# Joint Product Signals of Quality

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September 1991

# Abstract

In the absence of other information about the quality of an *experience good*, the price of a jointly produced *search good* provides consumers with a signal of the former good's quality.. This hypothesis provides an explanation for the heretofore unexplained pricing policies uncovered by Barron's and Umbeck's (1984) empirical investigation of gasoline retailing.

# Joint-Product Signals of Product Quality

# I. Introduction

In a paper concerning the relationship between advertising and product quality, Nelson [1970] makes the useful distinction between "search" and "experience" goods. According to Nelson's definitions, a good is a search good if consumers can discern its quality <u>prior</u> to purchase. On the other hand, if consumers can only discern a good's quality <u>after</u> its purchase, it is then defined to be an experience good. Examples of search goods include salt, electricity, branded gasoline or other reputable brand name goods that consumers have previously used. Examples of experience goods include automobile repairs, restaurant meals and movies.<sup>1</sup> Sellers of experience goods often engage in costly quality demonstration activities that signal product quality to buyers.

While the signaling literature is extensive, its results are confined to the case of a seller producing a single experience good [Spence, 1973; Nelson, 1974; Frank, 1985; Milgrom and Roberts, 1986].2. This paper expands this literature by initiating a discussion of the signaling problem facing a firm that produces an experience good not in isolation, but <u>jointly</u> with a search good.

Two insights emerge from the analysis. First, the price of the jointly produced search good can act as a signal of the quality of the firm's experience good. Second, the price of a firm's search good is shown to vary depending on whether it is produced jointly with another search good, jointly with an experience good or in isolation.

#### II. The Model

The structure of the problem is straightforward. A firm jointly produces a search good and an experience good, where the goods are measured in the same units. There is an input constraint imposed by the joint production which is stylistically represented as a linear tradeoff in the production of the two goods. The firm's objective is to maximize current profits taking into account the impact of current productions decisions on its reputation and hence, its future revenue. Finally, following Milgrom and Roberts, it is assumed that this is a new firm, that consumers have no locational preferences, and that quality enhancement is a fixed cost.<sup>3</sup>

## A. The Firm's Reputation

The simple linear reputational function that is employed here is based on three notions. First, firms will obtain some repeat business as long as the quality of their product meets consumers' expectations. Thus, even low quality firms will obtain some repeat business as long as the quality of their products is in accordance with consumers' expectations. Second, if actual quality is greater than expected quality, the firm's reputation is enhanced and repeat business will increase. Third, if actual quality is less than expected quality, a firm's reputation will be damaged and repeat business will decline.

Symbolically, reputational revenue from product I, R<sub>i</sub>, is:

$$\mathbf{R}_{i} = [\boldsymbol{\alpha}_{i} + \boldsymbol{\beta}_{i}(\mathbf{Q}_{i} - \mathbf{Q}_{i}')]\mathbf{X}_{i}, \tag{1}$$

where  $X_i$  is the quantity of good i,  $Q_i$ , is the actual quality of good i and  $Q_i'$  is the expected quality of good i.  $\alpha_i$  is the "normal" reputational revenue from selling good i (which occurs when  $Q_i' = Q$ :), and  $\beta_i$  represents a parameter which translates the "non-normal" reputational effects into long-run revenues for good i.

## **B.** Joint Production of Search Goods

If a firm jointly produces two search goods, the qualities of the goods, by definition, are known to the consumer prior to purchase. Thus,  $Q_i = Q_i'$ , so that  $R_i = \alpha_i X_i$  for i=1,2.

In the two search good case, the firm maximizes profits subject to the joint production constraint of

$$X = X_1 + X_2^{4}$$
(2)

Generally, the firm's objective function is

$$L = \sum_{i=1}^{2} [P_i(X_i, Q_i)X_i + R_i - C_i(X_i)] + v(X - X_1 - X_2),$$
(3)

where v is the lagrangian multiplier,  $C_i(X_i)$  is the cost function for good i, and  $P_i(X_i,Q_i)$  is the demand function for good i. Assuming that the demand and cost functions are linear, equation (3) becomes

$$L = \sum_{i=1}^{2} [(a_i - b_i X_i + e_i Q_i) X_i + \alpha_i X_i - c_i X_i] + v(X - X_1 - X_2),$$
(4)

where, demand parameters  $a_i$ ,  $b_i$ ,  $e_i$  are positive for both goods 1 and 2, and cost parameters  $c_1$  and  $c_2$  are positive.

