“A Model of Sales” with Quality

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Abstract

If a consumer faces two products of the same kind but different in their prices and quality, which one does he choose? I show that if firms compete in both prices and quality, and if there are some consumers on the market who do not search for the best offer, then the competition is always such that it is best for a consumer to buy the cheapest product. In an equilibrium the quality will either grow with price but not sufficiently, or it will fall with price. The result holds for a wide class of consumers' preferences.

Key Words: oligopoly, competition, price, quality.

JEL Classification: D43, D83, L13, L15.

1 Introduction

When discussing which particular product of a certain kind to buy, people are usually talking about prices, overall quality and value for money. Think of buying a camera, for example. But how do those criteria relate? Can one infer quality from price? Does a higher price mean a higher quality? Why are there different prices and quality in the first place? How much of these differences shall be attributed to preference heterogeneity and how much to information asymmetry? These and other similar questions are relevant for modelling consumers' choice, for doing welfare analysis, for understanding competition mechanisms.

In studying how markets of close substitutes operate when there is asymmetric information, two assumptions shape the results: how information asymmetry is modelled and what kind of production technology is assumed. Various authors have emphasised the importance of a setting where firms can compete in both prices and quality (Chan and Leland, 1982; Cooper and Ross, 1984; Schwartz and Wilde, 1985; Wolinksy, 1983; Rogerson, 1988; Besancenot and Vranceanu, 2004; Armstrong and Chen, 2008). In this paper I also study a setting of price/quality competition. My model comes from extending Varian's “Model of Sales” (Varian, 1980, 1981) with quality choice. Namely: firms are allowed to compete in both price and quality; consumers have preferences over

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(price, quality) offers; there are two groups of consumers – those in the first group are fully informed about price and quality aspects of the firms' offers, those in the second group are fully uninformed. The motivation behind such a setup is simplicity. Varian has shown that approximating information asymmetry by saying that some consumers know all the prices and others know none is sufficient to explain sales and price dispersion. I extend this idea to price/quality competition and see if there are any theoretical answers to the aforementioned questions within such a simple setting.

I obtain two results. First, there is a unique symmetric Nash equilibrium in mixed strategies – firms mix over prices and quality of their products. So, the presence of uninformed consumers can explain not only the dispersion of prices, but also the dispersion of quality. If mixed strategies in prices are sometimes illustrated with sales – firms use sales as a mechanism to randomise prices, mixed strategies in quality can be illustrated with seasonal ranges of clothing or with computer gadgets, when new ones are introduced faster than the technology or needs grow.

Second, when the most general preferences are allowed, the equilibrium can be of two types: (i) consumers prefer the cheapest product and quality is either positively or negatively correlated with price, or (ii) consumers prefer the most expensive product and quality is always positively correlated with price. However, if preferences exhibit marginal returns to quality that are decreasing in price, i.e. if informed consumers shift their choices to products of lesser quality when all the offers equally increase in price, then the equilibrium is always of type (i) – consumers will prefer the cheapest offer. In a way, this result backs up a rule of thumb that some persue – to simply buy the cheapest product when you are no expert on the quality.[1] When consumers prefer the cheapest product, quality either declines with price or it increases with price, but not sufficiently. Quality declining with price may seem counterintuitive at first, but then, if firms target the uninformed consumers, increasing prices and lowering quality is the best way to increase profits. Consequently, higher prices can be correlated with lower quality.

It can also be the case the equilibrium is of type (ii) – quality increases with price fast enough so as to shift the preference towards the most expensive product. But we may expect such an equilibrium only if the following necessary condition holds: consumer's preferences exhibit marginal returns to quality that are increasing in price, i.e. informed consumers shift their choices to products of better quality when all the offers equally increase in price. Arguably, marginal returns to quality that are decreasing in price are more common, so it is more likely the equilibrium is of type (i).

