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Quality Competition, Welfare, and Regulation

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In this paper, we study the supply of quality in imperfectly competitive markets, and explore the role of regulation in markets where firms may use both quality and price to compete for customers. In a model where firms first choose qualities and then prices, we find that quality decisions have strategic effects: firms react to quality disadvantages by price reductions. Because of this strategic effect, firms do not have the correct incentive to set socially efficient quality levels. Price and quality competition results in a socially suboptimal quality level. Efficiency can be restored by lump-sum transfers and price regulatory policies. Simple price regulation may result in lower price and higher quality.

1. Introduction

In this paper, we study price regulation and the supply of quality in imperfectly competitive markets. We explore the role of regulation in markets where firms may use both quality and price to compete for customers. It is well-known that the market cannot be relied upon to supply a socially efficient quality level in general. Spence (1975) made this point very clearly. According to Spence, the source of "market failure" is the divergence between consumers' marginal and average valuations of quality. A profit-maximizing firm will choose a quality

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level that equates the marginal cost of quality and the marginal revenue of quality, which is the marginal valuation of quality by the marginal consumer multiplied by the quantity. But the social surplus-maximizing quality level equates the marginal cost of quality and the total valuation of quality by all consumers.[1] Depending on the difference between consumers' marginal and average valuations, the supply of quality may be higher or lower than the social optimum.

Spence's analysis was conducted with a monopoly model; his results are also robust with respect to other market structures. It remains, however, an open question whether the factor Spence identified is the only source of inefficiency. More precisely, does a monopoly structure allow for the study of other relevant aspects of efficiency properties of market quality? In this paper, we identify another source of market inefficiency when firms *compete* for consumers by setting prices and qualities.

In the basic competitive model, firms first choose quality levels, and then compete in prices. To isolate the strategic effect of quality choices, we use linear demand functions in the analysis. Consequently, consumers' marginal and average valuations of quality are always equal; the Spence effect is therefore eliminated. Nevertheless, we show that when products with higher quality can be produced with higher fixed costs (regardless of whether higher quality requires higher marginal cost), the market quality level is still inefficient; in particular, the equilibrium quality is *below* the social optimum. Alternatively, if higher quality products require higher *marginal* production costs *exclusively*, then the equilibrium quality becomes efficient.

These findings can be explained by the following two basic effects. First, in the price competition subgame, a firm with a lower quality product will set a lower price in order to compensate for its otherwise lower market share. This "price undercutting" effect tends to depress the returns to quality investment: a firm is deterred from adopting a higher quality level at the first stage for fear of more intense price

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[1] More formally, let Q denote quantity, T quality; $P(Q, T)$ is the demand function, and $C(Q, T)$ is the cost of producing Q at quality T. Profit maximization implies $Q(\partial P/\partial T) = \partial C/\partial T$. Social surplus (consumer surplus less cost of production) maximization implies $\int(\partial P/\partial T)\,\mathrm{d}Q = \partial C/\partial T$. The two maximization programs yield identical first order conditions only if the cross partial derivatives of P with respect to Q and T are zero, which is to say that consumers' marginal and average valuations of quality are always equal. This fundamental failure is analogous to the inefficient outcome that occurs in the market provision of a public good: quality of a good benefits all consumers and there is no separate price for quality.

competition from the rival at the second stage. But there is also a second counter-effect: in the price competition subgame, a firm with a higher *marginal* cost will compete at a disadvantage, and therefore can expect its opponent to set a higher price — an "increased marginal cost" effect.

In general, a firm may incur both higher fixed and marginal costs to produce higher quality products. Then the overall price reaction from its opponent is a combination of both effects; that is, a firm will react by setting a lower price if its "quality–marginal cost differential" is lower than that of its rival's. While the increased marginal cost effect is capable of balancing the price undercutting effect with respect to the part of quality investment requiring higher marginal cost, it is ineffective with respect to the component requiring higher fixed cost. Hence, whenever high product quality can be brought about by incurring higher fixed costs, the equilibrium quality becomes suboptimal. On the other hand, when higher quality requires higher marginal costs alone, or alternatively, when higher fixed cost cannot contribute to higher quality, the second effect exactly matches the first, and the corresponding equilibrium allocation yields a socially efficient quality level.

In the basic competitive model, qualities are chosen first and prices later. This sequential methodology is probably suitable for most applications; since quality choices usually involve technological decisions, it is natural to assume that quality is less flexible and less frequently changed than price. But to make our point about the strategic effect of quality even more effectively, we also consider a version of the competitive model where qualities are assumed to be chosen concurrently with prices. We find that equilibrium qualities then become efficient! The reason for this result is that when qualities are chosen simultaneously with prices, firms can neither use quality choices to influence pricing decisions nor use price decisions to react against quality choices of rivals. With the absence of the Spence effect due to linear demand functions, and the correct market shares for each firm, the market can yield the socially optimal quality level.

Our work is related to the vertical product differentiation literature (Shaked and Sutton, 1982, 1983). The main result in this literature says that firms will tend to develop different quality levels in order to relax Bertrand competition. Market equilibria are characterized by a finite number of (active) firms, each choosing a different quality level. In models with vertical product differentiation, consumers have identical preferences over quality. If firms choose identical qualities, Bertrand competition implies that prices equal marginal cost; firms may earn zero profits. Thus firms have incentives to choose different quality levels, thereby segmenting the market.

Our model incorporates both horizontal and vertical product differentiations. We present an effect that acts in reverse of the Shaked–Sutton result. Because of (exogenous) horizontal product differentiation, firms in our model do not have to relax Bertrand competition through vertical product differentiation. In fact, any attempt by a firm to differentiate its product will lead to price cuts from the rival firm, which eliminates the demand enhancing effect of an increase in quality. Whereas, in Shaked and Sutton, qualities that are too similar lead to more intense price competition, in our model qualities that are too dissimilar lead to more intense price competition.

