Advertising: the Persuasion Game

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Abstract

The "Persuasion Game" was originally configured to analyze a firm's choice of how much vertical product information it would wish to reveal. Perhaps unsurprisingly, a firm wants to reveal its true quality. We extend the persuasion game to bring it squarely into the economics of advertising. Extending Anderson and Renault (2006), we analyze advertising content and the information disclosed to consumers. We show that quality information takes precedence over price information and horizontal product information.

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1 Introduction

Many advertisements contain quality information about the product advertised. Quality may be considered a "vertical" characteristic insofar as all consumers agree that a higher quality is better. Ads also frequently contain "horizontal" product information that tells the consumer more about whether her particular tastes and preferences mesh well with those the product provides. They also may or may not deliver price information.[1]

The economics literature has scarcely addressed the informational content of ads.[2] The literature on informative advertising (see for example Butters, 1977, for a competitive analysis, and Shapiro, 1983, for the monopoly case) has been mostly concerned with advertising "reach," which is the number of consumers that see the ad, and whether this is socially excessive or not. Since the typical assumption is that the product sold is homogenous, all the ad needs to communicate is the product price and where the consumer can buy it.

The other set of economics models pertaining to informative ads are those associated with quality signaling. The signaling explanation for advertising allows for consumers to infer high product quality from seeing copious advertising expenditure, but the ad need convey nothing in terms of hard information about the actual product. Money just needs

[1]The marketing literature has developed a field called "content analysis" that looks at the information contained in ads. Most of the literature has followed the taxonomy of Resnik and Stern (1977) in categorizing 14 possible "information cues" that an ad may or may not contain. These information cues are attributes the ad mentions, such as price, quality, performance, availability, nutrition, and warranties. The basic idea is to describe information content by the number of information cues the ad claims.

Abernethy and Butler (1992) find price information was given for 68% of newspaper ads, and that 39.6% of ads had 4 or more cues. The numbers are lower for the advertising content of magazine advertising, and much lower for the advertising content of television advertising. Abernethy and Franke (1996) present a "Meta-analysis" that compiles the results from previous studies. Only 19% of magazine ads reported price information (based on 7 studies of US magazines), and the mean number of cues was 1.59, with only 25.4% having three or more cues, and 15.6% having no cues. They do not report the price figure for TV ads, but one can only presume it to be very low. The mean number of cues in US television advertising (based on 4 previous studies) was 1.06, with only 27.7% having two or more cues, and 37.5% having no cues.

Other papers in the content analysis tradition have compared content over time (e.g., Stern and Resnik, 1991), across regulatory regimes and across cultures (e.g., Madden, Caballero, and Matsukubo, 1986). Abernethy and Franke (1998) compare content when the FTC was pursuing more or less vigorous campaigns against misleading ads, and find that content was significantly lower when the campaign was more vigorous.

[2]An excellent survey of the Economics of Advertising is Bagwell (2007).

to be conspicuously "burnt" to communicate the point to the viewer of the ad (see Nelson, 1970, 1974, Kihlstrom and Riordan, 1984, and Milgrom and Roberts, 1986b).

There is though another strand of economics literature that can be bought to bear on the issue of advertising and product quality. This is the "Persuasion Game" due to Milgrom (1981), and simultaneously analyzed by Grossman (1981). Milgrom and Roberts (1986a) elaborate the basic persuasion game of Milgrom (1981), while Matthews and Postlewaite (1985) give an interesting perspective on voluntary disclosure of information when the firm can choose whether or not to engage in research that uncovers the product quality.

Our aim in this paper is to bring the persuasion game squarely into the economics of advertising. This we do by treating quality as a search attribute, and the product sold as a search good, so that consumers can tell the product's quality on inspection. However, they need to incur a search cost to inspect the good, whether they buy it or not. Within this framework, we can also address whether or not price information is advertised by the firm along with quality information. We then build on Anderson and Renault (2006) to also allow the firm to advertise horizontal product information. Thus, our analysis complements the existing literature on firms' incentives to disclose quality by including horizontal product characteristics.

This helps give richer foundations to the patterns of advertising content one might expect to observe, with consumer search costs and vertical product quality forming the principle basis for the comparative statics properties. Our results suggest that ads are most likely to include quality information, with price or horizontal match information depending on how much control the firm has over the type of horizontal match information it can transmit. Also, low quality firms are more likely to advertise additional attributes and price.

The paper is organized as follows. The model is described in Section 2. Section 3 discusses quality-only advertising and quality-and-price advertising. This analysis constitutes the basic persuasion game applied to search goods and allowing price advertising. In Section 4, we

allow in addition for advertising over horizontal characteristics, and we treat two variants. The first is that horizontal product advertising must fully reveal the consumer's valuation for the good. The second is that the firm has full control over just how much information may be revealed (subject to the constraints of Bayesian updating for the consumer). This will transpire to be threshold match advertising. Section 5 concludes.

2 Persuasive Advertising and the Persuasion Game

In the original persuasion game, a firm must choose what quality attributes to reveal to the consumer, where the disclosed information is verifiable. For example, a car manufacturer may state that the car goes from zero to 60 m.p.h. in 5.3 seconds, or it may not report the acceleration information. There is a single consumer type, whose quantity demanded rises with the expected quality level. The price of the good is fixed exogenously. There is no consumer search so that she buys on the grounds of expected quality. The good sold may therefore be thought of as an experience good, though only at a rather superficial level insofar as there is no repeat purchase option. As Milgrom (and others) show, the firm will reveal all of its quality information: withholding some quality information would only reduce willingness to pay since the consumer in equilibrium infers that the withheld information is unflattering. The result can be considered as an unraveling result insofar as qualities can be thought of as being revealed from the top down, so that the consumer will expect the worst about quality attributes not mentioned in the ad. Indeed, Farrell (1986) puts it as follows: "Suppose that the seller refuses to disclose q. What should buyers infer about q? Clearly, they should not infer that q is at the top of the range - for if they did so, then lower q's would follow that concealment strategy. But then the buyers' beliefs have to be such that if q were in fact at the top of the range, then the seller would rather reveal q. Next we apply the same argument to the range remaining after the top q's drop out...and so on." (Farrell,

1986).