For convenience, in the following text I abbreviate the original "Model of Sales" as MSV. A certain technical equivalence can be established between my model and MSV, this equivalence allows me to reuse some of Varian's results. Consequently, I lay out the rest of the paper as follows. Section 2 recollects MSV and extends it along the way to include quality. Section 3.1 establishes

[1] In a simple model I consider there are, however, no consumers who infer quality from price as some know both and others know neither. Together with Maarten Janssen (Dubovik and Janssen, 2008) we study a more complete model, where there is also a group of partially informed consumers. Partially informed consumers know the prices but not the quality of the goods offered. The price becomes a signal of quality then, that changes competition, but the result about preferring the cheapest product still holds.

the referred equivalence between my model and MSV. Section 3.2 discusses the resulting economic aspects of price/quality competition.

2 Model Setup

There are n firms. Let i, $i \in \{1, \dots, n\}$, stand for the offer of firm i and let r stand for the outside option. Also, let p and q stand for price and quality respectively. Informed consumers in MSV prefer offer i against offer j if offer i has a lower price:

$$i \succ j \Leftrightarrow p_i < p_j \quad \forall\, i, j \in \{1, \dots, n, r\} \tag{1}$$

To account for quality, suppose that all the consumers have preferences defined over (p, q) bundles. I represent these preferences by a utility function $U(p, q)$, i.e. the informed consumers prefer offer i against offer j if offer i provides a higher utility:

$$i \succ j \Leftrightarrow U(p_i, q_i) > U(p_j, q_j) \quad \forall\, i, j \in \{1, \dots, n, r\}$$

Uninformed consumers in MSV are shared equally between the firms and they do not buy (they choose the outside option) if $p > p_r$. I assume the same, but adding quality gives that they do not buy if $U(p, q) < U(p_r, q_r)$.

Let I be the total number of the informed consumers and let T be the number of the uninformed consumers *per firm*. Also, let π denote profits of a firm. I consider a case with zero marginal production costs and with fixed entry costs k.[2] The expected profits of firm i, if to consider MSV, are then given by[3]

$$\mathbb{E}\pi_i(p) = \Big(\mathbb{P}\Big(p < \min_{j \neq i} p_j\Big) I + T\Big) p - k \tag{2}$$

Here I talk about *expected* profits because the rivals of firm i can play a random strategy, in which case the event $p < \min_{j \neq i} p_j$ is not certain.

To consider my model I additionally need to introduce the costs of producing a single unit of good of quality q, I denote these costs by $w(q)$. In my model the expected profits are then given by

$$\mathbb{E}\pi_i(p, q) = \Big(\mathbb{P}\Big(U(p, q) > \max_{j \neq i} U(p_j, q_j)\Big) I + T\Big)(p - w(q)) - k \tag{3}$$

Regarding functions $U(p, q)$ and $w(q)$ I make two assumptions. The first assumption is trivial.

Assumption 1. *Utility function $U(p, q)$ is strictly decreasing in p, strictly increasing in q, continuous in (p, q). Cost function $w(q)$ is strictly increasing in q.*

[2] This is the simplest case that fits the assumptions of MSV. I want to stay within those assumptions as to be able to reuse some of Varian's results.

[3] I assume a firm does not expect to get any of the informed consumers in cases of ties (equal prices). A more usual assumption is that a firm expects to get an equal share of the informed consumers. Whatever the assumption is – the results do not change. However, the former assumption is notationally more convenient.

As for the second assumption, let us consider the set of Pareto-efficient allocations. By definition, any Pareto-efficient allocation (p, q) is a solution to the following problem

$$\begin{aligned} &\max_{(p,q)} \ p - w(q) \\ &\text{s.t. } U(p, q) \geq u, \end{aligned} \tag{4}$$

where u is a certain level of utility. If the solution is unique, I will denote it by $(p^*(u), q^*(u))$. Ceteris paribus, consumers and firms have opposing interests with repsect to (price, quality) combinations. Therefore, it is reasonable to assume that (4) has a solution. For technical reasons I introduce a slightly stronger assumption:

Assumption 2. *Problem* (4) *has a unique solution for every* u. *Moreover, there exists a continuous function* $g(p)$ *such that* $q^*(u) = g(p^*(u))$ *for every* u.

The second part of the assumption simply tells that the contract curve – the set of all Pareto-efficient allocations – can be represented as a continuous function in (p, q) space.

