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"Download for Free" - When Do Providers of Digital Goods Offer Free Samples?

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Abstract

In a monopoly setting where consumers cannot observe the quality of the product we show that free samples which are of a lower quality than the marketed digital goods are used together with high prices as signals for a superior quality if the number of informed consumers is small and if the difference between the high and the low quality is not too small. Social welfare is higher, if the monopolist uses also free samples as signals, compared to a situation where he is restricted to pure price signalling. Both, the monopolist and consumers benefit from the additional signal.

Keywords: Digital Goods, Free Samples, Multi-dimensional Signalling

JEL classification: D21, D82, L15

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1 Introduction

In the internet economy we often observe providers which offer free samples of their products. North-Holland, for example, allows non-subscribers of their scientific journals to download certain complimentary articles. Software providers like Qualcomm offer so-called light or sponsored versions of their software for free, which are either not as capable as the full version or contaminated with advertisements that open up, while these versions are used. Also publishing houses and record labels place parts of their newly released novels or records in the internet for free downloads.[1]

Certainly, potential buyers of a novel would not pay less for the book, if they received five pages of the novel for free from the internet. In case of software programs that deliver at least the basic features of the full version, as Qualcomm's Eudora Light, one would, however, expect a reduction in the willingness to pay for the full version because of the free availability of the light version. Software and most other digital goods are durable. Therefore consumers would only pay for the extra benefit which the full version delivers and not for the full benefit. Why do providers of digital goods then offer free samples?

Shapiro and Varian (1998) suggest several reasons. Consumers might receive one product out of a bundle for free in order to increase their willingness to pay for some complementary components. Firms might want to create a critical mass in order to ensure high enough network externalities. They might want to catch the attention of the consumers for some advertisements, or they might want to achieve some competitive advantage by the preemption of other competitors. Shapiro and Varian (1998) also mention that firms might want to convince potential customers of the quality of their products.

The latter motivation is the focus of this paper. Firms which want to convince potential consumers of the quality of their digital product face the same kind of problem as has already been identified by Arrow (1962) with respect to information as a commodity. The value of a certain software, for example, is not known until a consumer has it, but if he has it, it can no longer be sold to him, and the software can be reproduced and distributed at little or no cost. Thus, the questions which are addressed in this paper are: how comprehensive must a free sample of a digital good be in order to serve as a signal for a high quality, would a monopolist use free samples if he could also set a high price in order to signal a high quality, how are profits, consumer's

[1] See e.g. the internet pages of the *Deutsche Grammophon* and the *Aufbau-Verlag*, a German publishing house.

surplus and social welfare affected by the use of free samples as a signalling device, and, finally, should free samples be restricted?

Free samples have been a major issue in the marketing literature. There are lots of empirical studies which try to evaluate the effect of free samples on consumers' behavior.[2] With the exception of Smith and Swinyard (1983), who chose an experimental approach, all these studies rely on survey data, and all consider non-durable products (mostly food and detergents) which cannot easily be reproduced.

This is also true for most of the much scarcer economic literature on free samples. Moraga-Gonzalez (2000) analyzes a monopolistic market with asymmetric information concerning the quality of a good. The monopolist can endogenously influence the number of informed consumers by the number of distributed free samples. Moraga-Gonzalez (2000) does not assume that the free samples reduce demand, and does definitely not allow for a good which is easily reproduced, because otherwise it would be impossible for the monopolist to perfectly control the number of informed consumers. Lecocq *et al.* (1999) also consider a non-durable and a non-reproducable product. They report the results of an experiment, they pursued during a conference of the Vineyard Data Quantification Society, where the subjects bid in a wine auction with and without tasting the wine, before they placed their bids.

Only Foster and Horowitz (1996) and Kamp (1998), who comments on the former, consider free samples of a durable good. They investigate, whether the resale of complimentary textbooks by professors increase the price that the students have to pay for new textbooks. The textbook market, where students pay and professors decide, is, however, very special and not easily comparable to the markets for digital goods.

Contrary to Moraga-Gonzalez (2000)and to Foster and Horowitz (1996) and Kamp (1998), I assume here that every consumer receives the free sample, in order to map the easy access to free digital samples in reality. Similar to a recent contribution by Anton and Yao (2002) on the sale of new ideas, I also assume that the value of the digital product is additive. Thus, consumers only want to pay for the quality they expect to receive in addition to the free sample, if there is one. Contrary to Anton and Yao (2002), I assume that the utility levels of the consumers are, however, not verifiable. Therefore the providers of digital products cannot condition the payments of their clients on their realized levels of satisfaction.

In the next section the main assumptions of the model are introduced. It

[2] See e.g. Scott (1976), Smith and Swinyard (1983), Marks and Kamins (1988), McGuinness *et al.* (1995), Gedenk and Neslin (1999) and Moore and Lutz (2000).

is an adverse selection version of the well known model of vertical product differentiation, first used by Mussa and Rosen (1978), that is extended to asymmetric quality information and free samples. Then I show that free samples can serve as a signal for good quality in a monopoly framework. The mechanism is pretty similar to Cooper and Ross (1984) and Bagwell and Riordan (1991). Since some consumers can observe the true quality of the product, a high quality provider can find a level of quality for his free sample and a price level, that cannot be imitated by the low quality provider and that allows him to sell his premium quality still for a high enough price in order to be more profitable than without differentiating from a low quality provider. Focussing on the perfect Bayesian equilibrium that fulfills the intuitive criterion from Cho and Kreps (1987), I show that signalling via free samples takes place only together with price signalling. Free samples are provided if the number of informed consumers is rather small and if the low quality is in an intermediate range compared to the high quality. Social welfare is always enhanced by using free samples as a signal for high quality.