The persuasion game approach needs to be clearly distinguished from what is often (somewhat colloquially) known as persuasive advertising. Such advertising, while commonplace in marketing discussions, often sits uneasily with economists who are disturbed by the idea that tastes might be shifted. One response from the Chicago School was to configure tastes to include an effect through complementary advertising which would alter willingness to pay for the basic product. The literature on advertising as a complementary good was developed by Stigler and Becker (1977) and elaborated upon by Becker and Murphy (1993). The latter authors consider that ads "give favorable notice" (p.942) to the products advertised, and they model this as admitting advertising expenditures as complementary goods in the consumer's utility function. While they "agree that many ads create wants without producing information, we do not agree that they change tastes" (p.941). On the latter point, they are likely reacting to the attempt by Dixit and Norman (1979) to undertake welfare analysis even under the possibility that ads change tastes: the question they address is this. Given demand shifts from advertising, should one use the pre-advertising or the post-advertising demand curve as the basis for the welfare evaluation? Since the emphasis in this "taste-shifting" approach is on persuasion, one might presume that the tangible informational content of the ad would be negligible, at least in the pure form of persuasion.

3 The Model

A monopolist sells a product of intrinsic quality $q \in [\underline{q}, \bar{q}]$. This quality is known to the firm, but not to the consumer. The product is produced at constant marginal cost, normalized to zero and the firm maximizes expected profit.

The consumer incurs a search cost (or visiting cost), c, in order to be able to buy from the firm. This cost is incurred whether or not the product is actually bought, but the consumer

can avoid it by not visiting (which precludes her from buying). If she visits, she either buys one unit of the product from the firm, at price p, or else does not buy. Conditional on incurring the search cost and buying, consumer utility from buying a product of quality q at price p is given by

$$u = q - p + \varepsilon.$$

We assume that the consumer-specific valuation (henceforth her "match value") ε is distributed on $[0, b]$ where $b > 0$. This implies that $\underline{q} > -b$ or else the lowest quality product would never be bought. In this sense, $\underline{q} = -b$ is a natural lower bound to the possible quality. Note that negative qualities, $-b < q < 0$, will only be bought for sufficiently good realizations of ε at any positive price. However, if $q > 0$, the consumer will always buy if the price is low enough. Here consumers are ex-ante identical since they share the same search cost and the same prior about their match (which is also the firm's prior). The number of consumers is normalized to one, where the only source of heterogeneity among consumers is captured by the probability distribution on $[0, b]$ for the match realization.

Let f be the density and F the corresponding cumulative distribution of the match value. We assume further that $1-F$ is strictly log-concave.[3] All this is common knowledge. It means that, absent any advertising that might inform her otherwise, the consumer's valuation of the product is unknown to her before inspection of the good. One example is the standard uniform distribution with $b = 1$ and $f(\varepsilon) = 1$ for $\varepsilon \in [0, 1]$, which yields a standard linear expected demand curve with price intercept $1 + q$.

Once she is at the store, the consumer is willing to buy if $q + \varepsilon \geq p$, because she then observes everything.[4] Her visit decision hinges around whether her expected surplus exceeds the search cost, c.[5] Because she always has the option of not buying, her expected surplus

[3]Equivalently, we suppose that the "hazard rate" $f/(1 - F)$ is strictly increasing.
[4]We assume she buys if she is indifferent between buying and not.
[5]We assume she visits if she is indifferent between visiting and not.

is the expected maximum of $q + \varepsilon - p$ and 0.

If advertising features the price, it is assumed to be binding. If it does not give the price, the consumer must predict it when deciding if she should visit. Advertising may also provide information on the product quality, q. In keeping with the standard persuasion game, we assume that the firm may not over-claim quality. But any quality claim lower than the actual value is a valid choice, corresponding to partial quality information. Finally, an ad may tell the consumer more about her specific value of ε. This is information that the firm may furnish that enables the consumer to update her priors. Any such updating is Bayesian. Note that the firm does not know the actual ε value of the consumer.

Advertising is assumed to be costless. We do invoke a tie-breaking rule, that any broad type of information, be it price, quality or match, will only be advertised if so doing strictly increases profit.[6]

4 No advertising

If the firm provides no information, the consumer must rationally anticipate the price it will charge and the quality of its product, conditional on observing that the firm does not advertise. She will then visit if her expected surplus exceeds the search cost, c. Anderson and Renault (2006) analyze the case where the consumer knows the quality, and do not draw out the impact of different quality levels.

If there is no advertising and the consumer does not know the quality beforehand, we need to think through what the firm and consumer will do. Notice here that if the consumer were to visit, she would then observe the quality and her match (our search good assumption), and would then buy if her combined valuation exceeds the price. The probability the consumer

[6]The rule is loosely based on the idea that including more information in an ad is more costly. We shall not invoke this rule when we speak about gradations of information within a particular information class. For example, it is unclear whether it is more intricate (costly) to describe a quality range (e.g., a quality minimum), to pinpoint an exact quality, or to indicate a set of points/intervals to which the actual quality may belong.

buys at price p is $1 - F(p - q)$.