In our model, qualities have strategic effects on price competitions. It appears that this strategic effect is comparable to the strategic commitment effect in research and development noted by Brander and Spencer (1983). In their model firms undertake R&D in the first stage and then engage in a Cournot quantity competition subgame in the second; besides reducing cost of production, costly R&D adopted by a firm also enhances its revenue (holding quantities fixed). Brander and Spencer show that firms overinvest in R&D and do not minimize the overall cost of production in a symmetric equilibrium. In contrast, firms in our model underinvest in qualities. In our framework, the strategic interdependence between quality and price seems even stronger, since the quality level chosen by a firm is a determinant of its rival's demand.

With our analysis of competitive allocations, we then consider regulation. Our focus differs from that of most papers in the regulation literature. First, we study regulation in an environment where firms still can use quality as a strategic instrument to compete for customers in the regulation regime. Second, unlike most regulation models where the regulated firm is a monopoly or a public enterprise, we compare the allocation under regulation with that under competition.

Our addition to the potential role for regulation rests precisely on the undesirable effect of quality choice on price competition. With prices being fixed by the regulator, firms can choose only quality to attract consumers. Most important, with prices being imposed upon them, firms lack the incentive to use quality to influence the outcome of price competition. The elimination of price competition thus helps to correct the distorting effect of quality competition. When price and lump-sum transfer policies are feasible, optimal regulation leads to the socially efficient allocation. Price regulation alone may generate lower equilibrium prices and higher equilibrium qualities as compared with equilibrium firm decisions in the quality–price competition regime.

The paper is organized as follows. The model is defined in the next section. The equilibria of the quality–price competitive game are derived in Sect. 3. Next, in Sect. 4, we study optimal price regulation; the allocation under optimal regulation will be compared to the competitive equilibria. Illustrative examples and discussion are in Sect. 5.

2. The Model

In this section, we define the model and the regulatory environment. There are two firms, A and B; they produce differentiated products. Throughout the paper, we use a symmetric model where firms have identical technological and cost structures. We assume that the capacity of each firm is sufficient to meet demands. The total cost of producing a quantity Q at quality T is $\theta(T)Q + \phi(T)$, where $\theta(T)$ represents the (constant) unit cost of the good at quality T, and $\phi(T)$, a fixed cost of quality. We normalize the functions θ and ϕ so that $\theta(0) = \phi(0) = 0$; further assumptions on θ and ϕ will be discussed shortly. In most applications, a higher quality product requires either a higher unit or marginal cost, a higher startup or fixed cost, or both. Here, we assume that higher quality results from higher marginal *and* fixed costs; this is a simplifying assumption and can be easily relaxed — see the discussion following Proposition 1.

There is a continuum of consumers; each of them values the good sufficiently highly to buy one unit from a firm. Consumers have preferences on two dimensions of product characteristics. First, a consumer always prefers a higher quality, T. Second, besides the quality (T) of the good, each consumer also has some other "ideal" product characteristic, unique to himself, as in a standard Hotelling spatial model. Thus our model incorporates both vertical and horizontal product differentiations. More precisely, consumers are assumed uniformly distributed on a "line" of length ℓ, with a firm being located at each end of the line. The total density of consumers is μ. Firm A (resp. B) is located at position 0 (resp. ℓ). The distance between a consumer and a firm represents the deviation of the firm's product characteristic from the consumer's ideal. A consumer with index x, where $0 \leq x \leq \ell$, has to cover distance x to Firm A or distance $(\ell - x)$ to Firm B. A consumer's utility depends positively on the quality of the good from a firm and negatively on the distance he has to travel to the firm and the price. Suppose Firms A and B offer qualities T_{A} and T_{B}, and charge prices P_{A} and P_{B}, respectively, then a consumer with index x will have utility $T_{\mathrm{A}} - cx - P_{\mathrm{A}}$ if he buys from Firm A, and $T_{\mathrm{B}} - c(\ell - x) - P_{\mathrm{B}}$ if from Firm B, where $c > 0$ is a parameter that can be thought of as the unit cost of transportation. A consumer is assumed to buy from the firm that offers him the higher utility. In this paper, we do not consider firms' location choices.

Demand functions can be derived straightforwardly. If T_A and T_B are the firms' qualities, and P_A and P_B are the firms' prices, then demand functions of Firms A and B, respectively $Q^A(T_A, T_B, P_A, P_B)$ and $Q^B(T_A, T_B, P_A, P_B)$, are:

$$Q^A(T_A, T_B, P_A, P_B) = \tag{1}$$
$$= \begin{cases} \mu & T_A - P_A - T_B + P_B > c\ell \\ \mu \frac{c\ell + T_A - P_A - T_B + P_B}{2c\ell} & |T_A - P_A - T_B + P_B| \leq c\ell \\ 0 & T_B - P_B - T_A + P_A > c\ell \end{cases} ,$$

$$Q^B(T_A, T_B, P_A, P_B) = \mu - Q^A(T_A, T_B, P_A, P_B) . \tag{2}$$

For future use, for $|T_A - P_A - T_B + P_B| \leq c\ell$, let us define

$$Y(T_A, T_B, P_A, P_B) = \frac{\ell}{2} + \frac{T_A - P_A - T_B + P_B}{2c} . \tag{3}$$

The term $Y(T_A, T_B, P_A, P_B)$ denotes the index (location) of the consumer who is just indifferent between buying from Firms A and B given their qualities, T_A and T_B, and prices, P_A and P_B. Notice that demand functions in our models actually describe the distribution of market shares among the two firms.