2 The Model

There is a continuum of risk neutral consumers whose mass is normalized to one. With probability of λ each consumer is an expert who can instantaneously recognize the quality of an offered product.[3] With probability of $1-\lambda$ the consumer is uninformed, cannot observe the quality of a product, but knows the distribution of qualities in the market. Consumers differ in the parameter θ which indicates the strength of their preference for quality. The parameter θ is independently and uniformly distributed on the interval $[0, 1]$. Each consumer's willingness to pay for the known quality q is given by θq, if there is no free sample. If a free sample with quality s is available, then the consumer's willingness to pay for the known quality q is reduced to $\theta(q-s)$.

There is only one firm in the market, which offers a durable digital good. The firm's probability to produce a product with the high quality q_h is $\gamma \in (0, 1)$.

[3]Experts are needed in order to have a punishment for low quality providers which imitate the strategy of high quality providers. The alternative assumptions of repeat purchases, used e.g. by Kihlstrom and Riordan (1984), Milgrom and Roberts (1986), and Orzach *et al.* (2002), or of different constant marginal costs for high and low quality providers as in Zhao (2000) and Bagwell and Overgaard (2005) do not make sense with durable digital goods.

With probability $1 - \gamma$ it produces a low quality $q_l < q_h$.[4] The firm knows the true quality of its product, but it cannot distinguish between informed and uninformed consumers. The firm maximizes its profits. It can decide on providing free samples of its product to all consumers and can determine the quality s of this free sample. The quality of the firm's free sample cannot exceed its product's quality $q \geq s \geq 0$ with $q \in \{q_l, q_h\}$. If the monopolist chooses $s = 0$, this means that he does not provide a free sample. The firm also sets its price and may use it as well in order to signal its digital good's quality.[5] Note that contrary to conspicuous advertising that has been combined with price signalling in a model by Milgrom and Roberts (1986) the free samples have a potential social value if some of the consumers consume only them and do not buy the monopolist's product.

Neither the distribution of a free sample nor the distribution of the digital final good causes any costs. This assumption maps the low distribution and reproduction costs of digital goods via the internet. In case of digital goods the main costs of production are the costs of the first copy, in case of software, the development costs, which are not further considered here.

In the following we investigate, whether perfect Bayesian equilibria exist in which the provider of a high and of a low quality separate by their pricing decision and/or by the provision of free samples.

3 The Market Outcome with Perfect Information

Suppose that $\lambda = 1$ holds, meaning that all consumers are experts and can recognize the quality of the offered product. If the monopolist of type $i = h, l$ provides free samples with the quality $0 \leq s_i \leq q_i$ then all consumers buy whose willingness to pay $\theta(q_i - s_i)$ exceeds p_i which is equal to:

$$\theta \geq \frac{p_i}{q_i - s_i} \equiv \underline{\theta}(p_i, q_i, s_i). \qquad (1)$$

[4] We concentrate throughout the paper on adverse selection and do not consider moral hazard issues.

[5] See, e.g., Cooper and Ross (1984) and Bagwell and Riordan (1991) for models, in which high quality is signaled via a high price.

Thus, the monopolist's profit coincides with:

$$\begin{aligned} \pi(p_i, q_i, s_i) &= p_i \max\left\{\left[1 - \underline{\theta}(p_i, q_i, s_i)\right], 0\right\} \\ &= \begin{cases} p_i \left(1 - \frac{p_i}{q_i - s_i}\right) & \text{if } 0 \leq p_i \leq q_i - s_i, \\ 0 & \text{if } p_i > q_i - s_i. \end{cases} \end{aligned} \tag{2}$$

The monopolist sets p_i and s_i in order to maximize this profit function. The firm does not have to take into account any change of the consumers' beliefs as a response to its chosen (p_i, s_i) because all the consumers are perfectly informed by assumption. Therefore it is easy to derive the following proposition.

Proposition 1 *If all the consumers are informed ($\lambda = 1$) then the monopolist does not provide any free sample ($s_i = 0$), no matter whether he is of type h or l. The firm of type $i = h, l$ sets $p_i = q_i/2$ and realizes a profit of $\pi(q_i/2, q_i, 0) = q_i/4$.*

Proof: Since $\partial\pi(p_i, q_i, s_i)/\partial s_i \leq 0$ holds for all p_i, $s_i = 0$ follows immediately. The profit maximizing price $p_i = q_i/2$ results from maximizing $\pi(p_i, q_i, 0)$ with respect to p_i. Substituting $p_i = q_i/2$ in $\pi(p_i, q_i, 0)$ yields $\pi(q_i/2, q_i, 0) = q_i/4$. ■

If all consumers are perfectly informed then providing a free sample with $s_i > 0$ results only in a smaller demand for any given price, because then the monopolist has to compete with its digital product of quality q_i against the free sample with the quality s_i. Of course, the monopolist wants to avoid such a situation and does not provide a free sample.