Define now $p^m(q)$ as the monopoly price for a firm with quality q, so that the monopoly price p^m maximizes expected revenue $p[1 - F(p - q)]$. The strict log-concavity assumption ensures the marginal revenue curve to the demand curve $1 - F(p - q)$ slopes down. This implies that the marginal revenue curve is either still positive at an output of one or else crosses the marginal cost curve (which is zero by assumption here) for an output below one. The former corresponds to a price $p^m = q$ (when there is no interior solution to the first-order condition), and this case arises for all q exceeding a (unique) threshold level denoted $\tilde{q}$. The latter case means a price above q (but below $q + b$, or else no-one would buy) and given by the interior solution to the first-order condition, $p^m f(p^m - q) = (1 - F(p^m - q))$, which we rewrite as

$$p^m \frac{f(p^m - q)}{1 - F(p^m - q)} = 1, \tag{1}$$

where the strict log-concavity assumption implies that $\frac{f(z)}{1-F(z)}$ is an increasing function of the argument z. An increase in q, with p constant, raises the LHS of (1); an increase in p is therefore needed to restores the equality in (1). We then have:

Lemma 1 *The monopoly price $p^m(q)$ increases in q under the strict log-concavity assumption, with $p^m(q) > q$ for $q < \tilde{q}$ and $p^m(q) = q$ for $q \geq \tilde{q}$.*

Since we have just shown that $p^m(q)$ increases in q when (1) holds, then $p^m - q$ must decrease with q for $q < \tilde{q}$, again to retain the equality in (1). This implies that the consumer is better off with higher quality, since the price rise does not fully offset the quality rise. Indeed, call the corresponding level of conditional consumer surplus

$$S^m(q) = E(\max\{q + \varepsilon - p^m, 0\}) = \int_{p^m - q}^{b} (q + \varepsilon - p^m) f(\varepsilon) d\varepsilon, \tag{2}$$

which is increasing in $q - p^m$ when this is not negative. Then we have:

Lemma 2 *The consumer surplus $S^m(q)$ increases in $q < \tilde{q}$ under the strict log-concavity assumption. For $q \geq \tilde{q}$, consumer surplus S^m is independent of q: in this case all consumers buy and increases in quality are fully captured in price increases.*

Hence, the lowest possible surplus, with consumers rationally anticipating monopoly pricing, avails when the quality is as low as possible, $\underline{q}$. Moreover, the higher the actual quality, the higher the corresponding surplus, even though the monopoly price rises - it does so at a rate slower than the quality and that is what raises surplus.[7]

If advertising is infeasible, the consumer will be prepared to incur the visit cost (rationally anticipating the monopoly price for whatever quality value she finds) for values of c up to the expectation over q of $S^m(q)$, which value we call $\tilde{c}$. In summary:

Proposition 1 *If advertising is not feasible, the market is served if $c \leq \tilde{c}$ and the monopoly price $p^m(q)$ is charged corresponding to the actual quality q.*

As we shall shortly see, this outcome continues to be an equilibrium when qualities can be advertised, but the ability to advertise also generates other equilibria with disclosure, and these will constitute our main focus in what follows.

5 Quality Advertising

Suppose now that it is possible to advertise quality, but not price (nor any horizontal match information). The monotonicity property of Lemma 1 will separate out the firms' actions by quality level. We continue to invoke the tie-breaking rule that a firm will not advertise quality when it is indifferent.

Clearly then no firm advertises for $c \leq S^m(\underline{q})$. This is because consumers anticipate a positive surplus even with the lowest quality firm at its monopoly price. For larger search

[7] This is similar formally to the property that unit taxes (or indeed, unit cost hikes) are absorbed under monopoly with well-behaved (i.e., log-concave) demand. For more on such properties, see Anderson, de Palma, and Kreider (2001).

costs, one equilibrium involves all firms pooling on not revealing quality. This can arise for c between $S^m(\underline{q})$ and $\tilde{c}$, so the consumer is still willing to visit while expecting to be charged the monopoly price and having no information on quality. Likewise, the firms have no incentive to declare their actual qualities since the consumer always visits. From a welfare perspective, this pooling equilibrium is dominated by the separating one. For $c > \tilde{c}$, there is no such full pooling equilibrium because the consumer will not visit without price or product information, and a high quality firm will deviate from an equilibrium in which quality is not revealed.

There are, however, many other equilibria as long as c is not too large. We concentrate on those equilibria that lead to the widest possible disclosure of quality (by active firms) since in subsequent sections, when search costs are high enough, the only equilibrium that survives is such that quality is always revealed.[8] In order to characterize the equilibrium where firms have the strongest incentive to disclose quality, assume that whenever the consumer observes out-of-equilibrium quality information she expects the worst, conditional on the information provided to her.

Anticipating the pricing outcome, the consumer (after learning that quality is q) will only visit if the search cost is at most $S^m(q)$. The monotonicity property in Lemma 2 implies that only firms with higher q's are visited and hence choose to advertise. Define $c_{1q} = S^m(q)$. Then for search cost $c_{1\hat{q}}$, any firm with $q < \hat{q}$ is stuck with no sales because consumers rationally anticipate a hold-up problem should they visit. This is an extended version of the "Diamond paradox" (Diamond, 1971).

It is only firms with $q \geq \hat{q}$ which, by advertising information certifying that quality is at least $\hat{q}$, can convince consumers that they will retain positive expected surplus should they visit. Note that it does not matter whether the firm advertises up to its true quality, just as

[8] As in the original example by Milgrom, full disclosure of quality by *all* firms is an equilibrium because advertising is costless. However, the tie-breaking rule (that when indifferent, a firm chooses not to reveal) would ensure that those who would not sell upon revealing their information would therefore not reveal it.

long as it covers the minimum threshold level of $\hat{q}$.