In the competitive models, both prices and qualities are set by firms. Given their prices, P_A and P_B, and qualities, T_A and T_B, firms' profit functions are

$$\Pi^A = (P_A - \theta(T_A))Q^A(T_A, T_B, P_A, P_B) - \phi(T_A) , \tag{4}$$
$$\Pi^B = (P_B - \theta(T_B))Q^B(T_A, T_B, P_A, P_B) - \phi(T_B) . \tag{5}$$

Let us now write down assumptions on ϕ, the firm's quality cost function:

(i) The function θ is increasing, convex, and satisfies $\lim_{T \to 0} \theta'(T) = 0$;
(ii) the function ϕ is increasing, convex, and satisfies $\lim_{T \to 0} \phi'(T) = 0$, and $\lim_{T \to c\ell} \phi(T) = \infty$;
(iii) the function ϕ is three times differentiable, with $\phi''' > 0$ for all T.

Thus, higher product quality requires higher marginal and fixed costs. These assumptions also ensure that in equilibrium both firms will operate. To see this, suppose not; that is, suppose that in an equilibrium Firm B captures the entire market. From (ii), we know that Firm B never chooses a quality level above $c\ell$. Then Firm A will earn positive profit by setting a price equal to that of Firm B's, and setting a strictly positive and arbitrarily small quality level. With $P_A = P_B$, if $T_A > 0$ and $T_B < c\ell$, then from the demand function (1), Firm A will capture a positive share of the market. Then for sufficiently small T_A, Firm A will earn strictly positive profit. Part (iii), only used in the regulation analysis, says that the function ϕ' is convex.

To establish a benchmark, we write down the socially efficient quality level. For the time being suppose that the regulator can explicitly enforce quality levels and market shares of each firm. Since technology and consumer preferences are symmetric, it is optimal to let each firm serve that half of all consumers who are nearest to it; that is, Firm A will serve consumers located between 0 and 0.5ℓ. As quality is similar to a public good, we obtain the socially efficient quality level for each firm by maximizing the sum of utilities of consumers served by each firm less the cost of quantity and quality provision: $\max\,(T - \theta(T))\mu/2 - \phi(T)$. Hence the efficient quality level, T^S, is given by

$$\theta'(T^S) + \phi'(T^S)\frac{2}{\mu} = 1\ .$$

3. Quality and Price Competition

In this section, we study the equilibrium allocations under quality and price competition. We begin by looking at a model where firms simultaneously choose qualities in the first stage, and then simultaneously choose prices in the second stage, a standard setup in quality and product differentiation models in the literature.

Consider the second stage, the price competition subgame, defined by Firms A and B's quality levels in stage one, respectively T_A and T_B. Because in equilibrium each firm obtains a positive market share, we look at the first order derivatives of the profit functions with respect to prices when demands are given by the middle part of (1):

$$\frac{d\Pi^A}{dP_A} = \left\{\frac{\ell}{2} + \frac{T_A - P_A - T_B + P_B}{2c}\right\}\frac{\mu}{\ell} - [P_A - \theta(T_A)]\frac{\mu}{2c\ell}\,, \quad (6)$$

$$\frac{d\Pi^B}{dP_B} = \left\{\frac{\ell}{2} - \frac{T_A - P_A - T_B + P_B}{2c}\right\}\frac{\mu}{\ell} - [P_B - \theta(T_B)]\frac{\mu}{2c\ell}\,. \quad (7)$$

The second order derivatives with respect to prices are negative. Price reaction functions are obtained by setting the first order derivatives above to zero. It is easy to see that these reaction functions are linear and intersect in the positive quadrant. The unique equilibrium prices are obtained by solving the reaction functions simultaneously for P_A and P_B:

$$P_A(T_A, T_B) = c\ell + \frac{T_A - T_B}{3} + \frac{2\theta(T_A) + \theta(T_B)}{3}, \tag{8}$$

$$P_B(T_A, T_B) = c\ell + \frac{T_B - T_A}{3} + \frac{2\theta(T_B) + \theta(T_A)}{3}. \tag{9}$$

In fact, the equilibrium price strategies in (8) and (9) describe *two* fundamental effects of quality choices on price competition. The first is a "price undercutting" effect. Suppose that $T_A < T_B$, so that Firm A has invested less in quality than has Firm B. Then the *second* term in the right hand side of (8) says that Firm A will set a price lower than Firm B's in the price subgame. Firm A attempts to make up for its lower quality by reducing price. Even though Firm B has a higher quality product and hence should gain a larger share of the market, its quality superiority is counteracted by Firm A's price cutting reaction.

The second is an "increased marginal cost" effect that tends to work against the first. Still with $T_A < T_B$, the *last* term in the right hand side of (8) says that the higher is Firm B's marginal cost of producing the better quality product, the higher Firm A sets its equilibrium price. Because Firm B's higher quality product can only be produced at a higher marginal cost, its advantage over Firm A is reduced. Thus, Firm A's need to cut its own price to make up for the loss of market share is mitigated.

The same effects can be illustrated alternatively if we rewrite the above equilibrium prices in terms of price–cost margins:

$$P_A(T_A, T_B) - \theta(T_A) = c\ell + \frac{[T_A - \theta(T_A)] - [T_B - \theta(T_B)]}{3}, \tag{10}$$

$$P_B(T_A, T_B) - \theta(T_B) = c\ell + \frac{[T_B - \theta(T_B)] - [T_A - \theta(T_A)]}{3}. \tag{11}$$

Thus, a firm's equilibrium price–cost margin is positively related to the discrepancy between its own quality–marginal cost differential and that of its rival.

Clearly, if higher product quality results from higher marginal costs alone, then the second, increased marginal cost effect will tend to balance off the price undercutting effect. If, however, higher product quality also requires an increase in fixed costs, then the price undercutting effect will tend to depress the return to quality investment. Because the equilibrium in the price-subgame is determined independently of the levels of fixed cost, the increased marginal cost effect is incapable of influencing the fixed cost decisions. Thus, the price undercutting effect on fixed cost choices will not be counteracted. We now characterize equilibrium quality.