4 Free Samples with Uninformed Consumers

4.1 Characterization of the Perfect Bayesian Equilibria

Now we assume that there are some uninformed consumers meaning $0 < \lambda < 1$. These uninformed consumers can observe the price and the quality of the free sample if there is one. Suppose that these consumers believe that $(p, s) = (p_h, s_h)$ signals a high quality and $(p, s) \neq (p_h, s_h)$ signals a low quality, then these beliefs must come true in a Perfect Bayesian equilibrium.

Given these beliefs a monopolist with the quality q_l should either choose (p_h, s_h) or the combination $(p_l, s_l) = (q_l/2, 0)$ which maximizes $\pi(p_l, q_l, s_l)$ defined in equation (2). The latter is true because the λ informed consumers observe his low quality anyway, and the $1-\lambda$ uninformed consumers expect that he is a low type as soon as he chooses $(p, s) \neq (p_h, s_h)$. Since the beliefs of the uninformed consumers must come true in equilibrium, a producer with q_l must prefer $(p_l, s_l) = (q_l/2, 0)$ to (p_h, s_h), the price and free sample that would be interpreted by the uninformed consumer as a signal for a high quality. Therefore (p_h, s_h) must satisfy

$$\lambda\pi(p_h, q_l, s_h) + (1-\lambda)\pi(p_h, q_h, s_h) \leq \pi(q_l/2, q_l, 0) \tag{3}$$

where $\pi(\cdot)$ is defined in equation (2). This coincides with either:

$$\begin{aligned} p_h \quad &> \quad \frac{q_l\sqrt{(q_h - s_h)(q_l - s_h)}}{2\left[\sqrt{(q_h - s_h)(q_l - s_h)} - \sqrt{(1-\lambda)(q_h - q_l)q_l - s_h(q_h - s_h)}\right]} \\ &\equiv \bar{f}(q_h, q_l, s_h, \lambda), \end{aligned} \tag{4}$$

or:

$$\begin{aligned} p_h \quad &< \quad \frac{q_l\sqrt{(q_h - s_h)(q_l - s_h)}}{2\left[\sqrt{(q_h - s_h)(q_l - s_h)} + \sqrt{(1-\lambda)(q_h - q_l)q_l - s_h(q_h - s_h)}\right]} \\ &\equiv \underline{f}(q_h, q_l, s_h, \lambda). \end{aligned} \tag{5}$$

Note that $\bar{f}(\cdot) \geq \underline{f}(\cdot)$ for all $0 \leq s_h \leq 1/2[q_h - \sqrt{q_h^2 - 4(1-\lambda)q_l(q_h - q_l)}] < q_l$. For $1/2[q_h - \sqrt{q_h^2 - 4(1-\lambda)q_l(q_h - q_l)}] < s_h \leq q_l$ condition (3) is satisfied independent of the price level. Any $s_h > q_l$ cannot be imitated by a low quality provider and would therefore clearly identify a high type.

The high quality provider should also have no incentive to deviate from (p_h, s_h). If he deviates to any $(p, s) \neq (p_h, s_h)$ the informed consumers still identify him, whereas the uninformed expect him to be a low quality provider. Thus, his profit would be

$$\lambda\pi(p, q_h, s) + (1-\lambda)\pi(p, q_l, s) = p\left(1 - \frac{\lambda p}{q_h - s} - \frac{(1-\lambda)p}{q_l - s}\right).$$

This profit is decreasing in s, no matter which price p the deviating high quality provider would choose. Thus, his best deviation from (p_h, s_h) would always imply that he does not provide any free samples any more. He would always set $s = 0$. Given $s = 0$, the high quality provider's profit, when he deviates from (p_h, s_h), is maximized if he chooses

$$\tilde{p} = \frac{q_h q_l}{2[(1-\lambda)q_h + \lambda q_l]}. \tag{6}$$

Thus, his best deviation from (p_h, s_h) is $(\tilde{p}, 0)$. In a perfect Bayesian equilibrium even the best deviation $(\tilde{p}, 0)$ should be less profitable than sticking to (p_h, s_h). Therefore

$$\lambda \pi(\tilde{p}, q_h, 0) + (1-\lambda)\pi(\tilde{p}, q_l, 0) \leq \pi(p_h, q_h, s_h) \tag{7}$$

must hold. Condition (7) coincides with

$$\underline{g}(q_h, q_l, s_h, \lambda) \leq p_h \leq \bar{g}(q_h, q_l, s_h, \lambda) \text{ with} \tag{8}$$

$$\begin{aligned}\underline{g}(\cdot) \quad \equiv \quad & \frac{1}{2}\Bigg(q_h - s_h \\ & - \frac{\sqrt{[(1-\lambda)q_h + \lambda q_l]\left\{[(1-\lambda)q_h + \lambda q_l](q_h - s_h) - q_h q_l\right\}(q_h - s_h)}}{(1-\lambda)q_h + \lambda q_l}\Bigg)\end{aligned}$$

and

$$\begin{aligned}\bar{g}(\cdot) \quad \equiv \quad & \frac{1}{2}\Bigg(q_h - s_h \\ & + \frac{\sqrt{[(1-\lambda)q_h + \lambda q_l]\left\{[(1-\lambda)q_h + \lambda q_l](q_h - s_h) - q_h q_l\right\}(q_h - s_h)}}{(1-\lambda)q_h + \lambda q_l}\Bigg).\end{aligned}$$

After analyzing the conditions in equation (4), (5) and (8) one can derive proposition 2 where the critical level

$$\hat{\lambda}(q_l, q_h) \equiv \frac{q_h(q_h - 2q_l)}{(q_h - q_l)^2}$$

of the number of informed consumers is introduced.