By Lemma 2, the threshold level of cost c_{1q} is increasing in $q < \tilde{q}$ and is constant for $q \geq \tilde{q}$, which implies the next result.

Proposition 2 *If only quality advertising is feasible, for $c \in (c_{1\underline{q}}, c_{1q}]$ then a firm with quality q advertises its quality. It charges its monopoly price $p^m(q)$ and consumers rationally anticipate this and buy. If $c > c_{1q}$, a firm with quality q cannot sell. The critical value of search cost, c_{1q}, is increasing in $q < \tilde{q}$, while $c_{1q} = c_{1\tilde{q}}$ for $q > \tilde{q}$.*

It is important for what follows to note that if $c \in (c_{1\underline{q}}, c_{1q}]$, there is no benefit to the firm from advertising any additional information since it already attains the monopoly price and profit. If $c > c_{1q}$, a firm with quality q must add to the advertising mix because consumers need further inducement to incur the search cost.

Note finally that for $c < c_{1\bar{q}}$ (which is the range of search costs for which the market does not vanish with only quality advertising in the equilibrium of Proposition 2) there are many other equilibria where some subset of quality types would pool and provide only partial quality information. This only requires that the conditional expectation of quality for the pool be sufficiently high so that the consumer would choose to visit. For $c \geq c_{1\bar{q}}$, however, the only equilibrium is such that there is no advertising and no product is sold.

6 Quality and Price Advertising

We now introduce price advertising as well, so that firms may advertise both price and quality. This ability will save the lower quality firms from extinction. Low-quality firms will advertise price and quality, whereas high-quality firms need advertise only quality (or at least some minimum quality threshold, as above). In what follows (in this and the subsequent sections), we start with pre-supposing that the consumer does actually know the quality,

and we then derive what the rest of the information disclosure strategy looks like. We then argue that indeed quality disclosure does form part of the equilibrium strategy.

If the consumer does not (yet) know her match value, she bases her sampling decision on the price and quality she sees advertised. Seeing an advertised quality, q, she visits if and only if the price is below some threshold value $\hat{p}(q)$, where $\hat{p}(q)$ equates the consumer's expected surplus to the search cost, that is

$$\int_{\hat{p}-q}^{b} (q + \varepsilon - \hat{p}) f(\varepsilon) d\varepsilon = c. \tag{3}$$

The lower bound of the integral means that the consumer only buys ex-post when surplus is non-negative: this expression holds true whether or not the consumer always buys (if the lower bound of the integral were negative, the corresponding value of $f(\varepsilon)$ would be zero.)

Comparing this expression with (2) shows that $\hat{p}(q)$ exceeds $p^m(q)$ when $c < c_{1q}$, so that the firm's best strategy would be to advertise the monopoly price, $p^m(q)$ (rather than a higher one that would leave the consumer with zero expected surplus). Hence, in this case, the firm has nothing to gain through reassuring price advertising since the consumer searches anyway while rationally anticipating the monopoly price $p^m(q)$. Thus the firm does just as well without price advertising.

For higher search costs, $c > c_{1q}$, $\hat{p}(q)$ is clearly less than $p^m(q)$. Without price advertising, the consumer would not visit because of the hold-up problem by which the firm would charge $p^m(q)$ if she did. Then in order to sell the firm must commit to a price of at most $\hat{p}(q)$ by advertising its price. Since profit increases in price for p below $p^m(q)$, the consumer rationally expects the advertised price to be chosen (since a firm is allowed to choose a lower price than that advertised, though not a higher one). The consumer then visits, but only buys when she finds $q + \varepsilon \geq \hat{p}(q)$. Here price advertising enables a market to exist because it credibly caps the firm's price. Note from (3) that the price $\hat{p}(q)$ is decreasing in the search cost c: a lower price is required to induce the consumer to visit when search costs are higher. For any

q, the greatest possible search cost for which price-only advertising is feasible corresponds to a zero price for $\hat{p}(q)$. Inserting this bound in (3) gives the critical search cost value, $c_{pq} = \int_0^b (q+\varepsilon) f(\varepsilon) d\varepsilon$, in the following proposition. Clearly, c_{pq} is increasing in q, and linearly increasing for $q > 0$.[9]

It remains to be shown that the quality is revealed if each other type is revealing its quality for $c_{1\underline{q}} < c \leq c_{pq}$. This means formulating what (reasonable) off-equilibrium path beliefs would be subsequent on observing a firm not playing part of the purported equilibrium strategy. If a firm deviated to giving no information at all, then the consumer can take it as the lowest-quality type (and indeed, for $c_{1\underline{q}} < c \leq c_{pq}$, such a firm would indeed be indistinguishable from the lowest types). The consumer would not visit, and so the firm would not wish to make such a deviation. Consider then a deviation with only price revealed without quality. We can again assume (to support the equilibrium in a simple manner) that the consumer might take this as the actions of the lowest-quality firm, and so not visit, which renders unattractive the deviation.[10]

[9]Price advertising is qualititatively different according to whether $q \gtrless \tilde{q}$. If $q > \tilde{q}$, we know that the consumer always buys at the monopoly price. Since price advertising reduces the price below the monopoly price, this means that the consumer will ex-post always find the price below quality plus match realization $(q+\varepsilon)$, and so must always buy under price-only advertising. For $q < \tilde{q}$, even though the consumer does not always buy at the monopoly price, price advertising below the monopoly price will cause her to actually buy for more realizations of ε. Since the lowest possible price for which price advertising might be used is zero, then the consumer always buys in this case (i.e., when $c = c_{pq}$) if and only if $q \geq 0$.