Assuming that demand is given by the middle part of (1) and that P_A and P_B are given by (8) and (9) [or by (10) and (11)], we obtain Firm A's profit function in terms of T_A and T_B:

$$\Pi^A = \frac{\mu}{18c\ell}\left\{3c\ell + [T_A - \theta(T_A)] - [T_B - \theta(T_B)]\right\}^2 - \phi(T_A) .$$

In general, the profit function Π^A is not concave with respect to T_A; nevertheless, the appropriate first order conditions still will be necessary at an equilibrium.

Differentiating the above profit function of Firm A with respect to T_A, we obtain:

$$\begin{aligned} &\frac{d\Pi^A}{dT_A} = \\ &= \frac{\mu}{9c\ell}[1 - \theta'(T_A)]\left\{3c\ell + [T_A - \theta(T_A)] - [T_B - \theta(T_B)]\right\} - \phi'(T_A) . \end{aligned} \tag{12}$$

By interchanging the indexes A and B, we obtain a similar expression for the first order derivative of Firm B's profit function with respect to T_B. Observe that in equilibrium, $1 - \theta'(T) \geq 0$; otherwise (12) will be strictly negative. Setting these first order derivatives to zero, we have:

$$\begin{aligned} &[1 - \theta'(T_A)]\left\{3c\ell + [T_A - \theta(T_A)] - [T_B - \theta(T_B)]\right\} = \\ &= \frac{9c\ell}{\mu}\phi'(T_A) , \end{aligned} \tag{13}$$

$$\begin{aligned} &[1 - \theta'(T_B)]\left\{3c\ell + [T_B - \theta(T_B)] - [T_A - \theta(T_A)]\right\} = \\ &= \frac{9c\ell}{\mu}\phi'(T_B) . \end{aligned} \tag{14}$$

We first argue that any T_A and T_B fulfilling the above must satisfy $T_A = T_B$. Suppose there is an asymmetric equilibrium, and, without loss of generality, let $T_A = T$ and $T_B = T - d$, where $d > 0$. After simplifying and taking the difference between (13) and (14) we obtain

$$2\theta(T-d) - 2\theta(T) = \frac{9c\ell}{\mu}\left\{\frac{\phi'(T)}{1-\theta'(T)} - \frac{\phi'(T-d)}{1-\theta'(T-d)}\right\} .$$

The left hand side of the above equation is negative, since $d > 0$. With $1 - \theta'(T) \geq 0$ (a necessary condition for an equilibrium), $\phi'(T)/(1-\theta'(T))$ has a positive derivative with respect to T, and hence the right hand side must be positive. So the above equation cannot hold if $d > 0$. Therefore, any equilibrium quality can be obtained by setting $T_A = T_B$ in either (13) or (14). The equilibrium price can be obtained from either (10) or (11).

Proposition 1: In the game in which firms simultaneously choose qualities in stage one and prices in stage two, the subgame-perfect equilibrium price P^α and quality T^α are given by

$$P^\alpha = c\ell + \theta(T^\alpha) , \tag{15}$$

$$\theta'(T^\alpha) + \frac{3}{\mu}\phi'(T^\alpha) = 1 . \tag{16}$$

Comparing T^S and T^α, we see that the equilibrium quality level is smaller than the social optimum; Fig. 1 illustrates the determination of T^S and T^α. Observe that the inefficiency of T^α is entirely due to the fixed cost component of producing high quality. If the function ϕ were set to zero, then T^S and T^α would be identical. When only higher marginal costs are required to produce high quality, then the price undercutting and increased marginal cost effects exactly match each other. The price undercutting effect, however, is detrimental to the incentives for providing quality through increased fixed costs.

The inefficiency result in Proposition 1 holds more generally. Consider a model in which product quality can be enhanced by either higher marginal costs, higher fixed costs, or both. Suppose a firm's product quality is a sum of two parts, T_1 and T_2. Each firm can increase T_1 by adopting a production process with a higher marginal cost, and T_2 by one with a higher fixed cost. The total cost of producing Q units of the good at quality $T = T_1 + T_2$ becomes $\theta(T_1)Q + \phi(T_2)$. Thus, a firm in this version of the model chooses both marginal and fixed costs to determine the product quality. The socially efficient quality

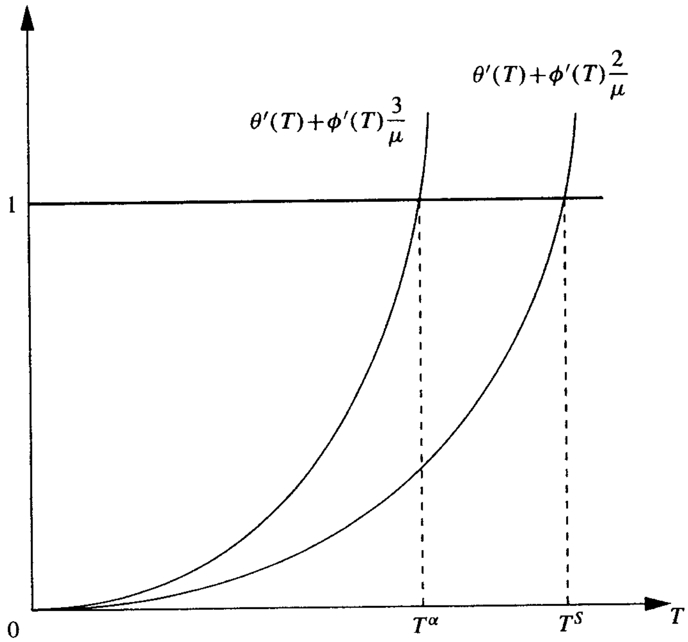

Fig. 1: Equilibrium and efficient qualities

level, T^S, can be derived easily: $T^S = T_1^S + T_2^S$, where $1 = \theta'(T_1^S)$ and $\mu/2 = \phi(T_2^S)$.