The first order conditions are

$$L_{Xi} = a_i - 2b_iX_i + e_iQ_i + \alpha_i - c_i - v = 0, i=1,2, and$$
 (5)

$$L_{v} = X - X_{1} - X_{2} = 0.$$
(6)

When equations (5), and (6) are totally differentiated the following comparative static result is obtained:

$$\frac{\mathrm{dX}_2}{\mathrm{dQ}_1} = \frac{-\mathrm{e}_1}{|\Omega|},\tag{7}$$

where  $\Omega$  denotes the Bordered Hessian matrix. Given that the second order conditions are met (ie.,  $|\Omega| > 0$ ), it follows that  $dX_2/dQ_1 < 0.5$ 

Thus, profit maximizing firms find it optimal to lower the quantity (raise the price) of good 2 as the quality of good 1 is increased. Consumers will then observe this behavior in the marketplace. This observed behavior provides a guideline to consumers when confronting a firm which jointly produces an experience good and a search good.

### C. Signaling

Now consider a firm that produces an experience good (good 1) jointly with a search good (good 2). As an experience good,  $Q_1$  is no longer equal to  $Q_1'$ . On the other hand,  $Q_2 = Q_2'$  as good 2 is a search good.

To infer the quality of good 1, consumers use the firms behavior in the two search good case as a guideline for formulating a signal. From the comparative static result listed as equation (7) above, consumers infer the following relationship:

$$Q_1 = f(X_2), f'(X_2) < 0.$$
 (8)

Thus, consumers will choose a signal for the quality of good 1,  $Q_1^*$ , which is a function of  $X_2$ . This signal is assumed to be of the following form

$$Q_{1*} = k - zX_2, \quad k, z > 0.^6$$
 (9)

Substituting equation (9) into equation (1) yields the relevant reputation revenue for good 1:

$$\mathbf{R}_{1}^{*} = [\alpha_{1} + \beta_{1}(\mathbf{Q}_{1} - \mathbf{Q}_{1}^{*})]\mathbf{X}_{1}.$$
(10)

Note that because good 2 is still a search good,  $R_2 = \alpha_2 X_2$  as before. Substituting these relationships into equation (3) gives the new lagrangian, L<sup>\*</sup>:<sup>7</sup>

$$L^{*} = (a_{1}-b_{1}X_{1}+e_{1}Q_{1}^{*})X_{1} + (a_{2}-b_{2}X_{2}+e_{2}Q_{2})X_{2} + R_{1}^{*} + \alpha_{2}X_{2}$$

$$- c_{1}X_{1} - c_{2}X_{2} + V(X-X_{1}-X_{2}).$$
(11)

The relevant first order conditions are

$$L_{X1}^{*} = (a_1 - 2b_1X_1 + e_1Q_1^{*}) + [\alpha_1 + \beta_1(Q_1 - Q_1^{*})] - c_1 - V = 0$$
(12)

$$L_{X2}^{*} = (a_2 - 2b_2X_2 + e_2Q_2) + \beta_1 z X_1 - e_1 z X_1 + \alpha_2 - c_2 - V = 0$$
(13)

$$L_{V}^{*} = X - X_{1} - X_{2} = 0.$$
(14)

Totally differentiating equations (12), (13) and (14), one finds the comparative static result

$$\frac{\mathrm{dX}_2}{\mathrm{dQ}_1} = \frac{-\hat{\mathrm{S}}_1}{|\Omega^*|} < 0 , \ |\Omega^*| > 0.^8$$
(15)

This equation indicates that for any firm there is, in equilibrium, a negative relationship between the quality of the experience good and the quantity of the search good. The profit maximizing behavior of the firm confirms consumers initial belief in such a relationship.

In other words, consumers' beliefs are self-confirming -- an exogenous increase in the actual quality of the experience good,  $Q_1$ , leads the firm to decrease the quantity of the

search good sold (or equivalently, to increase the price of the search good). Furthermore, this comparative static result indicates that it is not in the firm's interest to arbitrarily adjust quantity and price in the absence of a change in quality. That is, the firm cannot gain by trying to fool consumers by such adjustments.