[10]One might object to this belief if the purported price set is clearly inconsistent with the lowest-firm's profitability. For example, the price could be way above its profit-maximizing price, $p^m(\underline{q})$. One might then impose the consistency condition that the price be consistent (should the consumer visit) with a price that would give the firm at least as much profit as if it specified its true quality and the corresponding price $\hat{p}(q)$.

We now show how this will unravel. Note first that if a price $\grave{p}$ were observed, then no firm with a quality exceeding $\grave{q}$ such that $\grave{p} = \hat{p}(\grave{q})$ would prefer this to full revelation and price $\hat{p}(q)$. However, firms with qualities just below $\grave{q}$ would prefer to quote $\grave{p}$ if indeed the consumer would visit, since they would ex-post get rents from the consumer without paying the cost of sweetening the deal. Recognizing this incentive, the consumer would realize that the visit cost could not be covered by the expected surplus, and would therefore choose not to visit. The firm with quality $\grave{q}$ would then prefer to announce its quality and price, $\hat{p}(\grave{q})$. Deviation to partial quality information is not attractive because the consumer would then expect the worst consistent with that partial information (and with the requirement that the deviation is profitable). This means that the consumer would expect a quality at best equal to that of the deviant, so the deviant cannot be strictly better off.

Proposition 3 *If the firm can only advertise its price and quality, it advertises if and only if* $c_{1\underline{q}} < c \leq c_{pq}$. *If* $c_{1\underline{q}} < c \leq c_{1q}$, *it advertises only quality, and the consumer then visits rationally anticipating the monopoly price* $p^m(q)$. *If* $c_{1q} < c < c_{pq}$, *the firm advertises price along with its quality. It chooses the price* $\hat{p}(q)$ *given by (3), which is strictly below the monopoly price,* $p^m(q)$, *and is decreasing in c.*

The equilibrium in the Proposition is not the only one for the full range of parameters covered there. There may also be various pooling equilibria over some of the parameter range. However, the next Proposition determines a range of qualities for which the unique equilibrium outcome is that of Proposition 3.

Proposition 4 *Assume only quality and price may be advertised and* $c > c_{1\bar{q}}$. *If the firm's quality is such that* $c_{pq} > c$, *then it advertises price and some quality information and quality is perfectly inferred by the consumer. Furthermore, the equilibrium outcome is such that prices and qualities are as in Proposition 3.*

Proof. For the purpose of the proof we spell out the details of the game under consideration. In the first stage, the firm selects an advertising strategy (price and quality information) given its quality realization. The consumer observes the ad and in the second stage the consumer decides whether or not to visit after updating her beliefs about quality. Third, the firm chooses the price if this were not chosen already. Fourth, the consumer makes her purchasing decision. Hence the latter two stages are undertaken where players have perfect information. The outcome of third stage subgame is unique under our assumptions and perfectly anticipated by players in the first two stages. In what follows, the firm's type is its quality. The proof proceeds in three steps.

Step 1: There is no measurable subset of $[\underline{q}, \bar{q}]$ such that $c < c_{pq}$ for some q in that set and all quality types in that set select the same strategy with positive probability in equilibrium.

In other words, there cannot be any pooling of qualities that are high enough to make some strictly positive profit in the market.

Suppose that such a set exists and let it be denoted by A. Let s denote the common strategy for all types in A. Let q be some quality in A. Since $c > c_{1\bar{q}}$, the firm would make no sales if it did not commit to a price and, since $c < c_{pq}$, s would then be dominated by a strategy where the type q firm discloses its quality along with $\hat{p}(q)$. Hence s must involve advertising a price, which we denote p_s. Let $\gamma \equiv \sup A$. Since $c > c_{1\bar{q}}$, we must have $p_s < \hat{p}(\gamma)$ so that the consumer is willing to visit. Hence for $q \in A$ sufficiently close to γ, $\hat{p}(q) > p_s$ so that the firm would choose to deviate to disclosing q and $\hat{p}(q)$ (keeping in mind that $\hat{p}(q) < p^m(q)$). Hence such a set A cannot exist in equilibrium.

Step 2: in equilibrium, all firm types such that $c_{pq} > c$ charge $\hat{p}(q)$.

From Step 1 we know that each relevant firm type q selects a strategy $s(q)$ such that, after observing $s(q)$, the consumer infers that quality is q with probability 1. We also know that $s(q)$ involves revealing some price $p(q) \leq \hat{p}(q)$ so that the consumer does visit. Since $\hat{p}(q) < p^m(q)$, a firm with quality q would deviate from a strategy involving $p(q) < \hat{p}(q)$ to a strategy where it discloses that its quality is q and its price is $\hat{p}(q)$.

Step 3: A firm with quality satisfying $c_{pq} > c$ discloses some quality information.

Assume this is not the case so that some firm with quality q satisfying $c_{pq} > c$ advertises price $\hat{p}(q)$ with no quality information. Now consider a firm with quality $q - \epsilon$, where $\epsilon > 0$. If ϵ is small enough then we still have $c_{pq-\epsilon} > c$ and the firm charges $\hat{p}((q - \epsilon))$. Since $\hat{p}(q) < p^m(q)$ and $p^m(q - \epsilon)$ tends to $p^m(q)$ as ϵ tends to zero, if ϵ is small enough then $\hat{p}(q) < p^m(q - \epsilon)$ so that firm type $q - \epsilon$ would deviate to charging $\hat{p}(q)$ while disclosing no quality information; the consumer would visit expecting quality q. So in equilibrium, the firm with quality q must be providing some quality information such that firm types with qualities slightly below q cannot pretend that they have quality q. ■

In the sequel, we shall not provide specific proofs of analogous propositions to this one.

Suffice it to note now that such analogous results can be shown for the other cases considered below, whereby the uniqueness of the equilibrium outcome can be established for some ranges of quality.

