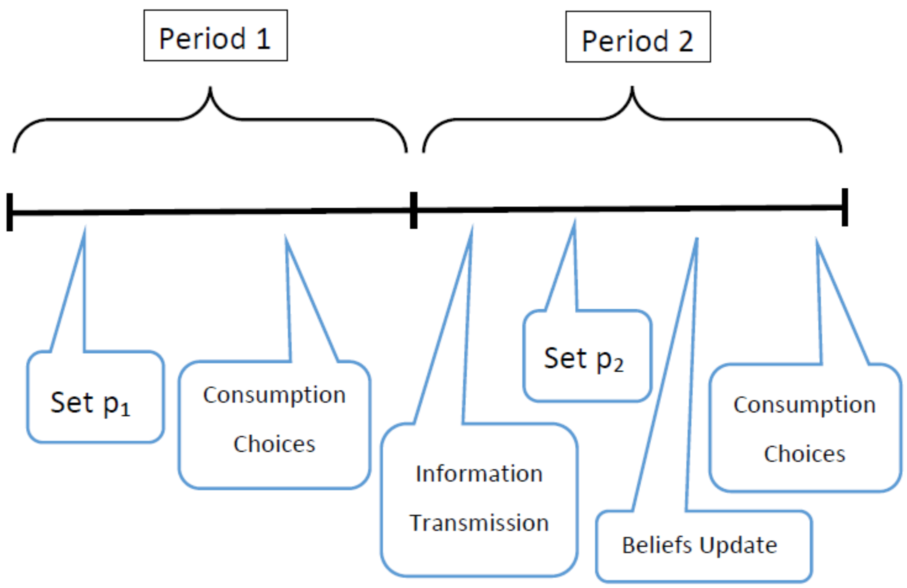

Figure 1: Timing of the game.

function. In the first period, because of this utility form and the normal distribution of the quality, maximizing the expected utility of the consumer i is equivalent to maximize the following linear certainty equivalent:

$$CE_i = \mu - \frac{1}{2}\rho\sigma^2 - p_1 - x_i + z_1 \tag{1}$$

where $\rho > 0$ is the risk-aversion coefficient, p_1 is the price charged by the monopolist in period 1 and x_i is the location of the consumer.[3] z_1 represents the effect of the campaign, and it affects all consumers in the same way.[4] The monopolist assumes $z_1 \sim \mathcal{U}[-Z, Z]$

[3] The transportation cost parameter has been normalized to $\tau = 1$.

[4] Although I have provided an interpretation in terms of an advertising campaign, the framework works for any pair of independent random shocks on preferences with 0 mean across the periods 1 and 2.

with sufficiently large value of $Z > 0$: on average the campaign has no effect, but the probability that the campaign does not affect the utility is 0. Normalizing the utility of not acquiring the good to 0, the marginal consumer in the first period, that determines the demand bounded by 0 and 1, is

$$\hat{x}_1(\mu, \rho, \sigma, p_1, z_1) = \frac{1}{2}(2\mu - \rho\sigma^2 - 2p_1 + 2z_1) \tag{2}$$

Remember that in the second period there is no advertising campaign. Denoting the true quality by $\bar{q}$, the demand from the informed consumers, bounded by 0 and $\hat{x}_1$, is

$$\phi(\bar{q}, p_2) = \bar{q} - p_2 \tag{3}$$

The demand from the uninformed consumers, bounded by $\hat{x}_1$ and 1, would be referred as $\omega(\rho, p_2, \hat{x}_1)$. The price here has two effects: first, the direct effect of decreasing the demand; second, the signaling effect. The first-period market share only has a signaling effect. From now on, the total demand of the second period will be denoted by x_2.

3 Equilibrium

Since the monopolist is forward looking, the backward induction applies. Notice that negative prices are weakly dominated strategies in the second period, but not in the first.

3.1 Equilibrium of the second period

We may have three different situations, depending on the amount of informed consumers.

3.1.1 Full information

This situation takes place when $z_1 \geq \frac{1}{2}(2+2p_1-2\mu+\rho\sigma^2)$,[5] that is, when all second-period consumers are informed. From the profit-maximization problem making $x_2 = \phi(\bar{q}, p_2)$ subject to $0 \leq x_2 \leq 1$, the equilibrium is

$$p_2^I = \begin{cases} 0 & \text{if } \bar{q} \leq 0 \\ \bar{q}/2 & \text{if } \bar{q} \in (0, 2) \\ \bar{q} - 1 & \text{if } \bar{q} \geq 2 \end{cases} \qquad x_2^I = \begin{cases} 0 & \text{if } \bar{q} \leq 0 \\ \bar{q}/2 & \text{if } \bar{q} \in (0, 2) \\ 1 & \text{if } \bar{q} \geq 2 \end{cases} \tag{4}$$

In the full-information equilibrium, the higher the quality, the higher the charged price and the larger the share of served consumers.

[5] $z_1 \geq \frac{1}{2}(2+2p_1-2\mu+\rho\sigma^2)$ means that the most distant consumer obtained a strictly positive surplus when acquiring the good.