Proposition 2 *There are infinitely many separating perfect Bayesian equilibria where the uninformed consumers believe that a firm which chooses* (p_h, s_h) *is a high quality firm and a firm which chooses* $(p, s) \neq (p_h, s_h)$ *is a low quality firm and where the high quality provider indeed chooses* (p_h, s_h) *and the low quality provider* $(p_l, s_l) = (q_l/2, 0)$*. The beliefs* (p_h, s_h) *must satisfy (4), (5) and (8). If the number of informed consumers is low, meaning that* $0 < \lambda \leq \hat{\lambda}(q_h, q_l)$ *holds, then equilibria exist for all quality levels* $0 \leq s_h \leq q_l$ *of the high type's free sample. If there are many informed consumers with* $\max\{\hat{\lambda}(q_h, q_l), 0\} < \lambda < 1$ *then the quality of the high type's free sample in equilibrium is restricted to* $0 < s_h < q_h - q_l q_h/[(1-\lambda)q_h + \lambda q_l)]$.

Proof: See the argument above and note that $\bar{f}(q_h, q_l, s_h, \lambda)$ from equation (4) and $\bar{g}(q_h, q_l, s_h, \lambda)$ from equation (8) are both decreasing and $\underline{f}(q_h, q_l, s_h, \lambda)$ from equation (5) and $\underline{g}(q_h, q_l, s_h, \lambda)$ from equation (8) both increasing in s_h for all those $s_h < q_l$ for which they are defined. In addition $\bar{f}(q_h, q_l, s_h, \lambda) < \bar{g}(q_h, q_l, s_h, \lambda)$ holds for all $0 \leq s_h \leq 1/2[q_h - \sqrt{q_h^2 - 4(1-\lambda)q_l(q_h - q_l)}] < q_l$ for which $\bar{f}(q_h, q_l, s_h, \lambda)$ and $\underline{f}(q_h, q_l, s_h, \lambda)$ are defined. The functions $\bar{g}(q_h, q_l, s_h, \lambda)$ and $\underline{g}(q_h, q_l, s_h, \lambda)$ are defined for all $0 \leq s_h \leq q_h - q_l q_h/[(1-\lambda)q_h + \lambda q_l)]$ and $q_h - q_l q_h/[(1-\lambda)q_h + \lambda q_l) < q_l$ holds for $\lambda > \frac{q_h(q_h - 2q_l)}{(q_h - q_l)^2}$. ■

Thus, as long as there are some uninformed consumers ($\lambda < 1$) free samples together with an adequately chosen price can serve as a signal for a high quality. In addition, if there are only a few informed consumers $\lambda \leq \hat{\lambda}(q_h, q_l)$ the identifying combination of (p_h, s_h) can even imply any quality level $s_h \leq q_l$ of the high type's free sample. There are, however, infinitely many combinations of p_h and s_h which are perfect Bayesian equilibria. They are depicted as hatched areas in Figure 1 for the two cases.