7 Persuasion with (full) match revelation

We now introduce the possibility of advertising match information along with quality information. This adds a further (horizontal) dimension to the search version of the persuasion game, in addition to the price dimension just studied. For $c \leq c_{1\underline{q}} = S^m(\underline{q})$, there is no advertising (anticipating monopoly pricing), as above. For larger search costs, the firm's strategy in a separating equilibrium where quality is revealed is now addressed.

We start with full match information. This means that the firm must tell the consumer her exact match value (her ε) if it advertises at all in the horizontal dimension. For c just larger than $c_{1q} = S^m(q)$, advertising only quality is just infeasible (because the consumer will not incur the search cost), but the full monopoly profit was attainable for slightly lower c (the argument follows that in Anderson and Renault, 2006). By continuity, advertising a price slightly below the monopoly price will induce the consumer to buy as long as c is sufficiently close to $S^m(q)$, and this will enable the firm to make a profit arbitrarily close to the monopoly profit. However, if price and full match are revealed along with quality (which we shall call "full-match" advertising, for short), the profit is strictly below the monopoly level. This is because the demand price under full match advertising is lower by c than the demand price conditional on visiting. Hence the highest profit attainable under this demand must be strictly below the monopoly level.

The argument above establishes that price-only advertising (by which we mean price along with quality) must dominate full-match advertising in a neighborhood of c values just exceeding c_{1q}. However, for c too large ($c > c_{pq}$), price-only advertising results in a zero price,

given all consumers are to be induced to visit, and averaging across all possible outcomes for ε, whereas price-and-match advertising still leads to positive profit at such a value of c. Anderson and Renault (2006) show that, for given q, the profit function for price-only advertising is concave in c while it is convex in c under full-match advertising. This means there is a unique critical c, call it c_{fq}, for which price-only advertising dominates for $c < c_{fq}$ and full-match advertising dominates for $c > c_{fq}$.

We now show that the critical switch point between the two advertising types, c_{fq}, is increasing in q. This means that price-only advertising will be used up to larger values of c for higher qualities.

Under price-only advertising, the price is given by the threshold value $\hat{p}(q)$ which equates the consumer's expected surplus to the search cost, as per (3) above. The corresponding profit is

$$\hat{\pi} = \hat{p}(q)\left[1 - F\left(\hat{p}(q) - q\right)\right],$$

and this applies whether or not the consumer always buys ex-post (if she does, then simply $F\left(\hat{p}(q) - q\right) = 0$).

The derivative of this profit with respect to q is (using (3) to show that $\frac{d\hat{p}(q)}{dq} = 1$: note we have not applied the envelope theorem)

$$\frac{d\hat{\pi}}{dq} = \left[1 - F\left(\hat{p}(q) - q\right)\right], \tag{4}$$

which is just the demand under price-only advertising. Intuitively, a quality increase enables an equal price increase, leaving the demand base the same.

Under full-match advertising, the demand is $1 - F(p + c - q)$, and applying now the envelope theorem to the profit function gives the demand derivative as

$$\frac{d\pi^f}{dq} = \left[1 - F\left(p^f(q) + c - q\right)\right]. \tag{5}$$

Once again, this expression applies too when the consumer always buys. However, it is readily shown that the price-only strategy is preferred if the consumer always would buy at

the optimal full-match price. This is because a price that brings in the marginal consumer realization (namely, $\varepsilon = 0$), i.e., $p = q - c$ under full-match advertising, would necessarily bring in the consumer, who would always buy, under price-only advertising: this holds for slightly higher prices too, since the surplus provides a buffer.

Evaluating these derivative expressions, (4) and (5), at a point where the profits are equal (the switch-over point, c_{fq}) indicates that the profit derivative for full-match is lower because demand is lower (the profit equality from the two strategies at such a point comes from the low-price/high volume price-only strategy equalling the high-price/low volume price and match strategy).[11] Hence, starting from any (quality-cost) point where profits are equal, price-only dominates for higher qualities. However, as noted above, starting from any (quality-cost) point where profits are equal, full-match dominates for higher costs. The derivative properties above imply that c_{fq} is an increasing function of q, as shown below in Figure 1.

Finally, the largest value of c at which anyone will buy for full-match advertising (at a price of zero) is where $c = b + q$, which is clearly increasing (linearly) in q. This is the right-most locus in Figure 1 below, which pulls together the above results for price-only and full-match advertising.

On the vertical axis we indicate quality, starting out with the lowest possible one, $\underline{q} = -b$,[12] and search cost, c, is on the horizontal axis. First, the region on the left of the graph has only quality being advertised. Moving right, price-only is advertised, and, for $q > \tilde{q}$, this means that all consumers buy. For $q < \tilde{q}$, there is always a region where the consumer incurs the search cost but then does not necessarily buy under price-only advertising; for

[11] Recall that the price $\hat{p}(q)$ is below the monopoly price $p^m(q)$ (and is decreasing in c) for $c > c_{1q}$ with equality (and continuity) at $c = c_{1q}$. However, under full match advertising, the "full" price faced by consumers, $p^f(q) + c$, is increasing in c. This latter property follows from the strict log-concavity of demand, $1 - F\left(p^f(q) + c - q\right)$, and it means that the full price is above the monopoly price (which attains under full match advertising at $c = 0$). This in turn means that the quantity demanded under the price-only strategy must be higher.

[12] This would indicate $c_{1\underline{q}} = 0$ if indeed there were such quality in the marketplace.

$q > 0$, there is also a region where she always buys under price-only advertising. Further right, full-match advertising dominates, and eventually this regime is crowded out by high visit cost. Note there is a kink in the loci separating regimes only where $c = c_{1\tilde{q}}$: otherwise there is a smooth transition since the defining derivatives limit to the same expressions.