3.1.2 No information

This situation takes place when $z_1 \leq \frac{1}{2}(2p_1 - 2\mu + \rho\sigma^2)$,[6] that is, when no agent knows the true quality of the good, including the firm. In this case, the consumers correctly infer that the price does not convey any information and the uncertainty cannot be ruled out.[7] Then, $\omega(\rho, p_2, 0) = (2\mu - \rho\sigma^2 - 2p_2)/2$. Solving the profit-maximization problem making $x_2 = \omega(\rho, p_2, 0)$ subject to $0 \leq x_2 \leq 1$, the solution is

$$p_2^U = \begin{cases} 0 & \text{if } \rho \geq 2\mu/\sigma^2 \\ (2\mu - \rho\sigma^2)/4 & \text{if } \mu \leq 2 \quad \text{and} \quad \rho < 2\mu/\sigma^2; \quad \text{or} \\ & \text{if } \mu > 2 \quad \text{and} \quad (-4 + 2\mu)/\sigma^2 < \rho < 2\mu/\sigma^2 \\ (2\mu - \rho\sigma^2 - 2)/2 & \text{if } \mu > 2 \quad \text{and} \quad \rho \leq (-4 + 2\mu)/\sigma^2 \end{cases} \tag{5}$$

$$x_2^U = \begin{cases} 0 & \text{if } \rho \geq 2\mu/\sigma^2 \\ (2\mu - \rho\sigma^2)/4 & \text{if } \mu \leq 2 \quad \text{and} \quad \rho < 2\mu/\sigma^2; \quad \text{or} \\ & \text{if } \mu > 2 \quad \text{and} \quad (-4 + 2\mu)/\sigma^2 < \rho < 2\mu/\sigma^2 \\ 1 & \text{if } \mu > 2 \quad \text{and} \quad \rho \leq (-4 + 2\mu)/\sigma^2 \end{cases} \tag{6}$$

Here, both the price and the share of served consumers increase as the expected quality increases, and they decrease as the risk-aversion coefficient increases.

3.1.3 Intermediate

This situation takes place when $\frac{1}{2}(2p_1 - 2\mu + \rho\sigma^2 < z_1 < \frac{1}{2}(2 + 2p_1 - 2\mu + \rho\sigma^2)$: the monopolist and some consumers are informed, whereas the rest of the consumers use the price p_2 and the market share $\hat{x}_1$ as signals to update their beliefs.[8]

As this is a game of asymmetric information, the equilibrium concept used is the Perfect Bayesian Nash Equilibrium (PBNE): (i) given beliefs, each player chooses strategies that are sequentially rational; (ii) beliefs are established consistently with players' strategies, in the sense that they do not contradict Bayes' rule.

Proposition 1. *For a given $\hat{x}_1 \in (0, 1)$, there exists a semi-separating equilibrium such that*

- *the qualities $\bar{q} \leq 0$ pool at a price $p_2^s = 0$;*
- *the rest of qualities charge a price $p_2^s = \bar{q} - \hat{x}_1$ if $\bar{q} \geq 2\hat{x}_1$, and $p_2^s = \bar{q}/2$ otherwise.*

[6] $z_1 \leq \frac{1}{2}(2p_1 - 2\mu + \rho\sigma^2)$ means that the closest consumer would have obtained a strictly negative surplus if she had acquired the good.

[7] Notice that, even if the monopolist would have learned his quality after the first period, the second-period price cannot be a valid signal in this case because there are no costs derived from charging a price not corresponding to the true quality: there are no future penalties because the game ends after the second-period purchases and, since there are no informed consumers, the monopolist is not losing money from the informed sector if he charges a price higher than the one corresponding to the actual quality.

[8] The signaling problem follows the spirit of Spence (1973). An analysis of signaling games with a continuum of types can be found in Mailath (1987). See Athey (2001) for a study of games of imperfect information with a continuum of actions. For a discussion of signaling equilibria with multiple signals and a continuum of types, check Ramey (1996).

Proof: in the Appendix.

The beliefs that support this equilibrium predict a higher quality from a higher price, but weighting by the share of informed consumers: this share is used to measure the money that the monopolist will stop earning if he charges a price not corresponding to the true quality. Intuitively, the equilibrium works because the beliefs are such that the demand from the uninformed consumers is always zero. Regarding the separating part of the equilibrium, given a strictly positive quality and a share of informed consumers $\hat{x}_1 \in (0, 1)$, it turns out that the corner pricing strategy[9] is the most profitable option when $\bar{q} \geq 2\hat{x}_1$ —otherwise, the interior solution in which only a fraction of the informed consumers acquire the good is optimal. That is, if the quality is sufficiently low with respect to the share of informed consumers, distortion on prices is not necessary because the monopolist maximizes his profits just by charging the full information price; however, if the quality is sufficiently high with respect to the share of informed consumers, distortion on prices appears: given that the demand from the uninformed sector is zero, it is optimal for the monopolist to fix a price such that the marginal consumer of the first period receives exactly no surplus. This optimal price is higher than the full information price, but the distortion decreases as $\hat{x}_1$ increases. In summary, by using p_2^s and $\hat{x}_1$, the uninformed consumers can infer the true value $\bar{q} > 0$ with no error, although no consumer belonging to this group will buy the product. On the contrary, if the quality is negative, the monopolist is indifferent among all the pricing strategies because the profits will always be null, so he pools at a zero price without loss of generality.[10]

The characterization of the equilibrium shows some similarities with Milgrom and Roberts (1986) and Tirole (1988): the marginal buyer of the first period does not obtain a positive surplus in the second period. Although only the former involves a quality-signaling problem in the first period, the problem of the second period is essentially the same in the two models: the monopolist can choose to milk the consumers who previously purchased the good, or he can choose to attract new consumers. In these models, any consumer i may be satisfied with the product (implying a gross utility of r_i) or not (implying a gross utility of 0). The consumer can only know whether she likes the product after consumption. In this framework, the quality is defined as the probability with which the product will satisfy any random consumer. Then, in the second period a share q of the first-period consumers are satisfied and have a higher willingness to pay than: (i) those who are not satisfied, and (ii) those who have not purchased the good and whose willingness to pay is determined by the expected utility. The strategy of expanding the customer base in the second period is dominated because new consumers can only be reached by a substantial price decrease (price discrimination is not allowed). Although in my model the quality is not subjective and the signaling problem may only arise in the second period, the problem of the second period is more extreme: in order to sustain the semi-separating equilibrium, the beliefs held by the uninformed consumers are such that

[9] The monopolist sets a price such that all the informed consumers acquire the good and the most distant informed consumer obtains zero surplus: $p_2^s = \bar{q} - \hat{x}_1$.