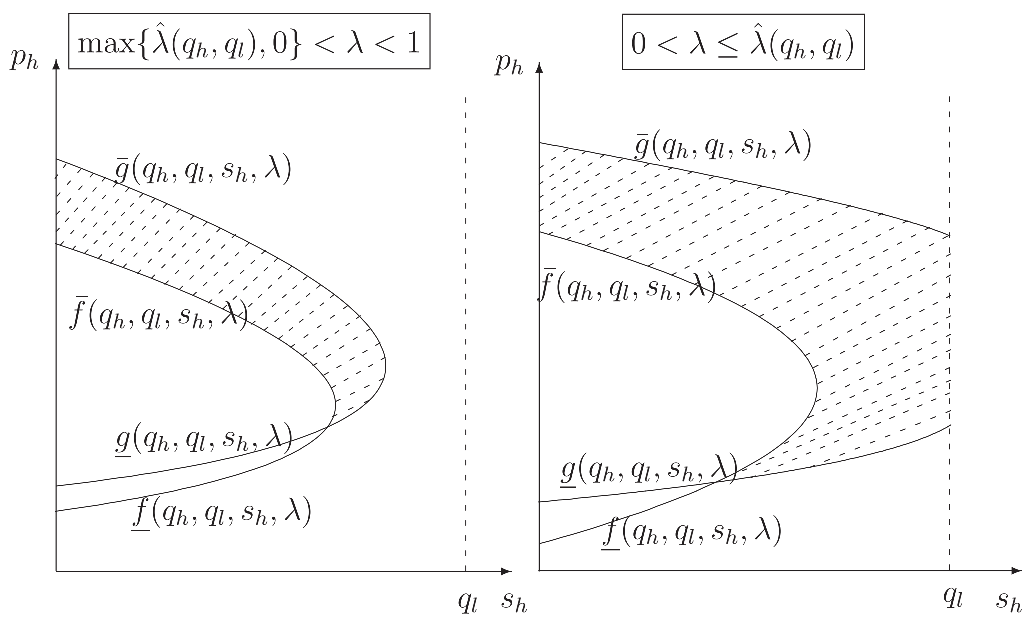

Figure 1: The Set of All Possible Separating Equilibria

4.2 The Intuitive Perfect Bayesian Equilibrium

Given the multitude of possible perfect Bayesian equilibria we want to focus in the rest of the paper on those perfect Bayesian equilibria which satisfy the intuitive criterion which roots back to Cho and Kreps (1987).[6] They are characterized in the next three Lemmas where we use the following definition:

$$\bar{\lambda}(q_l, q_h) \equiv \frac{q_l(q_h^2 - q_l q_h - q_l^2)}{(q_h - q_l)(q_h + q_l)^2}. \tag{9}$$

Lemma 1 *If there are relatively many informed consumers, meaning* $1 > \lambda > q_l/q_h$*, then the perfect Bayesian equilibrium which satisfies the intuitive criterion is unique. It implies that the two types of digital goods providers choose the same prices as in the case where all consumers are informed, meaning* $p_h = q_h/2$ *and* $p_l = q_l/2$*. Neither the high nor the low quality provider does provide a free sample.*

Proof: For a given quality of the free sample s_h a high quality provider maximizes his profit $\pi(p_h, q_h, s_h)$ defined in equation (2), if he could set $p_h = (q_h - s_h)/2$. It is possible to show that $\bar{f}(q_h, q_l, s_h, \lambda) < (q_h - s_h)/2 < \bar{g}(q_h, q_l, s_h, \lambda)$ for all $0 \leq s_h \leq \min\{q_l, q_h - q_l q_h/(q_h - \lambda(q_h - q_l))\}$ as long as $\lambda > q_l/q_h$. Then the high quality provider realizes $\pi((q_h - s_h)/2, q_h, s_h) = (q_h - s_h)/4$. This profit is maximized if he chooses $s_h = 0$ which is possible without violating (4) and (8) because $\bar{g}(q_h, q_l, 0, \lambda) > q_h/2 > \bar{f}(q_h, q_l, 0, \lambda)$ holds for all $0 \leq s_h \leq 1/2[q_h - \sqrt{q_h^2 - 4(1-\lambda)q_l(q_h - q_l)}] < q_l$. ■

The high quality provider can signal his superior quality without any free sample and with the same price he would choose in the case where all the consumers are informed if there are many informed consumers.[7] In this case the punishment by the informed consumers of a low quality provider, who chooses the high price of a high quality provider, is very severe. A large number of informed consumers identify him and reduce their demand for the product. In addition the reduction in demand is the higher the smaller is q_l/q_h or, equivalently, the larger is the difference between the low and the high quality.

Lemma 2 *If there is an intermediate number of informed consumers with* $\max\{\bar{\lambda}(q_l, q_h), 0\} \leq \lambda \leq q_l/q_h$ *where* $\bar{\lambda}(\cdot)$ *is defined in (9), then the perfect*

[6]The intuitive criterion is a refinement of perfect Bayesian equilibria. In the present context it selects all those equilibria where the sender of the signal may not realize a higher profit by another signal that would also identify his type.

[7]See Bagwell and Riordan (1991) for an analogous result in the case of pure price signalling.

Bayesian equilibrium which satisfies the intuitive criterion is unique. It implies that no provider type offers a free sample. The high quality provider chooses $(p_h, s_h) = (\bar{f}(q_h, q_l, 0, \lambda), 0)$ with $\bar{f}(q_h, q_l, 0, \lambda) > q_h/2$ where $\bar{f}(\cdot)$ is defined in (4). The low quality provider chooses $(p_l, s_l) = (q_l/2, 0)$.

Proof: If $\max\{\bar{\lambda}(q_l, q_h)\} \leq \lambda \leq q_l/q_h$ holds then the unrestricted profit maximizing price $(q_h - s_h)/2$ violates condition (4) for $0 < s_h < 1/2[q_h - (q_h - q_l)\lambda - \sqrt{[q_h(1-\lambda) + \lambda q_l]^2 - 4(q_h - q_l)(q_l - \lambda q_h)}]$. For these levels of s_h the price $p_h = \bar{f}(q_h, q_l, s_h, \lambda)$ is profit maximizing, given the restriction in (4) and (5). Since $\pi(\max\{\bar{f}(q_h, q_l, s_h, \lambda), (q_h - s_h)/2\}, q_h, s_h)$ is decreasing in s_h for all $0 < s_h < \min\{q_l, q_h - q_l q_h/(q_h - \lambda(q_h - q_l))\}$, the high type's profit maximizing choice which still transmits a credible signal is $s_h = 0$ and $p_h = \bar{f}(q_h, q_l, 0, \lambda)$. ■

For intermediate levels of informed consumers the high quality provider has to increase the price of his product above the profit maximizing price in order to credibly signal his superior quality. He abstains, however, from providing a free sample. Given the lower number of informed consumers compared to the situation in lemma 1, the punishment of a low quality provider who imitates a high quality provider is only high enough, if the price is increased above the level requested by the high quality monopolist with perfectly informed consumers. Of course, this reduces the high quality provider's profit, but not as much as if he would also provide free samples.