In summary:

Proposition 5 *If the firm can advertise its full match, price and quality, it advertises if and only if* $c_{1\underline{q}} < c \leq b + q$. *If* $c_{1\underline{q}} < c \leq c_{1q}$, *it advertises only quality, and the consumer then visits rationally anticipating the monopoly price* $p^m(q)$. *If* $c_{1q} < c \leq c_{fq}$, *the firm advertises price along with its quality. It chooses the price* $\hat{p}(q)$ *given by (3), which is strictly below the monopoly price,* $p^m(q)$, *and is decreasing in c. If* $c_{1q} < c \leq b + q$, *is also advertises its full match, and its price* p^f *decreases with q while the full price* $p^f + c$ *increases with q.*

8 Persuasion with partial match revelation

Under partial match information, the firm may resort to the most general information partitions, and so can communicate any truthful information about matches (full match information is a special case of this). Anderson and Renault (2006) showed (for fixed qualities) that the firm would choose a threshold match strategy that communicates to the consumer whether or not her match is above or below a chosen threshold level. The intuition is (loosely) that there is no point to having visit types who will not buy, and so these should be screened out (told that their matches are below some threshold). Otherwise information should be as vague as possible (meaning that all types above the threshold get the same signal) or else some types would get a less favorable signal and this would tighten the visit constrain faced by the firm, which must set a low enough price so that all consumer types above the threshold visit. The optimal disclosure strategy for the firm may be characterized by defining three critical search cost values at which the firm modifies the information provided through

its ads. Results applied to differential quality types are as follows.

As for the full match advertising problems analyzed above, there exists an equilibrium such that quality is revealed for all $q > c - b$, if and only if $c \leq c_{1\underline{q}}$. As before we will argue *ex post* that this is an equilibrium. This equilibrium also has the property that as long as $c \leq c_{1q}$, the firm does not advertise any information about price or match, and quality advertising alone is sufficient to reap the full monopoly profit. To describe the firm's behavior for larger search costs, let us define, for any $z \in (-\infty, b)$,

$$\phi(z) = \frac{\int_z^b (\epsilon - z) f(\epsilon) d\epsilon}{1 - F(z)}, \tag{6}$$

which represents the expected consumer surplus, net of $z + q$, of retaining only matches above z, and is a key to analyzing the case of partial match information. [13] For instance if the firm is charging p while informing consumers willing to pay that price that they are (i.e. by disclosing a threshold of $p - q$ for ϵ) then these consumers expected surplus net of p is $\phi(p - q)$. A special case is when the firm charges q so that all consumers are willing to pay the price: then expected consumer surplus is $\phi(0)$. Lemma 2 in Anderson and Renault (2006) shows that ϕ is decreasing if f is log-concave (so the expected conditional surplus falls with the threshold z). It tends to zero as z tends to b.

For $c > c_{1q}$, the firm may be able to still earn the full monopoly profit by judicial use of threshold information. Specifically, it gains nothing whenever the consumer does not buy after incurring the visit cost Advertising to the consumer that her match value is low (below the monopoly price net of quality) will lose no sales but will have the effect of raising the consumer's surplus when she visits. This broadens the footprint of the monopoly pricing regime to larger c values, but only if $q < \tilde{q}$, since otherwise the consumer always buys when she visits. More formally, if the firm charges $p^m(q)$ and discloses match information that reassures the consumer that she is willing to pay the monopoly price whenever $q + \epsilon \geq p_m$,

[13] Another way of writing this expression is $\phi(z) = \frac{\int_z^b \epsilon f(\epsilon) d\epsilon}{1 - F(z)} - z$.

expected consumer surplus conditional on such favorable information may be written as

$$\frac{\int_{p^m(q)-q}^{b}\left[q+\epsilon-p^m(q)\right]f(\epsilon)d\epsilon}{1-F(p^m(q)-q)}=\phi(p^m(q)-q). \tag{7}$$

Hence consumers with a favorable signal will choose to visit as long as $c \leq c_{2q} \equiv \phi(p^m(q)-q)$. It is important here that the firm need not advertise price at all since the consumer will rationally anticipate the monopoly price. This means that threshold match advertising alone (along with quality advertising) will ensure the monopoly profit.

For $q < \tilde{q}$ we have $c_{2q} = \phi(p^m(q) - q)$. Hence, ϕ being strictly decreasing and $p^m(q) - q$ being strictly decreasing in q, c_{2q} is strictly increasing in q. Simple inspection shows that for $q < \tilde{q}$, so that $p^m(q) > q$, we have $c_{2q} > c_{1q}$. For $q \geq \tilde{q}$, the monopoly price is q and the two expressions are the same: we have $c_{1q} = c_{2q} = \phi(0)$. It is also useful to show that $\tilde{q} > \phi(0)$: this is a direct consequence of results in Anderson and Renault (2003) according to which, if demand is log-concave, monopoly producer surplus exceeds consumer surplus (the result may be applied for $q = \tilde{q}$ where the first order condition for monopoly price holds with equality).