[10] The only prices that would be out-of-equilibrium are the negative prices. The out-of-equilibrium beliefs assign any negative quality (the value does not really matter) to a negative price with no error.

new customers cannot be reached through any price change, so expanding the customer base is simply impossible for the monopolist.

Notice that the equilibrium established in Proposition 1 collapses to the full-information equilibrium when $\hat{x}_1 = 1$. However, this continuity breaks down when $\hat{x}_1 = 0$. The reason is that, given a certain quality $\bar{q} > 0$, the distortion needed for maintaining the semi-separating equilibrium decreases as the amount of informed consumers increases. However, when the information about the quality cannot be credibly disclosed, only the risk-aversion parameter ρ and the expected quality μ matter for the consumers' utility.

It is worth explaining the difference between the signaling role played by the market share in Caminal and Vives (1996) and here. In the former it is assumed that some first-period consumers receive a signal about the quality differential between two competing brands before buying, whereas the firms are totally ignorant about this differential. Despite no direct communication among consumers of different periods, the difference in the first-period sold quantities is a noisy[11] signal of the quality differential: consumers always prefer higher qualities, and some of them made informed purchases. On the contrary, a larger first-period market share does not signal a higher quality in this framework, because both the monopolist and the consumers have no information before the first-period purchases. Instead, due to the communication between the consumers of the two periods, the market share is a measure of the amount of people who know the true quality in the second period and that, therefore, do not need any signal to update their beliefs. If the beliefs of the uninformed consumers are such that the demand from this group is always zero, the monopolist optimally maximizes the profits obtained from the informed group of consumers. Since the size of the informed group is publicly observed and equal to the first-period market share, the uninformed consumers can use this information and the second-period price to infer[12] the true quality of the product.

It is also remarkable that, given the share of informed consumers, the price distortion is unnecessary for some types. This result is a generalization of the conclusion obtained in Bagwell and Riordan (1991): with two possible types (high and low) such that the high type is more costly to produce and also more valued by consumers, the price distortion decreases as the amount of informed consumers increases in the separating equilibrium (and, eventually, the high type does not need to distort). Instead, I consider a continuum of types equally costly to produce such that the consumers' valuation increases as the type increases. Given the share of informed consumers, the types above $2\hat{x}_1$ optimally distort the price whereas the rest charge the full-information price. Consider the following example with three qualities: $\bar{q} = 0.4$, $\bar{q} = 1$ and $\bar{q} = 2.5$, with full-information prices 0.2, 0.5 and 1.5. Given $\hat{x}_1 = 0.3$, the equilibrium prices are 0.2, 0.7 and 2.2: the type $\bar{q} = 0.4$ charges its full-information price, whereas the other two types optimally distort. If, instead, $\hat{x}_1 = 0.6$, the equilibrium prices are 0.2, 0.5 and 1.9: now the type $\bar{q} = 1$ charges its full-information price and the type $\bar{q} = 2.5$ distorts, but less than when $\hat{x}_1 = 0.3$. However,

[11] The signal is noisy because, in addition to the informed consumers, there are some other consumers whose purchasing decisions are made at random.

[12] The inference is perfect for strictly positive prices. If the price is zero, the uninformed consumers can only infer that the quality is negative.

the information sets that yield to the separating equilibrium in Bagwell and Riordan (1991) and here are different: in the former, the consumers know the cost structure of the industry and ignore the share of informed agents; here, all the production costs are normalized to zero and the consumers know the share of informed agents. Specially with a continuum of types, it seems more reasonable to assume that the consumers know the past market share instead of the cost structure of the industry.

3.2 Equilibrium of the first period

The discount factor of the monopolist is 1, so it maximizes the sum of current and future profits.

Lemma 1. *The probability of the intermediate case is independent of the first-period price.*

Proof: in the Appendix.

Then, the *intermediate* case is irrelevant in the maximization problem. Denoting the expected[13] profit of the full-information case by Π_2^I and the profit of the no-information case by Π_2^U, the monopolist problem can be written as

$$\begin{aligned} \underset{p_1}{\text{maximize}} \quad & p_1 x_1^E(p_1) + Pr^I(p_1)\Pi_2^I + Pr^U(p_1)\Pi_2^U \\ \text{subject to} \quad & 0 \leq x_1^E(p_1) \leq 1 \\ & 0 \leq Pr^I(p_1) \leq 1 \\ & 0 \leq Pr^U(p_1) \leq 1 \end{aligned}$$

where

$x_1^E(p_1) = \dfrac{1}{2}(2\mu - \rho\sigma^2 - 2p_1)$ is the expectation of the first-period market share

$Pr^I(p_1) = \dfrac{1}{4Z}(2\mu - \rho\sigma^2 - 2 - 2p_1 + 2Z)$ is the probability of the full-information case

$Pr^U(p_1) = \dfrac{1}{4Z}(-2\mu + \rho\sigma^2 + 2p_1 + 2Z)$ is the probability of the no-information case