With this more general structure, the second-stage price competition equilibrium can be obtained as in (8) and (9). Using a similar method, one can derive the equilibrium qualities. Again, the price undercutting effect tends to suppress the return of fixed-cost quality investment. But the same effect is opposed by the increased marginal cost effect so that the quality investment from higher marginal costs remains socially efficient. It is straightforward to verify that the equilibrium quality is $T^{\alpha} = T_1^{\alpha} + T_2^{\alpha}$, where $1 = \theta'(T_1^{\alpha})$, and $\mu/3 = \phi'(T_2^{\alpha})$. ($T_1^{\alpha}$ and T_2^{α} correspond to the part of quality originating from higher marginal and fixed costs, respectively.) Thus, the price undercutting effect reduces the equilibrium supply of quality through increased fixed costs: $T_2^{\alpha} < T_2^S$; however, its effect on the equilibrium supply of quality through increased marginal cost is nullified: T_1^{α} equals T_1^S.

Firms in our model enjoy some market power from product differentiation and hence equilibrium prices are above marginal costs. One might suspect that the suboptimal equilibrium quality level is due to the excessive equilibrium price. But this suspicion is incorrect: the next version of the model yields an equilibrium in which quality is optimal even when prices are above marginal costs. The suboptimal equilibrium quality in Proposition 1 is clearly a result of the strategic effect of quality on price.

Let us return to our original cost function: $\theta(T)Q + \phi(T)$, and suppose that prices and qualities are chosen simultaneously by firms. That is, suppose that stages one and two in the previous game are merged; each firm chooses two strategic instruments simultaneously. The first order derivatives with respect to prices are still given by (6) and (7). Quality decisions, however, no longer have effects on price choices through (8) and (9). The first order derivatives of the firms' profit functions with respect to qualities are

$$\begin{aligned}\frac{\mathrm{d}\Pi^{\mathrm{A}}}{\mathrm{d}T_{\mathrm{A}}} &= [P_{\mathrm{A}} - \theta(T_{\mathrm{A}})]\frac{\mu}{2c\ell} - \\ &\quad - \theta'(T_{\mathrm{A}})\left\{\frac{\ell}{2} + \frac{T_{\mathrm{A}} - P_{\mathrm{A}} - T_{\mathrm{B}} + P_{\mathrm{B}}}{2c}\right\}\frac{\mu}{\ell} - \phi'(T_{\mathrm{A}})\ ,\end{aligned} \tag{17}$$

$$\begin{aligned}\frac{\mathrm{d}\Pi^{\mathrm{B}}}{\mathrm{d}T_{\mathrm{B}}} &= [P_{\mathrm{B}} - \theta(T_{\mathrm{B}})]\frac{\mu}{2c\ell} - \\ &\quad - \theta'(T_{\mathrm{B}})\left\{\frac{\ell}{2} + \frac{T_{\mathrm{B}} - P_{\mathrm{B}} - T_{\mathrm{A}} + P_{\mathrm{A}}}{2c}\right\}\frac{\mu}{\ell} - \phi'(T_{\mathrm{B}})\ .\end{aligned} \tag{18}$$

Any equilibrium will satisfy the first order conditions obtained by setting (6), (7), (17), and (18) to zero; by symmetry, in equilibrium firms adopt identical strategies. So we derive the equilibrium price and quality, P^{β} and T^{β}, by first setting $T_{\mathrm{A}} = T_{\mathrm{B}}$, $P_{\mathrm{A}} = P_{\mathrm{B}}$, and then solving the equations obtained from setting (6) and (17) to zero.

Proposition 2: In the game in which firms choose price and quality simultaneously, the equilibrium price P^{β} and quality T^{β} are given by

$$P^{\beta} = c\ell + \theta(T^{\beta})\ , \tag{19}$$

$$\theta'(T^{\alpha}) + \frac{2}{\mu}\phi'(T^{\alpha}) = 1\ . \tag{20}$$

The equilibrium price–cost margins in the two competitive models are identical. But the equilibrium quality level when qualities and prices are chosen together, T^{β}, is higher; in fact it is equal to the social optimum T^{S}. The "Spence" distortion stemming from non-separable price–quality demand functions as well as price reaction effects in the sequential model are absent. Hence, conditional on its market share, a firm's quality investment is efficient. Also, in equilibrium firms share the market equally, so each firm's equilibrium market share is identical to the socially efficient share. Therefore, each firm's equilibrium quality investment must be socially efficient.

4. Optimal Regulatory Policies

In this section, we analyze regulatory policies and compare the equilibrium allocation under regulation with that under competition; the competitive benchmark is the sequential model where qualities are chosen in stage one and prices in stage two. Regulatory policies potentially may achieve two goals in the context of our model. First, strategic effects of quality on the determination of equilibrium price cause the market to fail to deliver the socially optimal product quality. As a result one regulatory objective is to restore the supply of efficient quality. Second, because firms enjoy market power, they charge prices strictly above marginal costs, earning strictly positive profits in an equilibrium. Therefore, if the regulator weighs consumer surplus more than industry profits, the second regulatory objective is the elimination of these excessive profits.

In general, we allow the regulator to use two-part tariffs on both firms; a regulatory policy on a firm consists of a lump-sum transfer from the regulator, and a price set on the firm's product. Later, we also consider simple price regulations; in this regime, transfers are set at zero. Formally, we study the following two stage regulation game. In stage one, the regulator sets policies $(F_{\mathrm{A}}, P_{\mathrm{A}})$ and $(F_{\mathrm{B}}, P_{\mathrm{B}})$ for the two firms, where F_i and P_i denote the transfer and product price for Firm i, $i = \mathrm{A}, \mathrm{B}$. In stage two (with transfers and prices given), firms simultaneously choose qualities to compete for consumers. Then each consumer buys a unit of the good from his preferred firm, with firms' demand functions being determined by (1) and (2).

It is assumed that the regulator maximizes a weighted sum of total consumers' utility less the total transfers to firms, and industry profits, with a relatively higher weight on consumers' utility less transfers. Since consumers' utility functions are separable in money, this preference specification is identical to one in which the regulator maximizes a weighted sum of consumer surplus and industry profits.