Lemma 3 *If there is a small number of informed consumers with $0 < \lambda < \bar{\lambda}(q_l, q_h))$ where $\bar{\lambda}(\cdot)$ is defined in (9), then the perfect Bayesian equilibrium which satisfies the intuitive criterion is unique. It implies that the high quality provider offers a free sample with the quality:*

$$\begin{aligned} s_h &= \frac{q_h q_l - 4(1-\lambda)q_l^2 + q_h^2(1-4\lambda) - (q_h - q_l)\sqrt{q_h^2 - 4(1-\lambda)q_l(q_h - q_l)}}{2[(2-4\lambda) - (3-4\lambda)q_l]} \\ &\equiv \bar{s}(q_h, q_l, \lambda) \geq 0. \end{aligned}$$

The high quality provider chooses $(p_h, s_h) = (\bar{f}(q_h, q_l, \bar{s}(q_h, q_l, \lambda), \lambda), \bar{s}(q_h, q_l, \lambda))$ with $\bar{f}(q_h, q_l, \bar{s}(q_h, q_l, \lambda), \lambda) > (q_h - \bar{s}(q_h, q_l, \lambda))/2$ and the low quality provider $(p_l, q_l) = (q_l/2, 0)$.

Proof: If $0 < \lambda < \bar{\lambda}(q_l, q_h)$ holds then the unrestricted profit maximizing price $(q_h - s_h)/2$ still violates condition (4) for $0 < s_h < 1/2[q_h - (q_h - q_l)\lambda - \sqrt{[q_h(1-\lambda) + \lambda q_l]^2 - 4(q_h - q_l)(q_l - \lambda q_h)}]$, given the level of s_h. For these levels of s_h the price $p_h = \bar{f}(q_h, q_l, s_h, \lambda)$ is profit maximizing, given the restriction in (4) and (5). The function $\pi(\max\{\bar{f}(q_h, q_l, s_h, \lambda), (q_h -$

$s_h)/2\}, q_h, s_h)$ has an interior maximum at $s_h = \bar{s}(q_h, q_l, \lambda) < 1/2[q_h - (q_h - q_l)\lambda - \sqrt{[q_h(1-\lambda) + \lambda q_l]^2 - 4(q_h - q_l)(q_l - \lambda q_h)}]$. Therefore, the high type's profit maximizing choice which still transmits a credible signal is $s_h = \bar{s}(q_h, q_l, \lambda)$ and $p_h = \bar{f}(q_h, q_l, \bar{s}(q_h, q_l, \lambda), \lambda)$. ■

For small numbers of informed consumers the high quality firm gains if it does not only rely on higher prices in order to signal its superior quality. This is due to the fact that the credible price increases if there are fewer informed consumers and decreases if the high quality provider increases the quality of its free sample. Here the loss of profits from the provision of the free sample is more than compensated by the gain in profits from the possible reduction of the credible price. However the firm never abstains from using its price as a signalling device.[8] The chosen price always exceeds the profit maximizing price $(q_h - \bar{s}(q_h, q_l, \lambda))/2$.

From lemma 1, lemma 2 and lemma 3 it is now obvious, when the high quality provider uses free samples as a signalling device.

Proposition 3 *If we focus on the perfect Bayesian equilibrium which satisfies the intuitive criterion then the high quality provider uses free samples in order to signal his superior quality only if the number of informed consumers is low ($0 < \lambda < \bar{\lambda}(q_l, q_h)$). Free samples are always an additional signalling device which is only used combined with high prices and never used if the low quality is relatively high ($(\sqrt{5}-1)q_h/2 < q_l < q_h$).*

Proof: See lemma 1, lemma 2 and lemma 3 and note that $\bar{\lambda}(q_l, q_h) > 0 \Leftrightarrow 0 < q_l < (\sqrt{5}-1)q_h/2$. ■

Proposition 3 as well as lemma 1, lemma 2 and lemma 3 are illustrated in Figure 2. Note that for a given low number of informed consumers the high quality provider does not have to distort his price or to provide a free sample in order to credibly signal his superior quality as long as the quality difference measured by $1 - q_l/q_h$ between a high and a low quality provider is pretty big. Although there are only a few informed consumers and although the gain from misleading the uninformed consumers would be pretty high, the informed consumer punish a low quality provider imitating a high type severely enough that it is not necessary to distort prices or introduce free samples in order to increase the punishment and reduce the gain from imitation. If the difference in qualities becomes smaller this is not sufficient any

[8] Thus, the firm uses free samples in the same way as the conspicuous advertising expenses in Milgrom and Roberts (1986), the low advertising rates in Zhao (2000) and Bagwell and Overgaard (2005) or the distorted advertising in Orzach *et al.* (2002). These additional signals are used in order to save on the signalling costs from a distorted price.