These first order conditions can also be compared to those for the two search good case (equations (5) and (6)). Solving each set of equations for the optimal quality of good 2, one can show that quantity is larger in the jointly produced two search good case than when a firm jointly produces an experience good and a search good.

This latter provides an avenue for empirical testing this signaling model. That is, if such signaling is occurring, one would expect to find, ceteris paribus, firms pricing good 2 higher when it is produced jointly with an experience good, than when good 2 is produced in isolation or with another search good.

#### **III.** Some Preliminary Evidence

The theory presented above can be applied to the market for gasoline and automobile repairs. Gasoline stations use a common input, labor, to jointly produce full service gasoline, self service gasoline (search goods) and automobile repairs (an experience good). Service bay workers are sometimes called away from repair work to pump gasoline and collect money at the cash register. If consumers use the price of gasoline as a signal of the quality of the repair work, then, according to theory presented above, the price of gasoline should be higher at stations with repair bays than at stations without repair bays.

A recent study of the 1974 station divorcement law in the state of Maryland by Barron and Umbeck [1985] provides evidence in support of this hypothesis. Barron and Umbeck estimate the impact of this law on the prices of full service and self service gasoline. The above model predicts that if signaling is taking place, the price of gasoline will be higher when it is produced jointly with automobile repairs, than when it is produced in isolation. This implication is directly confirmed by Barron and Umbeck's estimates. They find the presence of a service bay increases the price of full service gasoline by approximately 2.95 cents with a t-statistic of ll.91 (adj R-sq.=.45). The presence of a service bay also increases the price of self-serve gasoline by 1.31 cents with t-statistic of 5.96 (adj. R-sq.=.16).

#### **IV.** Summary

The relationship between product quality, signals, and the firm's optimal pricing policy has been given much attention in Economics. This literature is extended in this paper by considering the signaling problem of a firm that jointly produces two commodities -- one of known quality to consumers (a search good) and one of unknown quality (an experience good).

The model presented employs a stylized reputation function, a linear cost structure, and linear demand schedules to produce two interesting insights. First, the search good's price can be potentially used as a signal of the quality of the experience good. Second, the price of a search good will depend upon whether it is jointly produced with another search good, with an experience good, or whether it is produced in isolation by a single product firm. Furthermore, evidence from a paper on gasoline pricing seems to support this contention.

#### FOOTNOTES

1 Some goods are search goods for some purchasers, but are experience goods for others. For example, a diamond may be a search good for a gemologist, but is probably an experience good for most purchasers. Similarly, dresses, computers and dishwashers may be search goods for some, but not all, purchasers.

2 In Spence's seminal article [1973] on applicant signaling, the firm uses the education level of the worker as a signal of the worker's innate abilities (an experience good). Similarly, Frank [1985] suggests that an employer may wish to use observable consumer purchases (suits, cars, *et cetera*) of prospective workers to signal their productivity. Finally, Nelson [1970, 1974] and Milgrom and Roberts [1986] show that uninformative advertising is positively correlated to product quality for those firms which produce a single experience good.

3 The last three assumptions assure that the demands for each firm's products are the same except for quality differences.

4 This constant one to one tradeoff is not necessary to the results of this paper. It was obviously chosen for mathematical convenience. Any linear constraint will do.

5 For convenience the analysis is done with respect to quantity. The signs are just changed in the case of price. While consumers will find it easier to observe price, rather than quantity, using quantity does not affect any of the conclusions.

6 It is not necessary that consumers know the exact relationship between the quality of the experience good and the quantity (price) of the search good, only that such a relationship

like equation (9) exists. A rational consumer would then estimate equation (9) empirically from his past observations of firms which jointly produce two search goods.

7 Firms realize, of course, that consumers are rational and use a variation of equation (9) to formulate their signal. Thus, they must take this consumer behavior into account when solving their maximization problem.

8 Note that  $\Omega^*$  is the Bordered Hessian matrix for the revised maximization problem. It is assumed that the second order conditions hold and thus the sign of the Bordered Hessian will be positive.

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