Consider the policies $(F_{\mathrm{A}}, P_{\mathrm{A}})$ and $(F_{\mathrm{B}}, P_{\mathrm{B}})$. Suppose consumers with indices between 0 and Y buy from Firm A, and the remaining consumers from Firm B. Then total consumers' utility less total transfer is

$$\frac{\mu}{\ell}\int_0^Y (T_A - P_A - cx)\,\mathrm{d}x + \frac{\mu}{\ell}\int_Y^\ell (T_B - P_B - c(\ell - x))\,\mathrm{d}x - F_A - F_B\ ,$$

which simplifies to

$$\frac{\mu}{\ell}\left\{Y(T_A - P_A) + (\ell - Y)(T_B - P_B) - [Y^2 - (\ell - Y)^2]\frac{c}{2}\right\} - \\ - F_A - F_B \equiv U\ . \tag{21}$$

Profits at Firms A and B are

$$\Pi^A = (P_A - \theta(T_A))\frac{Y\mu}{\ell} + F_A - \phi(T_A)\ , \tag{22}$$

$$\Pi^B = (P_B - \theta(T_B))\frac{(\ell - Y)\mu}{\ell} + F_B - \phi(T_B)\ . \tag{23}$$

Let Π denote $\Pi^A + \Pi^B$. Hence, the regulator's objective function can be written as $U + \lambda\Pi$, where $\lambda < 1$. This objective function can also be rewritten in terms of social surplus and profits: $U + \lambda\Pi = U + \Pi - (1 - \lambda)\Pi$, and $U + \Pi$ equals social surplus:

$$\frac{\mu}{\ell}\int_0^Y (T_A - \theta(T_A) - cx)\,\mathrm{d}x + \frac{\mu}{\ell}\int_Y^\ell (T_B - \theta(T_B) - c(\ell - x))\,\mathrm{d}x - \\ - \phi(T_A) - \phi(T_B)\ .$$

A policy $\{(F_A, P_A), (F_B, P_B)\}$ implements qualities T_A and T_B from Firms A and B respectively if, given the policy, T_A and T_B are the respective equilibrium qualities of the firms. From the previous section, we know that when firms choose quality and price contemporaneously and simultaneously, the equilibrium quality level will be socially efficient; so the regulator can always implement the socially efficient quality by setting prices equal to the equilibrium prices of that model. That is, set $P_A = P_B = c\ell + \theta(T^S)$. Profits at the firms can be taxed away entirely by setting transfers to $\phi(T^S) - \mu c\ell/2$. It is straightforward to verify that such a policy implements quality T^S at both firms, and that firms earn zero profits. Since $\lambda < 1$, this policy also maximizes the regulator's objective function.

Proposition 3: In the subgame-perfect equilibrium of the regulation game, the regulator sets the following policy: $P_A = P_B = c\ell + \theta(T^S)$, and $F_A = F_B = \phi(T^S) - \mu c\ell/2$. Each firm chooses the socially efficient quality level T^S and earns zero profit.

Thus, when two-part tariffs are feasible regulatory policies, the socially optimal quality will be implemented: the inefficiency resulting from the strategic effect of quality on price competition can be avoided completely. While the socially optimal quality level is always implementable, it will only be implemented if the regulator can tax away firms' profits. When lump-sum transfers are infeasible, implementing the efficient quality level results in a welfare loss in the form of excess profits. Under this circumstance, price regulation without lump-sum transfers will result in a "second-best" allocation. We now turn to optimal price regulation when lump-sum transfers cannot be levied on firms; here on, transfers, F_A and F_B, are set at zero. This case allows us to compare unregulated and regulated equilibria more directly.

For tractability, we make two assumptions. First, we assume that $\theta(T) = 0$, for all T, so that product quality can only be enhanced by investments in fixed costs. Because quality's strategic effect on price competition affects the equilibrium allocation through its influence on fixed-cost components of quality investment, the situation depicted by this assumption presents a *prima facie* case for regulation. Second, we assume that $\lambda = 0$, so that the regulator places no weight on industry profits.

Consider an arbitrary pair of (non-negative) prices (P_A, P_B). Clearly, it is never optimal for the regulator to let a single firm serve the whole market. Hence, in an equilibrium of the regulation model, a firm's demand function must be given by the middle part of (1). By setting $\theta(T) = \theta'(T) = 0$ in (17) and (18), we obtain the first order derivatives when firms maximize profit by choosing qualities:

$$\frac{P_A \mu}{2c\ell} - \phi'(T_A) = 0 \,, \tag{24}$$

$$\frac{P_B \mu}{2c\ell} - \phi'(T_B) = 0 \,. \tag{25}$$

Since ϕ is strictly convex, (24) and (25) are necessary and sufficient for profit maximization given arbitrary P_A and P_B. Also, the solutions of (24) and (25) are unique. Hence, given arbitrary P_A and P_B, (24) and (25) determine the unique equilibrium in the quality competitive subgame between firms. Hence, a pair of prices (P_A, P_B) implements (T_A, T_B) if and only if P_A, P_B, T_A, and T_B satisfy (24) and (25).

The regulator maximizes her utility by choosing prices P_A and P_B, taking into account their effects on firms' quality choices, T_A and T_B, which in turn influence consumers' selections of firms. Formally, the regulator chooses P_A, P_B, T_A, and T_B to maximize (21) subject to (24), (25), and (3). Substituting (24) and (25) into (21) and (3) to eliminate P_A and P_B, we can restate the regulator's problem as the maximization of

$$\frac{\mu}{\ell}\left\{Y\left[T_A - \frac{2c\ell}{\mu}\phi'(T_A)\right] + (\ell - Y)\left[T_B - \frac{2c\ell}{\mu}\phi'(T_B)\right] - \right.$$
$$\left. - [Y^2 + (\ell - Y)^2]\frac{c}{2}\right\} \tag{26}$$

subject to

$$Y = \frac{\ell}{2} + \frac{T_A - T_B}{2c} - [\phi'(T_A) - \phi'(T_B)]\frac{\lambda}{\mu} . \tag{27}$$

One can think of the regulator's decision being taken in two steps. First, for fixed quality levels T_A and T_B, the regulator finds the prices that implement them. This corresponds to using (24) and (25) to eliminate P_A and P_B in (21) and (3). Then the regulator chooses the quality levels that maximize her utility, which corresponds to choosing T_A and T_B to maximize (26) subject to (27).