3 Analysis

At first I will show that there is a certain technical equivalence between my model and MSV. This equivalence will allow me to reuse some of Varian's results, mainly the result on the existence of an equilibrium. After that I will discuss what the resulting equilibrium is and what it implies for the distribution of prices and quality.

3.1 Relation to the "Model of Sales"

A strategy of a firm is either to play a certain (p, q) bundle, or to play a random (p, q) bundle according to a certain distribution. The objective of a firm is to maximise its expected profits given the strategies of the opponents, i.e. the objective is

$$\max\nolimits_{(p,q)} \mathbb{E}\pi(p, q) \tag{5}$$

Here the strategies of the opponents implicitly enter through $\mathbb{E}$.

Suppose (p^*, q^*) is a solution to (5), then

$$\mathbb{E}\pi(p^*, q^*) \geq \mathbb{E}\pi(p, q) \quad \forall (p, q)$$

This inequality, in particular, implies that

$$\mathbb{E}\pi(p^*, q^*) \geq \mathbb{E}\pi(p, q) \quad \forall (p, q) : U(p, q) = U(p^*, q^*) \tag{6}$$

Expanding (6) and using $U(p, q) = U(p^*, q^*)$ gives

$$\begin{aligned} &\Big(\mathbb{P}\Big(U(p^*, q^*) > \max_{j \neq i} U(p_j, q_j)\Big) I + T\Big)(p^* - w(q^*)) - k \geq \\ &\qquad \Big(\mathbb{P}\Big(U(p^*, q^*) > \max_{j \neq i} U(p_j, q_j)\Big) I + T\Big)(p - w(q)) - k \end{aligned} \tag{7}$$

Therefore,

$$p^* - w(q^*) \geq p - w(q) \quad \forall (p,q) : U(p,q) = U(p^*,q^*)$$

So, (p^*,q^*) is a solution to the following problem as well:

$$\max_{(p,q):U(p,q)\geq U(p^*,q^*)} (p - w(q)) \tag{8}$$

Depending upon the strategies of the opponents a firm may choose different (p^*,q^*), but whatever those strategies are, (p^*,q^*) is always a solution to (8). Hence, choosing (p,q) from the contract curve, i.e. choosing (p,q) such that $q = g(p)$, strictly dominates all other choices.[4]

Notice, that I do not discuss yet what particular choices of (p,q) the firms make, rather I say that any optimal choice has to belong to the contract curve. Let

$$\tilde{p}(p) = p - w(g(p))$$

I will next show that consumers' behaviour and firms' profits can be fully rewritten in terms of $\tilde{p}$. Moreover, once rewritten, they will be functionally equivalent to their counterparts from MSV. Therefore, Varian's solution can be directly applied from there on.

Consider the informed consumers. As firms play $(p,q) = (p,g(p))$, the informed consumers prefer offer i to offer j if $U(p_i,g(p_i)) > U(p_j,g(p_j))$. The following lemma helps to express this relationship in terms of $\tilde{p}$.

Lemma 1. $U(p_i,g(p_i)) > U(p_j,g(p_j)) \Leftrightarrow \tilde{p}(p_i) < \tilde{p}(p_j)$

Proof. This lemma follows from assumptions 1 and 2. Indeed, from the definition of $g(p)$ it follows that there exists u_i such that

$$(p_i,g(p_i)) = \arg\max_{(p,q):U(p,q)\geq u_i} \Big(p - w(q)\Big)$$

$U(p,q)$ is strictly decreasing in p and is strictly increasing in q and $(p - w(q))$ is doing just the opposite, therefore the constraint $U(p,q) \geq u_i$ is binding and $u_i = U(p_i,g(p_i))$. The same holds for $(p_j,g(p_j))$.

Suppose $U(p_i,g(p_i)) > U(p_j,g(p_j))$. Then

$$\tilde{p}(p_i) = p_i - w(g(p_i)) = \max_{(p,q):U(p,q)\geq U(p_i,g(p_i))} \Big(p - w(q)\Big) < \max_{(p,q):U(p,q)\geq U(p_j,g(p_j))} \Big(p - w(q)\Big) = p_j - w(g(p_j)) = \tilde{p}(p_j)$$

Here, the strict inequality directly follows from assumption 1.