Let $L_1 = \frac{4}{\sigma^2}\sqrt{\Pi_2^I - 4Z + 4Z^2} - \frac{2(4Z-\mu)}{\sigma^2}$ and $L_2 = \frac{\Pi_2^I + 2Z\mu}{Z\sigma^2}$. The equilibrium price is:

$$p_1^* = \begin{cases} (2\mu - \rho\sigma^2)/2 & \text{if } \rho \geq L_2 \\ (2Z\mu - Z\rho\sigma^2 - \Pi_2^I + \Pi_2^U)/4Z & \text{if } L_1 > 0 \quad \text{and} \quad L_1 < \rho < L_2; \quad \text{or} \\ & \text{if } L_1 < 0 \quad \text{and} \quad \rho < L_2 \\ (2\mu - \rho\sigma^2 - 2)/2 & \text{if } L_1 > 0 \quad \text{and} \quad \rho \leq L_1 \end{cases} \tag{7}$$

This characterization would allow for an empirical test. Particularly, if different markets are considered (say, different countries) in which the product is introduced simultaneously, the price should decrease as the risk aversion of the consumers increases. Some measures about the risk aversion in different countries are available at the World Values Survey,

[13] $\Pi_2^I = Pr(q < 2)0 + Pr(q > 2)E[q - 1|q > 2] + Pr(0 < q < 2)E[q^2/4|0 < q < 2]$

but certain caveats should be kept in mind: the most important one would refer to the current possibility of the citizens of one country of buying the product in another country through the Internet. In that case, it would be more correct to analyze firms who work with "experiences" or services (for example, Smartbox) because these can only be consumed at a certain location.

The previous characterization also gives rise to the next proposition:

Proposition 2. *The larger the degree of risk aversion, the smaller the probability of observing a decreasing pattern of prices.*

Proof: in the Appendix.

Up to here, the model has been characterized for risk-averse consumers ($\rho > 0$). However, the characterization for risk-neutral consumers is straightforward by making $\rho = 0$. Then, I can state the following corollary:

Corollary 1. *It is less likely to observe a decreasing pattern of prices when the consumers are risk averse than when they are risk neutral.*

The intuition behind this result is simple: the risk-averse consumers need a compensation for the uncertainty faced in the first period that the risk-neutral consumers do not, which is translated into a lower first-period price when the consumers are risk-averse.

The patterns of prices and market shares predicted by the model have some similarities with those described in Shapiro (1983). In his model, Shapiro studies the optimal price path of a monopolist that supplies an experience good over an infinite number of discrete periods. There is a continuum of risk-neutral consumers of mass 1. They are heterogeneous in the valuation of the quality $\bar{q}$, that is not idiosyncratic and can only be learned after consumption. Although the monopolist knows his true quality, signaling considerations are not included. Two cases are analyzed: pessimistic and optimistic.

In the pessimistic case, the consumers expect a quality lower than the true one: $\mu < \bar{q}$. The monopolist sets a low introductory price to spread the favorable information followed by a higher price, that will be constant onwards. The market share is equal across all the periods and less than the corresponding to the full information situation. In my model, this outcome can be obtained even if $\mu > \bar{q}$ because of (i) the compensation required by the consumers due to the risk of buying in the first period, and (ii) the randomness of the first-period market share for the monopolist. Consider for instance the following set of parameters: $\mu = 3$, $\sigma = 1$, $\rho = 4$, $Z = 6$, $\bar{q} = 1.8$. In this case, the full-information market share is 0.9. The equilibrium price of the first period is $p_1^* = 0.426$. Suppose also that $z_1 = 0.126$, so that $\hat{x}_1 = 0.7$. In this case, the monopolist sets a second-period price $p_2^s = 1.1$ and supplies to $x_2 = 0.7$; that is, with these parameters the model predicts a price increase and a constant market share across the two periods. However, the real quality is below the expected one: first, the monopolist chose a low price to compensate the risk; second, the market share remains constant because, given $\hat{x}_1$, the true quality was sufficiently high for the consumers to wish to repeat the purchase, once the uncertainty was removed.

In the optimistic case, the consumers expect a quality higher than the true one: $\mu > \bar{q}$. The monopolist milks his reputation and decreases the price monotonically, reaching a market share larger than would occur under full information. Subsequently, the price and market share go back to their full-information levels (the price increases and the market share decreases) and remain constant onwards. The logic behind is that the monopolist does not let the unfavorable information diffuse too quickly: he can exploit the consumers who still expect the quality to be larger than what actually is. In my model, when the true quality is lower than expected, it is possible to find a similar pattern of market shares jointly with a reversed pattern of prices. Consider now the following set of parameters: $\mu = 3$, $\sigma = 1$, $\rho = 4$, $Z = 6$, $\bar{q} = 0.5$. As before, the equilibrium price of the first period is $p_1^* = 0.426$. If $z_1 = 0.126$ again, then $\hat{x}_1 = 0.7$. In this case, the monopolist sets a second-period price $p_2^s = 0.25$ and supplies to $x_2 = 0.25$. Then, both the market share and the price decrease in the second period with respect to their first-period levels. The reason is that in my framework the monopolist cannot really control how the information about the quality diffuses, because the first-period market share depends on a component that is unknown for him (and, therefore, considered as a random variable).

4 Welfare Analysis

In this section I discuss some options to improve the social welfare.