For larger search costs than c_{2q}, the firm must offer a more attractive package to the consumer to get her to pay the visit cost. Just as in price-only advertising analyzed above, it commits to pricing below the monopoly price in order to induce the consumer to undertake a costly visit. Again, a threshold partial match is advertised to purge the worst types. If the search cost is not too large, then the firm charges a price $\bar{p}$ that satisfies

$$c=\frac{\int_{\bar{p}-q}^{b}\left[q+\epsilon-\bar{p}\right]f(\epsilon)d\epsilon}{1-F(\bar{p}-q)}=\phi(\bar{p}-q), \tag{8}$$

so that the consumer is willing to visit as long as she is informed that her match is such that $q + \epsilon \geq \bar{p}$ and thus that she is certain to buy the product if she does visit. The firm may achieve this by disclosing match information that guarantees such a threshold. However, disclosing such information is unnecessary if $\bar{p} \leq q$, in which case the consumer knows that

she is willing to pay at least $\bar{p}$. Since $p = q + \phi^{-1}(c)$ (by (8)) and ϕ is decreasing (so that ϕ^{-1} is as well), this will be the case if $c \geq \phi(0)$. Hence the firm will disclose price and partial match information if $c < \phi(0)$, and will disclose only price information for $c > \phi(0)$.

The above strategy however is no longer optimal when c becomes larger than $\max\{\bar{p}, q\}$. The firm sets consumer surplus to zero which can be seen from the condition $c = \phi(\bar{p} - q)$. Then it captures the entire social surplus at price $\hat{p}$ and it should make it as large as possible. However, if $\max\{\bar{p}, q\} < c$ and all consumer types who are willing to pay at least $\bar{p}$ buy, there is some probability that the consumer buys even though social surplus is negative (that is when $\epsilon + q < c$) which deteriorates expected social surplus. The firm may prevent this from happening however, by disclosing a threshold of $c - q$ for ϵ so that only those consumers who are above that threshold visit and buy. To determine the critical c at which the firm would switch to that strategy, we distinguish two cases, depending on whether $\hat{p}$, which decreases as c increases, crosses c before or after it crosses q. Recall that $\bar{p}$ crosses q for $c = \phi(0)$ so that $\hat{p}$ crosses c first if and only if $q < \phi(0)$.

First assume that $q < \phi(0)$. Then the firm switches strategy when the price $\bar{p}$ falls below the search cost c that is, for $c > q + \phi^{-1}(c)$ or $c > \phi(c - q)$, again because ϕ is decreasing. Monotonicity of ϕ also implies that this condition is equivalent to $c > c_{3q}$ where c_{3q} is the solution to the fixed point relation $c_{3q} = \phi(c_{3q} - q)$. From Lemma 2 in Anderson and Renault (2006), such a solution exists, is unique and has the property that $c_{3q} > c_{2q}$. The firm then sets the price that captures the entire expected consumer surplus, that is $p = \phi(c - q)$. The firm adopts this strategy for $c_{3q} \leq c < b + q$, where $b + q$ is the search cost level at which no consumer type would wish to visit even if she could obtain the product for free.

Since c_{3q} satisfies $c_{3q} = \phi(c_{3q} - q)$ and ϕ is strictly decreasing, c_{3q} is strictly increasing in q, and we have $c_{3(-b)} = 0$ and $c_{3\phi(0)} = \phi(0)$.

Finally assume that $q \geq \phi 0$. Then the firm changes strategy when search cost c starts exceeding quality q. For c between $\phi(0)$ and q the firm needs not disclose any match informa-

tion since $\bar{p} < q$ so that all consumer types know they will buy if they visit and all are willing to pay more than the search cost c so there is no loss in social surplus from some inefficient purchase. The firm discloses partial match information only for search costs between q and $q + b$. Again the firm manages to capture the entire first-best social surplus by charging a price $p = \phi(c - q)$.

Figure 2 illustrates the partition of the parameter space according to the strategy used. For $c \leq c_{1q}$, the monopoly price is rationally anticipated and only quality is advertised, as we had before (see Figure 1). For $c \in (c_{1q}, c_{2q}]$ the consumer is also told the threshold match corresponding to the monopoly price, which does not need to be advertised since it is rationally expected.[14] For $c \in (c_{2q}, \min\{c_{3q}, \phi(0)\}]$, price is added to the advertising mix, with a threshold match announced that exceeds the search cost; while for $c \in (c_{3q}, \min\{q + b, \phi(0)\}]$, the information mix is the same except with a (gross) threshold match that equals the search cost. For $c > \phi(0)$ we have that price and quality are announced for $c \in (\phi(0), q]$ and price and quality and threshold match (equal to $c - q$) for $c \in (q, q + b]$.

Proposition 6 *If the firm can advertise a threshold match, price and quality, it advertises if and only if* $c_{1\underline{q}} < c \leq b + q$. *If* $c_{1\underline{q}} < c \leq c_{1q}$, *it advertises only quality, and the consumer then visits rationally anticipating the monopoly price* $p^m(q)$. *If* $c_{1q} < c \leq c_{2q}$, *the firm advertises quality and partial match information with a threshold such that* $\varepsilon \geq p^m(q) - q$, *and the consumer visits rationally anticipating the monopoly price* $p^m(q)$ *as long as she is informed her match exceeds the threshold. If* $c_{2q} < c \leq \min\{c_{3q}, \phi(0)\}$, *the firm advertises quality, price* $\bar{p}(q) > c$, *and partial match information with a threshold such that* $\varepsilon \geq \bar{p}(q) - q$, *where* $\bar{p}$ *decreases in* c. *If* $q \geq \phi(0)$, *then if* $c \in (\phi(0), q]$, *the firm advertises quality and a price equal to* $\bar{p}$, *and the consumer always buys after visiting, but if* $c \in (q, q + b]$ *the firm advertises*

[14] Recall that $c_{1q} = c_{2q}$ $(= \phi(0))$ for $q \geq \tilde{q}$ since the consumer always buys at the monopoly price and anticipates that this will be the case following the visit.

quality, price equal to $\phi(c-q)$, and threshold match $c-q$. The latter strategy also applies for $q < \phi(0)$ and $c \in (c_{3q}, q+b]$. [to check. is order OK?]

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