Suppose $U(p_i,g(p_i)) = U(p_j,g(p_j))$. Then $(p_i,g(p_i))$ and $(p_j,g(p_j))$ can both be represented as a solution to the same optimisation problem. According to assumption 1 the solution is unique, therefore $p_i = p_j$ in this case.

□

Given lemma 1, the informed consumers choose as follows:

$$i \succ j \Leftrightarrow \tilde{p}_i < \tilde{p}_j \quad \forall\, i,j \in \{1,\ldots,n,r\}$$

[4] *Strict* dominance follows from the uniqueness in assumption 2.

This expression is functionally equivalent to (1). As for the uninformed consumers, an analogous story holds.

From the lemma and from the definition of $\tilde{p}$ it also directly follows that

$$\mathbb{E}\pi_i(p, g(p)) = \Big(\mathbb{P}\Big(\tilde{p}(p) < \min_{j \neq i} \tilde{p}_j\Big) I + T\Big)\tilde{p}(p) - k$$

This expression is functionally equivalent to (2). Hence, we have the following proposition.

Proposition 1. *The extended model is analogous to MSV when in the latter the real price p is replaced with the pseudo-price $\tilde{p}$. Consequently, all the results established for MSV hold for the extended model as well, though expressed in terms of $\tilde{p}$. Mainly, there are no pure strategy Nash equilibria and there is a unique symmetric Nash equilibrium in mixed strategies (in which firms mix over different $\tilde{p}$).*

It is crucial for the above arguments that every consumer has the same information about the quality as he has about the prices. It permits us to always consider price and quality together, essentially translating multidimensional competition (price and quality) into a single dimensional one (utility). If there was a group of consumers who, for example, knew the prices but not the quality of the firms' offers, the story will be completely different (see Dubovik and Janssen, 2008).

3.2 Equilibrium Distribution of Prices and Quality

We will now consider how the mixed strategy strategy equilibrium in $\tilde{p}$ translates back into an equilibrium in (p, q).

The results of Varian tell us that there is a dispersion of pseudo prices $\tilde{p}$ because the firms play mixed strategies in an equilibrium, i.e. they choose $\tilde{p}$ at random from a certain distribution. Also, by definition, a pseudo price $\tilde{p}$ is a function of a real price p. Consequently, there will be a dispersion of real prices as well.

Given that there are different prices in the market, how do the informed consumers choose between them? Consider the following lemma.

Lemma 2. *Utility over a contract curve, namely $U(p, g(p))$, is strictly monotone in p.*

Proof. $U(p, g(p))$ is continuous in p as follows from assumptions 1 and 2. Therefore, the lemma does not hold if and only if there exist p_i, p_j such that $p_i \neq p_j$ and $U(p_i, g(p_i)) = U(p_j, g(p_j))$. But from $U(p_i, g(p_i)) = U(p_j, g(p_j))$ it follows that $p_i = p_j$ – see the proof of lemma 1 – hence, no such p_i, p_j exist and the lemma holds.

□

Whether $U(p, g(p))$ is strictly decreasing or whether it is strictly increasing depends upon the form of $U(p, q)$ and the form of $w(q)$. Both cases are possible.

First, consider a case when $U(p, g(p))$ is strictly decreasing. In this case

$$U(p_i, g(p_i)) > U(p_j, g(p_j)) \Leftrightarrow p_i < p_j$$

and the informed consumers will buy the cheapest product.

Going back to the distribution of prices, let $\tilde{F}$ and F be CDFs that represent the distributions of $\tilde{p}$ and p respectively. Please, refer to Varian (1980) for the expression of $\tilde{F}$. Here I only remind that $\tilde{F}$ depends, among other factors, on the number of informed and uninformed consumers. If either I or T goes to zero, the distribution, naturally, becomes degenerate.