Proposition 4: In the subgame-perfect equilibrium of the price regulation game, the equilibrium quality T^* and regulated price P^* at each firm are given by

$$\phi''(T^*) = \frac{\mu}{2c\ell} , \tag{28}$$

$$P^* = \frac{\phi'(T^*)}{\phi''(T^*)} . \tag{29}$$

The proof of this proposition is in the Appendix. In equilibrium the two firms share the market equally, and equilibrium quality is strictly positive. The regulator does not find it optimal to implement the socially optimal quality level T^S by setting prices equal to $c\ell$. The implementation of T^S by simple price policies typically requires allowing the firms to earn positive profits, which leads to a welfare loss. The second-best quality level is determined through the second order derivative of the cost of quality function ϕ. The regulated price depends on the curvature of ϕ.

The equilibrium allocation of the price regulation model can be compared with that of the model where firms choose qualities and prices sequentially. Consider the special case of $\theta(T) = \theta'(T) = 0$ in Proposition 1. Combining the results in Propositions 1 and 4, we have

$$\frac{P^*}{\phi'(T^*)} = \frac{2c\ell}{\mu} < \frac{3c\ell}{\mu} = \frac{P^\alpha}{\phi'(T^\alpha)} . \tag{30}$$

It is possible that $P^* < c\ell = P^\alpha$, but $T^* > T^\alpha$. In this case, a switch from competition to regulation *lowers* price and *raises* quality.

5. Concluding Remarks

The divergence between consumers' marginal and average valuations of quality has previously led Spence to argue that the market cannot be relied upon to produce socially optimal quality levels. But Spence's formal analysis was based on a monopoly model; strategic interaction among firms was not considered. In this paper, we have presented competitive and regulation models in which firms can compete for customers with qualities. In our model, the source of inefficiency Spence discovered is eliminated through the assumption of linear demand functions. In the competitive model where qualities are chosen before price decisions, the equilibrium quality is socially suboptimal. In our analysis, this inefficiency is entirely due to the distorting strategic effect of quality decisions on price competition; indeed, when prices and qualities are chosen concurrently, quality and price competition does generate socially efficient qualities. The strategic effect we identify operates relative to the social optimum in a particular direction; the market quality level tends to be lower. This inefficiency result suggests that price regulation may improve quality levels. Price regulation eliminates the distorting effect of quality on price, and may lead to higher quality without a corresponding increase in price. Furthermore, if, in addition, lump-sum transfers are feasible, full social efficiency can be restored.

In two recent papers, Kamien and Vincent (1991) and Ronnen (1991), respectively, study price and minimum quality regulations. Kamien and Vincent used a model similar to ours, but the price competition subgame has a finite number of stages and consumers are not fully informed about qualities. Also, their discussion on regulatory policies focuses on price ceilings and floors. Ronnen used a pure vertical product differentiation model. He analyzed the effect of minimum quality standards and their welfare effects. Minimum quality standards reduce the extent to which firms can diversify their qualities and may actually reduce prices; as a result all consumers can benefit.

In our model, firms' locations are exogenous. Economides (1989) showed that when firms can also (simultaneously) choose locations, they do differentiate maximally by locating at the two ends of the line. We therefore suggest that results in our paper can be extended to endogenous locations. Entry decisions are not considered in this paper. Nevertheless, results of the paper do not seem to rely on the number of firms in the market. Indeed, equilibrium qualities are socially efficient when firms choose qualities and prices together. When qualities and prices are chosen in stages instead, equilibrium qualities are inefficient. This contrast leads us to believe that the distorting effect of qualities on prices exists independently of the number of firms in the market.

Price regulation and quality competition are potentially important issues in the health and airline industries. Our model can be modified to accommodate insurance in the health industry easily. With health insurance, consumers may base their purchase decisions solely on qualities. In the competitive models, one can interpret that the (price and quality) demand functions represent demands from health maintenance or managed care programs which efficiently pool risk, and which maximize utilities of the members of the programs. In the regulation model, one can assume that consumers are fully insured by the government, which sets prices for the outputs of firms. But consumers are free to choose health care providers based on their qualities. The interested reader is referred to Ma and Burgess (1991) for details. Our result suggests that promoting quality and price competition, a direction that has been advocated by many health care policy makers (Feldstein, 1988), is not unambiguously desirable. Allowing health care providers to compete in both quality and price dimensions need not result in lower prices and higher qualities.

Our model also can be interpreted in the context of airline travel under the regulation and deregulation regimes. Two dimensions of airline travel quality that fit the interpretations in our model are safety and load factors of airplanes. Though consumers may base their purchase decisions more on price than consumers purchasing health care, the concern that the deregulated regime may generate lower qualities is similar. As Panzar and Savage (1989) suggested, policy makers need to be concerned with reduced safety level after deregulation, since airlines can be expected to lower both price and safety standards to compete for business. Furthermore, Graham et al. (1983) reported that the average load factor tends to have increased with the distance of flights after deregulation. We believe that our model provides a useful framework to address these quality issues under price regulation and price competition regimes.