In view of the above results, it would be desirable to expand the consumer base in the intermediate case of the second period: qualities that would sell more units under perfect information cannot reach new customers because of the signaling dynamics. However, to set a price ceiling in the second period may not be a good solution: among others, the types $\bar{q} < 0$ will find profitable to deviate by charging the maximum price. Then, the consumers will have to adapt their beliefs to include this behavior, decreasing the inferred quality from the price ceiling. Even more, the linearity of the certainty equivalent that allows for a simple characterization derives from the normal distribution of the types: since the separation of some positive and negative types will not be sustainable due to the price ceiling, the distribution of the pooling types will dramatically change with respect to the Gaussian case, perhaps making the characterization impossible.

Nevertheless, there exists another possibility: a price ceiling in the first period. Assuming that the realization of z_1 is also unknown for the social planner, a limit on the first-period price can determine the probabilities of the full information event and of the no information event. The problem of the social planner is then to maximize the expected total surplus.

The three graphs below show the first-period price chosen by the monopolist to maximize his expected profits (dotted line) and the first-period price chosen by the social planner to maximize the expected total surplus, for three different values of the expected quality μ with variance of $\sigma^2 = 1$ and $Z = 5$. A more complete characterization of the optimal policy of the social planner is provided in the Appendix.

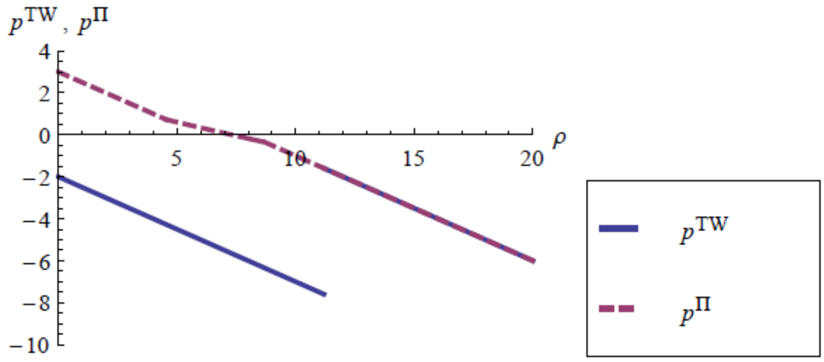

Figure 2: Prices chosen by the monopolist and by the social planner; $\mu = 4$.

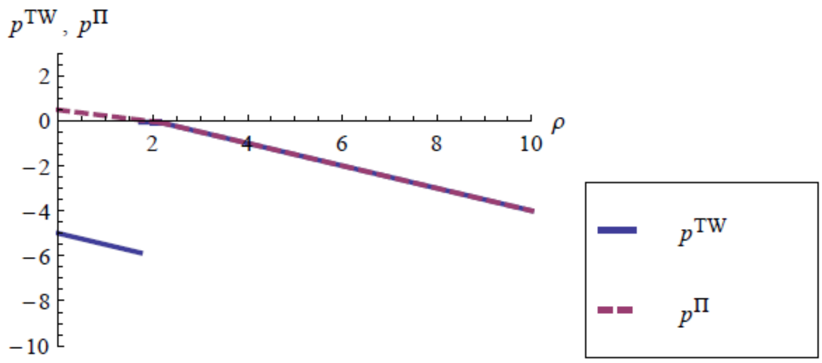

Figure 3: Prices chosen by the monopolist and by the social planner; $\mu = 1$.

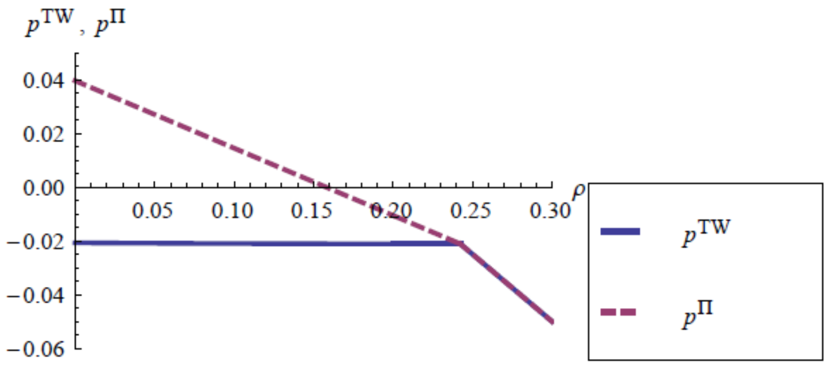

Figure 4: Prices chosen by the monopolist and by the social planner; $\mu = 0.1$.

There are two remarkable things. First, the price that maximizes the social welfare does not strictly decrease as the risk-aversion parameter increases when μ is large enough, as can be noticed from the discontinuities in Figure 2 and Figure 3 (in Figure 4 there is no discontinuity because μ is small enough). The reason is that, for μ large enough and low values of ρ, the option that maximizes the expected total welfare is to ensure the diffusion of the information (that is, to set a price such that the probability of the full information event is 1). However, if the value of ρ is over a certain threshold, this option becomes too costly and it is better for the society to allow for the no information event to happen with a strictly positive probability. Second, the social planner weakly prefers to diffuse more information than the monopolist; that is, the social planner always sets a lower or equal price than the one chosen by the monopolist. As can be observed in the three previous figures, for values of ρ large enough the prices set by the social planner and by the monopolist coincide: the best strategy is to set the expected market share of the period 1 equal to 0, and to allow for both the full information event and the no information event to happen with positive probability. This suggests that the authority should only take part to improve the social welfare when the consumers are not very risk averse.

5 Conclusion

I have presented a model that describes the optimal strategy of a forward-looking monopolist in a game of two periods when a new product is introduced, facing risk-averse consumers. The difference between the first period and the second is the amount of information spread in the market, that cannot be fully controlled by the monopolist.