Consider F now. Using that $U(p, g(p))$ is strictly decreasing and using lemma 1 gives:

$$F(x) = \mathbb{P}(p < x) = \mathbb{P}\big(\tilde{p}(p) < \tilde{p}(x)\big) = \tilde{F}(\tilde{p}(x))$$

Quality is always related to price by $q = g(p)$. If $g(p)$ is decreasing, quality is negatively correlated with price, and vice versa. Both cases are compatible with decreasing $U(p, g(p))$. Hence, if in an equilibrium the informed consumers buy the cheapest product, quality may be either positively or negatively correlated with price in that equilibrium.

The possibility of a negative correlation reflects the fact that firms have market power. Indeed, in the discussed model some consumers are fully uninformed and the firms may prefer to give them the lowest quality for the highest price simply because it is a profitable thing to do.

Now, consider a case when $U(p, g(p))$ is strictly increasing. In this case

$$U(p_i, g(p_i)) > U(p_j, g(p_j)) \Leftrightarrow p_i > p_j$$

and the informed consumers will buy the most expensive product. The basic reason for why consumers may prefer to buy the most expensive product is heterogeneity of products in quality. In this case more expensive products have sufficiently better quality and so they are preferred by the consumers.

In this case the resulting distribution of prices is given by

$$F(x) = \mathbb{P}(p < x) = \mathbb{P}\big(\tilde{p}(p) > \tilde{p}(x)\big) = 1 - \tilde{F}(\tilde{p}(x))$$

Here $g(p)$ is strictly increasing. Indeed, $U(p, q)$ is strictly decreasing in p and is strictly increasing in q. So, if to suppose that $g(p)$ is decreasing, then $U(p, g(p))$ is strictly decreasing in p, but this is not the case. Since $g(p)$ is strictly increasing, we have the following result. If in an equilibrium the informed consumers buy the most expensive product, it is certain that quality is positively correlated with price in that equilibrium.

Finally, let me consider a special case of a quasi-linear utility function. Suppose $U(p, q) = p + h(q)$. Then optimisation problem (4) gives a constant q and there will be no dispersion of quality. In other words, if every consumer does not change his choice between competing offers when their prices are all increased or decreased by the same amount, then all the firms will offer the same quality. Though, there still will be a dispersion of prices.

The following proposition summarises the cases we have discussed.

Proposition 2. *There is a dispersion of prices and quality in the equilibrium, except for a special case when $U(p, q) = p + h(q)$. In that case there is a dispersion of prices only, there is no dispersion of quality.*

In the equilibrium, whether the informed consumers prefer the cheapest or the most expensive product depends upon the form of $U(p, q)$ and the form of

$w(q)$. Both cases are possible. If the informed consumers prefer the cheapest product, then quality can be positively or negatively correlated with price. If they prefer the most expensive one, then quality is always positively correlated with price.

So far we have considered a rather general form of $U(p,q)$. This has a drawback that we can not give a definitive answer on whether consumers prefer the cheapest or the most expensive offer in the equilibrium. The following proposition improves upon this ambiguity.

Proposition 3. *If utility function $U(p,q)$ is strictly quasi-concave and twice differentiable in (p,q), if cost function $w(q)$ is convex and twice differentiable in q, if there are decreasing marginal returns to quality, i.e. $U_{qq} < 0$, and if the marginal returns to quality are also decreasing in price, i.e. $U_{qp} < 0$, then consumers prefer the cheapest product as $\frac{d}{dp}U(p,g(p)) < 0$.*

Proof. Consider an arbitrary point $(p^*, g(p^*))$. Let $\tilde{q}(p)$ define an isoutility curve going through this point, i.e.

$$\tilde{q}(p^*) = g(p^*), \quad U(p, \tilde{q}(p)) = U(p^*, g(p^*))$$

Let me use the following notation: $\tilde{U}$ stands for $U(p,\tilde{q}(p))$, $\tilde{U}_p$ stands for $U_p(p,\tilde{q}(p))$, et cetera. Also, let $\hat{U}$ stand for $U(p,g(p))$, let $\hat{U}_p$ stand for $U_p(p,g(p))$, et cetera.