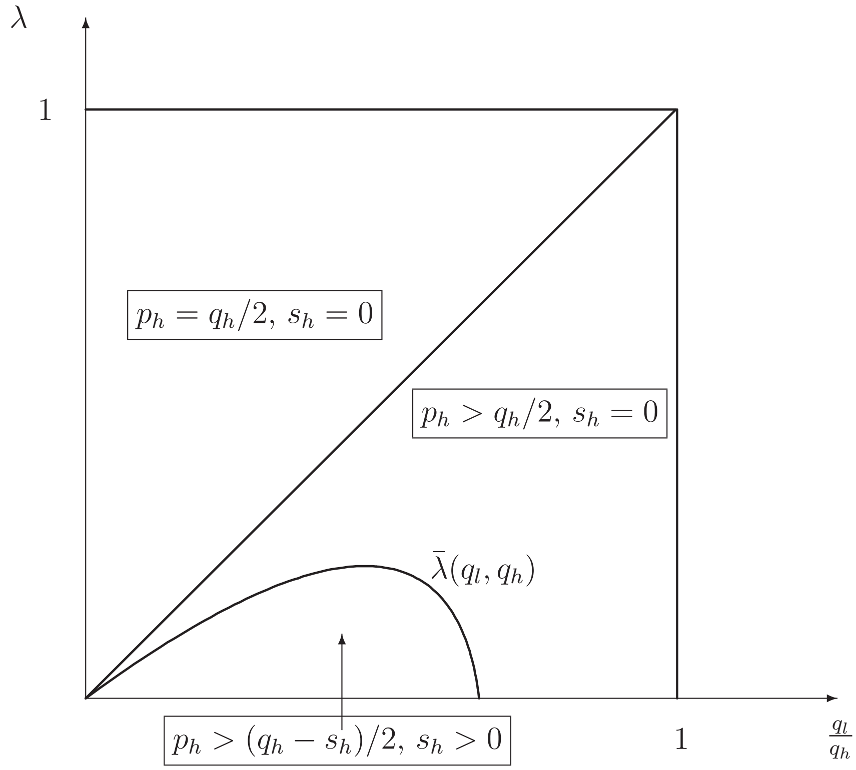

Figure 2: The Different Cases of Intuitive Equilibria

more and the high quality provider starts to distort prices, and provides for an intermediate range of the quality difference even a free sample in order to prevent imitation by a low quality provider.

Given that there are only very few experts ($\lambda < \bar{\lambda}(q_l, q_h)$) simple differentiation of $\bar{s}(q_h, q_l, \lambda)$ yields the comparative static results concerning the high quality provider's chosen quality level of the free sample in the intuitive perfect Bayesian equilibrium. They are summarized in corollary 1.

Corollary 1 *The high quality provider chooses higher quality levels for the free sample the smaller is the number of informed consumers ($\partial\bar{s}(q_h, q_l, \lambda)/\partial\lambda < 0$) and the higher is the quality level q_h of his digital product ($\partial\bar{s}(q_h, q_l, \lambda)/\partial q_h > 0$) in the intuitive perfect Bayesian equilibrium. The free sample's quality has a maximum in q_l, meaning that it increases in the low type's quality for low levels of q_l and decreases, if the low type's quality is already rather high.*

It is pretty intuitive that the quality of the free sample can be reduced in order to signal a high quality of the digital good if there are more informed consumers. The punishment of an imitating low quality provider increases in the number of informed consumers. Therefore it is not that necessary anymore to increase this punishment via a high quality of the free sample. An increase in the signalling activity if the quality of the high type increases is also not very surprising. If the high quality q_h increases for a given low quality q_l, then imitating the high quality provider becomes more profitable for the low quality provider. In order to reduce this incentive it is necessary to send more costly signals which translates into a higher quality s_h of the free sample. If the low quality q_l increases for a given high quality q_h, there are two countervailing effects. On the one hand, imitation of the high quality provider becomes less attractive for the low quality provider because the profit gain from misleading the uninformed consumers is reduced. On the other hand, the punishment by the informed consumers is also reduced which means that imitation becomes less costly for the low quality provider. The latter effect seems to dominate the former for relatively low levels of q_l which induces a higher signalling activity and, thus, a higher quality of the free sample. The former dominates, if q_l is already relatively high and reduces the necessity to send costly signals which means that the quality of the high quality provider's free sample can be reduced.

4.3 Comparison of the Market Outcome in the Intuitive Equilibrium with and without Free Samples

From the analysis so far it is obvious that the profit of a high quality provider increases in the intuitive equilibrium in all those cases where he provides free samples compared to a situation where he is confined to pure price signalling, because otherwise providing free samples would not be part of an intuitive perfect equilibrium. The profit of a low quality provider is independent of the chosen signalling device by a high quality provider. Therefore the following proposition for the expected profit of a digital goods provider who does not yet know whether his quality is high or low can be derived.