In particular, the monopolist introduces a new, non-storable product. The strategic variable of the monopolist is the price, and both intra-period discrimination and inter-period commitment are not allowed. There is a different mass of consumers in each period. In the first period there is no information about the quality of the product, although it is public knowledge that all the qualities are equally costly and that the quality is normally distributed with mean $\mu > 0$ and standard deviation σ. Thus, the purchasing decisions of the first-period consumers are based on the expected utility: the uncertainty is penalized whereas the expected quality is rewarded. Additionally, there is an element in the consumers' utility of the first period that cannot be observed by the firm, so I differentiate among three potential outcomes: all consumers buy the product, nobody buys the product, and only a share of consumers buy the product.

Consumers of the first period who acquired the good learn the quality, and the monopolist learns the quality if some consumers do. The information is transmitted to the second-period consumers through a very specific channel: the consumer located at x_i in the first period communicates her gathered information to the consumer located at x_i in the second period, so that the market is divided between informed and uninformed consumers. The informed consumers do not penalize the uncertainty, and the uninformed consumers use the first-period market share and the second-period price to update their beliefs.

The model has two main predictions. First, it is possible to observe an increasing pattern of prices when relatively low qualities are revealed. The likelihood of observing a decreasing pattern of prices decreases as the degree of risk aversion increases: the reason is that, the higher the degree of risk-aversion, the lower the first-period price. Second, if only a share of consumers are informed, there exists a semi-separating equilibrium in which the uninformed consumers can always infer with no error any strictly positive quality. Interestingly, distortion is only necessary for qualities above a certain threshold that depends on the share of informed consumers. Even more, the distortion necessary to sustain the semi-separating equilibrium is so intense that the uninformed consumers never buy in equilibrium. It is important to remark the key signaling role played by the first-period market share: it is unrelated to the quality, but the uninformed consumers know how many people are informed and they can understand the cost of charging a deceiving price in terms of lost profits from the informed sector. Since the consumers of the two periods are different and all qualities are equally costly, the prices cannot be credible signals by themselves if the first-period market share is not observed.

Also, I have explored some potential policies to improve the total welfare. I argue that setting a price cap in the second period breaks the signaling properties of the second-period equilibrium. Instead, the social planner can set a price cap in the first period. I show that the social planner weakly prefers to have more informed consumers than the monopolist. However, when the risk aversion parameter is large enough, both the social planner and the monopolist would implement the same price.

Finally, I discuss the role of some assumptions. First, the monopolist considers that the variable z_1, that he cannot observe, is uniformly distributed. The advantage of this distribution is that it allows to find the closed-form solution of the equilibrium. The distribution may be changed, but the equilibrium should be calculated through numerical methods. Also, this distribution makes irrelevant for the intertemporal problem the situation of the second period in which only some consumers are informed. The main properties of the equilibrium would not change if a different distribution was assumed, as long as the probability of the event in which only some consumers are informed was small enough. Second, it is possible to relax the assumption of perfect learning by considering that the consumers receive a noisy signal about the quality. Thus, the uncertainty would still be penalized in the second period, although not so intensely as in the first period. Even more, it is possible to find a semi-separating equilibrium analogous to the one existing with perfect learning, but instead of the true quality, the uninformed consumers would infer the signal received by the informed consumers. Third, it is important to remark that, when $\rho \geq 2\mu/\sigma^2$, the equilibrium with forward-looking consumers works as explained in the model, with a different mass of consumers in each period. The economic logic is as follows: first, no consumer with positive utility in the first period wishes to postpone her consumption, because her overall utility would be zero (if nobody buys, the second-period utility is zero because of the degree of risk aversion, and if she is more distant to the monopolist than the marginal consumer, she will be out of the second-period consumption); second, a consumer with negative utility may want to buy if consumers behind her in the line also buy. However, the most distant consumer does not want to buy in the first period if she has a negative utility, because the utility of the second period is zero for sure. Then, the marginal consumer buys only if she is indifferent between buying or not in the first period. However, more complicated dynamics arise if $\rho < 2\mu/\sigma^2$, in which the consumers will balance the information acquisition and the future prices. These considerations are left for future research.

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Appendix

Proof of Proposition 1

Proof. Let me set the beliefs of the uninformed consumers, $\tilde{q}$, when they observe a strictly positive price p_2^s and a first-period market share $\hat{x}_1 \in (0,1)$:

$$\tilde{q} = \begin{cases} 2p_2^s & \text{if } p_2^s < \hat{x}_1 \\ p_2^s + \hat{x}_1 & \text{if } p_2^s \geq \hat{x}_1 \end{cases}$$

Since these beliefs assign a single inferred quality to a given information set $\{p_2^s, \hat{x}_1\}$, the variance is zero. Then, the demand would be $\omega(\rho, p_2, \hat{x}_1) = \tilde{q} - p_2^s$. Moreover, since it is bounded below by $\hat{x}_1$, this sector in fact demands no quantity of the good for the previous beliefs. This implies that the monopolist is constrained to maximize its profits within the informed sector. It turns out that if the type, $\bar{q}$, is large enough compared to the size of the informed sector, $\bar{q} \geq 2\hat{x}_1$, the only price that maximizes the monopolist's profits is $p_2^s = \bar{q} - \hat{x}_1$: it corresponds to a corner solution in which the most distant informed consumer obtains zero surplus. If $\bar{q} < 2\hat{x}_1$, the only price that maximizes the monopolist's profits is $p_2^s = \bar{q}/2$, that corresponds to an interior solution within the informed sector. This is then a separating PBNE equilibrium: the beliefs are confirmed ($\tilde{q} = \bar{q}$) and no type has incentives to deviate.