Differentiating (3.2) gives

$$\tilde{q}'(p) = -\frac{\tilde{U}_p}{\tilde{U}_q}$$

Twice differentiating (3.2) gives

$$\tilde{U}_{pp} + 2\tilde{q}'(p)\tilde{U}_{pq} + \tilde{q}'(p)^2\tilde{U}_{qq} + \tilde{U}_q\,\tilde{q}''(p) = 0$$

By definition, any point $(p, g(p))$ is a solution to

$$\max_{(p,q)} \; p - w(q) \tag{9}$$

$$\text{s.t. } U(p,q) \geq U(p,g(p)) \tag{10}$$

From the first order conditions it then follows that

$$\frac{1}{w'(g(p))} = -\frac{\hat{U}_p}{\hat{U}_q}$$

or

$$\hat{U}_q + \hat{U}_p\,w'(g(p)) = 0$$

Differentiating (3.2) gives

$$w'(g(p))\hat{U}_{pp} + 2\hat{U}_{pq} + \frac{1}{w'(g(p))}\hat{U}_{qq} + \hat{U}_p\,w''(g(p)) + \left(\hat{U}_{qq} + w'(g(p))\hat{U}_{pq}\right)\left(g'(p) - \frac{1}{w'(g(p))}\right) = 0 \tag{11}$$

Consider $U(p, g(p))$. Differentiating it in p gives

$$\frac{d}{dp}U(p, g(p)) = \hat{U}_q \left(g'(p) + \frac{\hat{U}_p}{\hat{U}_q} \right)$$

Now, let us evaluate (3.2), (11) and (3.2) at point p^*. At this point $\tilde{U} = \hat{U}$, $\tilde{U}_p = \hat{U}_p$ and et cetera as follows from the definition of $\tilde{q}$. Also,

$$\tilde{q}'(p^*) = -\frac{\tilde{U}_p}{\tilde{U}_q}\bigg|_{p^*} = -\frac{\hat{U}_p}{\hat{U}_q}\bigg|_{p^*} = \frac{1}{w'(g(p^*))}$$

as follows from (3.2) and (3.2). Therefore, using (3.2), (11), (3.2) and (3.2) gives

$$\frac{d}{dp}U(p, g(p))\bigg|_{p^*} = \hat{U}_q^2 \left(-\frac{\hat{U}_q}{\hat{U}_p}\tilde{q}''(p) - \frac{\hat{U}_p}{\hat{U}_q}w''(g(p)) \right) / \left(\hat{U}_{qq} - \frac{\hat{U}_q}{\hat{U}_p}\hat{U}_{pq} \right)\bigg|_{p^*} \tag{12}$$

Since p^* was chosen arbitrary, this result holds in general:

$$\frac{d}{dp}U(p, g(p)) = \hat{U}_q^2 \left(-\frac{\hat{U}_q}{\hat{U}_p}\tilde{q}''(p) - \frac{\hat{U}_p}{\hat{U}_q}w''(g(p)) \right) / \left(\hat{U}_{qq} - \frac{\hat{U}_q}{\hat{U}_p}\hat{U}_{pq} \right) \tag{13}$$

Assumption 1 tells us that $U_p < 0$ and $U_q > 0$. Also, in this proposition we require that $\tilde{q}''(p) > 0$ (strict quasi-convexity of the utility function), that $w''(q) \geq 0$ (convexity of the cost function) and that $U_{qq} < 0$ and $U_{pq} < 0$. Taking these signs into account gives

$$\frac{d}{dp}U(p, g(p)) < 0$$

□

In a way, proposition 3 relays the ambiguity about whether the cheapest or the most expensive offer is preferred in the equilibrium to the ambiguity whether $U_{pq} < 0$ or $U_{pq} > 0$. The economic interpretation for the latter is as follows. Saying that $U_{pq} < 0$ is equivalent to saying that informed consumers shift their choices to products of lesser quality when all the offers they face equally increase in price (here I mean any arbitrary offers, not necessary equilibrium ones). So, if that is the case, then the competition is such that consumers prefer the cheapest offer in the equilibrium. Vice versa, if we are to expect an equilibrium where the most expensive offer is preferred, it should be that informed consumers shift their choices to products of higher quality when all the offers they face equally increase in price, i.e. it should be that $U_{pq} > 0$.[5]

[5]It is a necessary condition given that other requirements of proposition 3 are fulfilled.

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