Proposition 4 *If we focus on the perfect Bayesian equilibrium which satisfies the intuitive criterion, then the expected profit of a digital goods provider is increased, if he is allowed to signal his quality also via a free sample and if the number of consumers is small ($0 < \lambda < \bar{\lambda}(q_l, q_h)$), compared to a situation where he is confined to pure price signalling.*

Proof: See the argument above and Proposition 3. ■

The consumers are also only affected by a restriction to pure price signalling if they face a high quality provider, since the behavior of the low quality provider is the same no matter whether free samples are allowed or not, and if the high quality provider would provide a free sample. The aggregate expected consumer's surplus is given by:

$$CS = \gamma \left[\int_0^{\underline{\theta}_h} \theta s_h d\theta + \int_{\underline{\theta}_h}^1 \theta q_h - p_h d\theta \right] + (1-\gamma) \int_{\underline{\theta}_l}^1 \theta q_l - \frac{q_l}{2} d\theta \qquad (10)$$

where $\underline{\theta}_h \equiv \underline{\theta}(p_h, q_h, s_h)$ and $\underline{\theta}_l \equiv \underline{\theta}(q_l/2, q_l, 0)$ holds and $\underline{\theta}(\cdot)$ is defined in (1). From the analysis of the aggregate expected consumer's surplus proposition 5 follows immediately.

Proposition 5 *If we focus on the perfect Bayesian equilibrium which satisfies the intuitive criterion, then the aggregate expected consumer's surplus is increased, if the high quality provider is allowed to signal his quality also via a free sample and if the number of consumers is small ($0 < \lambda < \bar{\lambda}(q_l, q_h)$), compared to a situation where he is confined to pure price signalling.*

Proof: If $0 < \lambda < \bar{\lambda}(q_l, q_h)$ holds then we know from lemma 3 that the high quality provider chooses $(p_h, s_h) = (\bar{f}(q_h, q_l, \bar{s}(q_h, q_l, \lambda), \lambda), \bar{s}(q_h, q_l, \lambda))$. If he were not allowed to provide a free sample the intuitive perfect Bayesian equilibrium would imply $(p_h, s_h) = (\bar{f}(q_h, q_l, 0, \lambda), 0)$. Given that $\partial \bar{f}(\cdot)/\partial s_h < 0$ holds for all $0 \leq s_h \leq \bar{s}(q_h, q_l, \lambda)$, the price with signalling via the free sample is smaller than without the provision of a free sample. Thus, CS in (10) is higher with $s_h = \bar{s}(q_h, q_l, \lambda)$ than with $s_h = 0$, as long as

$$\underline{\theta}(\bar{f}(q_h, q_l, \bar{s}(q_h, q_l, \lambda), \lambda), q_h, \bar{s}(q_h, q_l, \lambda)) < \underline{\theta}(\bar{f}(q_h, q_l, 0, \lambda), q_h, 0)$$

holds which is the case for all $0 < \lambda < \bar{\lambda}(q_l, q_h)$. ■

The consumers gain because those who would not buy without a free sample derive a surplus from the free sample and those, who buy, no matter whether there is a free sample or not, profit from the lower price. In addition the high quality provider provides the free sample only in those cases where the market share of its digital product increases from the provision of the free sample. Thus, more consumers enjoy the digital product's high quality than without the free sample. The market share increases, because the competition effect of a free sample is more than compensated by the price reducing effect. The price reduction is favorable for the high quality provider because he had to distort his price upwards, compared to a profit maximizing price, in order to credibly signal his superior quality.

Since the aggregate expected social welfare is the sum of the expected profit of the digital good's provider and the aggregate expected consumer's surplus, we can conclude from proposition 4 and proposition 5:

Proposition 6 *If we focus on the perfect Bayesian equilibrium which satisfies the intuitive criterion, then the aggregate expected social welfare is increased, if the high quality provider is allowed to signal his quality also via a free sample and if the number of consumers is small ($0 < \lambda < \bar{\lambda}(q_l, q_h)$), compared to a situation where he is confined to pure price signalling.*

Proof: See proposition 4, and proposition 5. ■

5 Conclusions

Our analysis shows that free samples can indeed serve as a signaling device for a superior quality in the context of digital goods, if it is possible to provide a free sample of a lower quality than the marketed digital good. If we focus, however on the perfect Bayesian equilibrium which satisfies the intuitive criterion, we figure out that free samples are never used as signals in isolation. They are used as an additional signalling device together with upwardly distorted prices. They reduce the upward distortion and are used as soon as this effect more than compensates the negative effect of a costless competing product on the market. Thus, if they are used, they increase the aggregate expected profits of the digital goods provider, and the aggregate expected consumer's surplus, compared to a situation where the provider is confined to pure price signalling. Social welfare is, of course, also higher in the intuitive signalling equilibrium with free samples than in one where they cannot be introduced.

Since social welfare increases, if free samples are used as a signalling device, the provision of free samples should not be restricted in this case by any antitrust or fair competition law. However, in order to give any kind of policy recommendation one should extend the current model to situations with competing suppliers. Preliminary results in a duopoly setting show that free samples can only serve as a signal for a higher quality, if its quality exceeds the lower quality level in the market. Thus, a high quality provider is uniquely identified also for the uninformed consumers and low quality providers can no longer compete with a high quality provider, but are preempted out of the market by the high quality provider's free sample if it is used in equilibrium.

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