Appendix

We now prove Proposition 4. We begin by showing that in equilibrium the regulator implements an identical quality level for the two firms; that is, when choosing T_A and T_B to maximize (26) subject to (27), the solution must have $T_A = T_B$. First note that (26) and (27) are symmetric in T_A and T_B. Without loss of generality assume that the solution has $T_A \geq T_B$. Furthermore, let us change variables in (26) by putting $T_A = T$ and $T_B = T - d$, $d \geq 0$. Then (21) can be rewritten as (dropping the constant multiplier μ/ℓ):

$$\begin{aligned} &Y(T_A - T_B - P_A + P_B) + \ell(T_B - P_B) - [Y^2 + (\ell - Y)^2]\frac{c}{2} \\ &= Y[2cY - c\ell] + \ell(T_B - P_B) - [Y^2 + (\ell - Y)^2]\frac{c}{2} \\ &= cY^2 - \ell(T_B - P_B) - \frac{c\ell^2}{2} \\ &= cY^2 - \ell\left\{T_B - \frac{2c\ell}{\mu}\phi'(T_B)\right\} - \frac{c\ell^2}{2}\,, \end{aligned}$$

where the first equality follows from the definition of Y, (3). Replacing T_A by T and T_B by $T - d$, we simplify the above expression to:

$$cY^2 - \ell\left\{T - d - \frac{2c\ell}{\mu}\phi'(T - d)\right\} - \frac{c\ell^2}{2} \equiv U\,. \tag{31}$$

Also, (27) becomes

$$Y = \frac{\ell}{2} + \frac{d}{2c} - \frac{\ell}{\mu}[\phi'(T) - \phi'(T - d)]\,. \tag{32}$$

Hence the regulator problem is the maximization of (31) subject to (32).

The first order derivatives of (31) with respect to T and d are

$$\frac{\partial U}{\partial T} = 2cY\frac{\partial Y}{\partial T} - \left\{1 - \frac{2c\ell}{\mu}\phi''(T-d)\right\}\ell\ , \tag{33}$$

$$\frac{\partial U}{\partial d} = 2cY\frac{\partial Y}{\partial d} + \left\{1 - \frac{2c\ell}{\mu}\phi''(T-d)\right\}\ell\ . \tag{34}$$

At a solution to the regulator's problem, the first order derivative of U with respect to T is zero. Hence, from (33), we have

$$2cY\frac{\partial Y}{\partial T} = \left\{1 - \frac{2c\ell}{\mu}\phi''(T-d)\right\}\ell\ . \tag{35}$$

Substituting the above to the right hand side of (34) we have

$$\frac{\partial U}{\partial d} = 2cY\frac{\partial Y}{\partial d} + 2cY\frac{\partial Y}{\partial T}\ . \tag{36}$$

Furthermore, from (32) we have

$$\frac{\partial Y}{\partial T} = -\frac{\ell}{\mu}[\phi''(T) - \phi''(T-d)] \leq 0\ , \tag{37}$$

$$\frac{\partial Y}{\partial d} = \frac{1}{2c} - \frac{\ell}{\mu}\phi''(T-d)\ , \tag{38}$$

where the inequality in (37) follows from the assumptions of $\phi''' > 0$ and $d \geq 0$, and where the inequality is strict whenever $d > 0$.

Substituting (37) and (38) into (36) we obtain

$$\frac{\partial U}{\partial d} = 2cY\left[\frac{1}{2c} - \frac{\ell}{\mu}\phi''(T)\right] = Y\left[1 - \frac{2c\ell}{\mu}\phi''(T)\right]\ . \tag{39}$$

We now claim that (39) is always negative at a solution to the regulator's problem. Suppose not; that is, suppose that (39) is equal to zero and $d > 0$. Then

$$0 = \left[1 - \frac{2c\ell}{\mu}\phi''(T)\right] < \left[1 - \frac{2c\ell}{\mu}\phi''(T-d)\right]\ . \tag{40}$$

From (35) and (37), we have

$$2cY\frac{\partial Y}{\partial T} = \left[1 - \frac{2c\ell}{\mu}\phi''(T-d)\right]\ell < 0 \; .$$

But this inequality contradicts (40). Hence (39) is always negative at a solution, and it follows that $d = 0$.

The expressions for T^* and P^* in the proposition are obtained respectively by putting $d = 0$ in (37) and (35), and from (24).

Q.E.D.

References

Brander, J. A., and Spencer, B. J. (1983): "Strategic Commitment with R&D: The Symmetric Case." *Bell Journal of Economics* 14: 225–235.

Economides, N. (1989): "Quality Variations and Maximal Variety Differentiation." *Regional Science and Urban Economics* 19: 21–29.

Feldstein, P. (1988): *Health Care Economics*. 3rd edn. New York: Wiley.

Graham, D. R., Kaplan, D. P., and Sibley, D. D. (1983): "Efficiency and Competition in the Airline Industry." *Bell Journal of Economics* 14: 118–138.

Kamien, M. I., and Vincent, D. R. (1991): "Price Regulation and Quality of Service." Kellogg Graduate School of Management Discussion Paper No. 920, Northwestern University.

Ma, C.-t. A., and Burgess, J. F., Jr. (1991): "Regulation, Quality Competition, and Price in the Hospital Industry." Boston University Industry Studies Program Discussion Paper, No. 14.

Panzar, J. C., and Savage, I. (1989): "Regulation, Deregulation, and Safety: An Economic Analysis." In *Transportation Safety in an Age of Deregulation*, edited by L. N. Moses and I. Savage. Oxford – New York: Oxford University Press.

Ronnen, U. (1991): "Minimum Quality Standards, Fixed Costs, and Competition." *Rand Journal of Economics* 22: 490–504.

Shaked, A., and Sutton, J. (1982): "Relaxing Price Competition Through Product Differentiation." *Review of Economic Studies* 49: 3–13.

—— (1983): "Natural Oligopolies." *Econometrica* 51: 1469–1483.

Spence, A. M. (1975): "Monopoly, Quality, and Regulation." *Bell Journal of Economics* 6: 417–429.

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