Regarding the pooling part of the equilibrium, all the negative types pool at a zero price. If the uninformed consumers observe such a price, they know that the true type belongs to the interval $(-\infty, 0]$. The demand from this sector would be zero independently of the beliefs (that are required not to contradict Bayes' rule) and of the uncertainty penalization[14], and the demand from the informed consumers is also zero. Notice that the monopolist obtains no gains from deviation given the beliefs specified above for strictly positive prices. Then, this constitutes a pooling PBNE equilibrium. $\square$

Proof of Lemma 1

[14] This happens because, even in the most favorable case of an inferred quality of 0 with no penalty, the demand is zero.

Proof. There will be a first-period demand $\hat{x}_1 \in (0,1)$ if the random shock

$$z_1 \in \left(p_1 - \mu + \frac{1}{2}\rho\sigma^2, 1 + p_1 - \mu + \frac{1}{2}\rho\sigma^2\right)$$

By the uniform distribution of z_1, the probability of this event is

$$\begin{aligned} & F\left(1 + p_1 - \mu + \frac{1}{2}\rho\sigma^2\right) - F\left(p_1 - \mu + \frac{1}{2}\rho\sigma^2\right) && = \\ & \frac{2 + 2p_1 - 2\mu + \rho\sigma^2 + 2Z}{4Z} - \frac{2p_1 - 2\mu + \rho\sigma^2 + 2Z}{4Z} && = \\ & \frac{1}{2Z} \end{aligned}$$

$\square$

Proof of Proposition 2

Proof. By simple algebra it is possible to check that $p_1^* < p_2^U \quad \forall \rho \geq 0$. The intuition behind this result is that, in the first period, the monopolist has incentives to spread the information: if the uncertainty is removed, the willingness to pay of the consumers will increase in expected terms and he could charge a higher price in the second period. Then, to observe a decreasing pattern of prices, a first-period market share $\hat{x}_1 > 0$ is necessary. Depending on the value of $\hat{x}_1$, $\dot{p}_2$ will refer to p_2^I or to p_2^s.

Since I am looking for decreasing patterns of prices, I focus on $p_1^* > 0$ (if $p_1^* < 0$, the pattern of prices will be increasing because in the second period the negative prices are weakly dominated strategies). Consider a set of parameters μ, σ and ρ such that the corresponding first-period equilibrium price is $p_1^* > 0$. Given $\hat{x}_1$, I denote by $\dot{q}$ the quality for which $\dot{p}_2 = p_1^*$ holds: all the qualities below $\dot{q}$ yield a decreasing pattern of prices. Since p_1^* decreases as ρ increases, so does $\dot{q}$. $\square$

Characterization of the social planer's problem

The problem of the social planner is as follows:

$$\begin{aligned} \underset{p_1}{\text{maximize}} \quad & p_1 x_1^E(p_1) + \int_0^{x_1^E(p_1)} \left(\mu - \frac{1}{2}\rho\sigma^2 - p_1 - x_i\right) dx_i + Pr^I(p_1) TW_2^I + Pr^U(p_1) TW_2^U \\ \text{subject to} \quad & 0 \leq x_1^E(p_1) \leq 1 \\ & 0 \leq Pr^I(p_1) \leq 1 \\ & 0 \leq Pr^U(p_1) \leq 1 \end{aligned}$$

where

$$\begin{aligned} TW_2^I = & \Pi_2^I + Pr(q < 2)0 + Pr(q > 2)E[\int_0^1 q - (q-1) - x_i \, dx_i | q > 2] \\ & + Pr(0 < q < 2)E[\int_0^{q/2} q - (q/2) - x_i \, dx_i | 0 < q < 2] \end{aligned}$$

and

$$TW_2^U = \begin{cases} 0 & \text{if } \rho \geq 2\mu/\sigma^2 \\ 3(2\mu - \rho\sigma^2)^2/32 & \text{if } \mu \leq 2 \quad \text{and} \quad \rho < 2\mu/\sigma^2; \quad \text{or} \\ & \text{if } \mu > 2 \quad \text{and} \quad (-4+2\mu)/\sigma^2 < \rho < 2\mu/\sigma^2 \\ (2\mu - \rho\sigma^2 - 1)/2 & \text{if } \mu > 2 \quad \text{and} \quad \rho \leq (-4+2\mu)/\sigma^2 \end{cases}$$

Also, notice that the expected total welfare of the first period only depends on p_1 if $x_1^E(p_1) \in (0,1)$. In that case, its simplified expression is $[(2p_1 - 2\mu + \rho\sigma^2)^2/8] + [p_1(2\mu - \rho\sigma^2 - 2p_1)/2]$. If $x_1^E(p_1) = 0$, the expected total welfare of the first period is also 0. If $x_1^E(p_1) = 1$, the expected total welfare of the first period is $2\mu - \rho\sigma^2 - 1)/2$.

The welfare-maximizing price will correspond to one out of the following five options:

1. Option 1 (O1): p_1 such that $0 < x_1^E(p_1) < 1$, $0 < Pr^I(p_1) < 1$ and $0 < Pr^U(p_1) < 1$;[15]
2. Option 2 (O2): p_1 such that $x_1^E(p_1) = 0$, $0 < Pr^I(p_1) < 1$ and $0 < Pr^U(p_1) < 1$;
3. Option 3 (O3): p_1 such that $x_1^E(p_1) = 1$, $0 < Pr^I(p_1) < 1$ and $0 < Pr^U(p_1) < 1$;
4. Option 4 (O4): p_1 such that $Pr^I(p_1) = 1$ (mathematically, $x_1^E(p_1) > 1$ and $Pr^U(p_1) < 0$, so the corner solution $x_1^E(p_1) = 1$ and $Pr^U(p_1) = 0$ applies);
5. Option 5 (O5): p_1 such that $Pr^U(p_1) = 1$ (mathematically, $x_1^E(p_1) < 0$ and $Pr^I(p_1) < 0$, so the corner solution $x_1^E(p_1) = 0$ and $Pr^I(p_1) = 0$ applies).

By simple algebra, it is possible to show that the options O3 and O5 always generate less welfare than the other alternatives for any $\mu > 0$ and any $\rho > 0$. Also, it is easy to show that the option O2 maximizes the welfare for any $\mu > 0$ and large values of ρ. Intuitively, the option O2 generates the largest welfare when ρ is large enough because in the first period it provides no welfare in expected terms (the other options provide negative expected levels of welfare if ρ is large), and in the second period it provides no welfare if the information cannot be disclosed and a positive expected welfare in the full-information case, what happens with a strictly positive probability (whereas the rest of the options provide the same levels of expected welfare in the second period, but the probabilities of the two events differ). Then, it remains to determine the chosen options for lower values of ρ.

The characterization method works as follows: first, compare the welfare provided by the options O1 and O4 when $\rho = 0$ and find the value μ that make them equal. If we make the variance equal to $\sigma^2 = 1$, this threshold is approximately $\bar{\mu} = 0.442$: for lower values of μ the starting welfare-maximizing option is O1, and for higher values of μ the starting welfare-maximizing option is O4. Second, if the welfare-maximizing option for low values of ρ is O4, it is necessary to determine the $\tilde{\mu}$ that divides the paths of the options chosen by the social planner in two: (O4, O1, O2) and (O4, O2). To do it, equalize the total welfare obtained with O1 and O4 and keep the obtained $\rho(\mu)$. Then, plug this value into

[15] Notice that the structure of the price chosen under the option O1 changes depending on the corresponding value of Π_2^U.

x_1^E and evaluate it in the optimal price chosen under O1. The value of μ that makes x_1^E equal to 0 is the threshold $\tilde{\mu}$. In the case of the variance $\sigma^2 = 1$, $\tilde{\mu} = 1.461$, approximately. Then, for $\mu \in (0, \bar{\mu})$ the social planner chooses (O1, O2) and there is no jump in the price when moving from O1 to O2; for $\mu \in [\bar{\mu}, \tilde{\mu}]$ the social planner chooses (O4, O1 and O2) with a jump in the price when changing from O4 to O1; and for $\mu > \tilde{\mu}$, the social planner chooses (O4, O2) with a jump in the price when changing from O4 to O2.

References

Ackerberg, D. A. (2003, August). Advertising, Learning, and Consumer Choice in Experience Good Markets: An Empirical Examination. *International Economic Review 44*(3), 1007–1040.

Athey, S. (2001, July). Single Crossing Properties and the Existence of Pure Strategy Equilibria in Games of Incomplete Information. *Econometrica 69*(4), 861–89.

Bagwell, K. and M. H. Riordan (1991, March). High and Declining Prices Signal Product Quality. *American Economic Review 81*(1), 224–39.

Bar-Isaac, H. (2003). Reputation and Survival: Learning in a Dynamic Signalling Model. *Review of Economic Studies 70*(2), 231–251.

Bergemann, D. and J. Valimaki (2006, August). Dynamic Pricing of New Experience Goods. *Journal of Political Economy 114*(4), 713–743.

Bose, S., G. Orosel, M. Ottaviani, and L. Vesterlund (2006, Winter). Dynamic monopoly pricing and herding. *RAND Journal of Economics 37*(4), 910–928.

Caminal, R. and X. Vives (1996, Summer). Why Market Shares Matter: An Information-Based Theory. *RAND Journal of Economics 27*(2), 221–239.

Crawford, G. S. and M. Shum (2005, July). Uncertainty and Learning in Pharmaceutical Demand. *Econometrica 73*(4), 1137–1173.

Farina, T. (2012). How Do Experience and Shopping Frequency Affect Consumers' Brand Choice? *mimeo*.

Israel, M. (2005, December). Services as Experience Goods: An Empirical Examination of Consumer Learning in Automobile Insurance. *American Economic Review 95*(5), 1444–1463.

Judd, K. L. and M. H. Riordan (1994, October). Price and Quality in a New Product Monopoly. *Review of Economic Studies 61*(4), 773–89.

Mailath, G. J. (1987, November). Incentive Compatibility in Signaling Games with a Continuum of Types. *Econometrica 55*(6), 1349–65.

Milgrom, P. and J. Roberts (1986, August). Price and Advertising Signals of Product Quality. *Journal of Political Economy 94*(4), 796–821.

Nelson, P. (1970, March). Information and Consumer Behavior. *Journal of Political Economy 78*(2), 311–29.

Ramey, G. (1996, May). D1 Signaling Equilibria with Multiple Signals and a Continuum of Types. *Journal of Economic Theory 69*(2), 508–531.

Shapiro, C. (1983, Autumn). Optimal Pricing of Experience Goods. *Bell Journal of Economics 14*(2), 497–507.

Spence, A. M. (1973, August). Job Market Signaling. *The Quarterly Journal of Economics 87*(3), 355–74.

Tirole, J. (1988). *The Theory of Industrial Organization*, Volume 1 of *MIT Press Books*. The MIT Press.

Villas-Boas, J. M. (2006, 03). Dynamic Competition with Experience Goods. *Journal of Economics & Management Strategy 15*(1), 37–66.