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Reputation and product quality

Franklin Allen*

This article considers the role of reputation in a competitive market where product quality is unobservable. It is shown, among other things, that there can exist equilibria where price is equal to average cost but greater than marginal cost. No firm cuts its price because this would make it more profitable to produce low- rather than high-quality goods; consumers are aware of this and would not buy its products.

1. Introduction

■ With many products it is difficult to observe quality before purchase, and firms have an incentive to sell low quality at high-quality prices. A number of authors have developed theories of reputation which allow this moral hazard to be overcome (Schmalensee, 1978; Smallwood and Conlisk, 1979; von Weizsäcker, 1980; Shapiro, 1982; Dybvig and Spatt, 1983). In a recent article Klein and Leffler (1981) have suggested a competitive model where firms that produce low-quality goods and sell them at high-quality prices acquire a bad reputation and are excluded from the market. Consumers are assumed to behave as if they know the cost functions of firms, and, given the prices charged, they can put themselves in the firm's position and calculate whether the benefit of producing high-quality items and maintaining a good reputation is greater than the cost involved. They are thus able to infer indirectly the quality of goods a profit-maximizing firm produces, even though they cannot directly observe it.

Klein and Leffler show that, provided there is a sufficiently high price premium over and above the price that would obtain if quality were observable (i.e., the minimum average cost), the future stream of profits from producing the high-quality good is usually greater than the one-shot cost savings from producing low quality, and firms will have the correct incentives. This price premium means that if firms can sell all they want at the going price, they will make positive profits. This will not, however, be consistent with the free-entry condition. Klein and Leffler's solution to this is to argue that competition will occur in nonprice dimensions: firms will invest in nonsalvageable firm-specific assets, such as a firm logo or an expensive sign promoting the firm's name, that provide the greatest direct service value to consumers. This type of nonprice competition is perhaps realistic in a number of industries, but in many others it is not: firm-specific investments that increase the service value of products are either not feasible or have the nature of public goods, and are unlikely to cause more purchases.

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Shapiro (1983) has suggested a model without nonprice competition where firms enter the high-quality market by initially selling high-quality goods at the minimum-quality price. The price-quality schedule is such that this initial investment is of just the right size to reconcile the price premium in subsequent periods with the requirement that no firm can enter and increase its wealth.

In the model considered here, nonprice competition of the Klein-Leffler type is not necessarily feasible, and consumers are more sophisticated than in Shapiro's model. Consumers reassure themselves about the high quality of each firm's output by verifying that the price charged and quantity produced are consistent with high quality's being more profitable than low quality. The result of this behavior is that price can be above marginal cost. In such cases a firm does not cut its price and increase output, because this would change its incentives in such a way that its profit-maximizing choice would be low quality: consumers are aware of this and would refuse to buy any of the firm's output at the lower price. The quantity each firm produces, however, is such that average cost is equal to price, so zero profits are earned in every period and no firm can enter and increase its wealth. This contrasts with the equilibrium in Klein and Leffler's model, where price is equal to marginal cost and zero profits are earned every period because of initial investments in firm-specific assets. It also contrasts with Shapiro's model, where the firm makes a loss at the outset and subsequently earns profits which offset this.

The article proceeds as follows. The basic model is described in Section 2. In Section 3 stationary equilibrium is considered. Assuming that consumers can observe a firm's level of output and that warranties are not feasible, we show that there are three possibilities. The first is that equilibrium is unaffected by quality's being unobservable; the second is that equilibrium involves price's being greater than marginal cost as described above, and the third is that no stationary equilibrium exists.

Section 4 considers the effect of relaxing the assumption that firms' levels of output are observable. This does not affect the results except that equilibrium can exist in some circumstances where with observable output it does not.

Section 5 considers the role of warranties. If feasible, full warranties signal quality directly and equilibrium is the same as when quality is observable. In many cases, however, it cannot be established whether a product broke because it was of poor quality, or because it was badly maintained. The effect of this second moral hazard may be that full warranties distort consumers' incentives to look after products. In such cases, only partial warranties will be offered, and reputation will again be important in ensuring that firms produce high quality. Apart from changing the circumstances in which equilibrium exists, the main difference that results from including partial warranties is the possibility that there can be equilibria where price is less than marginal cost. If firms were to cut their output to equate marginal cost with price, their quality incentives would change, and consumers would be unwilling to buy their products.

Finally, Section 6 contains concluding remarks.

2. The model

■ The product market considered is competitive: there is a continuum of identical firms. Time is divided into discrete periods: at the beginning of each, firms make their production decisions, then produce the output, and finally attempt to sell it. All costs and revenues are given in terms of end-of-period dollars. Firms have an infinite horizon. Each firm must pay a fixed cost $I (>0)$, which cannot be recovered, to enter the industry. The costs of producing goods and the quality of the output cannot be directly observed. Initially it is assumed there is no scope for the use of warranties.

If a firm produces no output, it incurs no costs. If a firm produces a positive level of output, it incurs a cost of $f_H(x)$ and $f_L(x)$ for x high (H) and low (L) quality units of

the product, respectively. To allow for the possibility of fixed costs, representing such things as managerial overheads, recoverable investment costs, and so on, we have the following relationship:

$$f_H(0) \geq f_L(0) \geq 0. \quad (1)$$

These fixed costs are only incurred at positive levels of output, and are larger for high quality. The marginal cost of a high-quality good is always greater than that of a low-quality product, and cost functions are increasing and convex:

$$f'_H(x) > f'_L(x), \quad (2)$$

$$f'_q(x) > 0; \quad f''_q(x) > 0 \quad \text{for } q = H, L. \quad (3)$$

Unless otherwise stated, x is observable by consumers.

For simplicity we assume that output cannot be stored. It is then optimal for firms to choose the level of output to be equal to the level of sales. Output and sales are, therefore, not distinguished below.

The rate of interest is r (>0) per period.

There is a continuum of identical consumers. In every period one unit of the product is purchased by each consumer if its price is sufficiently low. Consumers obtain utility $U_q(p)$ from products with quality q , purchased at price p , and utility U_0 if no product is purchased. Utility is decreasing and convex in price:

$$U'_q(p) < 0; \quad U''_q(p) \geq 0. \quad (4)$$

The maximum price consumers are prepared to pay for the high-quality good is p_m :

$$U_H(p_m) = U_0. \quad (5)$$

It is assumed that they are not prepared to pay anything for the low-quality good:

$$U_L(0) < U_0. \quad (6)$$

As in many rational expectations models, consumers are taken to know the structure of the model. We shall see below that this can be considerably relaxed: all they strictly need to know when x is observable is the equilibrium price and quantity and, when x is unobservable, just the equilibrium price.

3. Equilibrium

■ A rational-expectations, Nash-equilibrium concept is used. Each firm chooses its strategy while taking the strategies of other firms and of consumers as given. Consumers act similarly. In equilibrium expectations are fulfilled.

In general, both stationary and nonstationary equilibria may exist. Little can be said, however, about the latter, so attention is focused on stationary equilibria. These equilibria are derived in the following way. Initially, strategies are constrained to be stationary, and the Nash equilibrium of this constrained game is found. It can then be seen that any equilibrium of this type is also an equilibrium if firms and consumers are free to choose nonstationary strategies.

Consider first a possible strategy for each consumer in the constrained game. We shall show below that this is an equilibrium strategy. The consumer enters the market in period t and observes the price p charged and the quantity x produced by each firm, as well as the quality history of each firm. The notion of reputation used is similar to the informal one adopted by Klein and Leffler (1981). When buyers have purchased a product, they discover its quality. Their evaluation eventually becomes known to other consumers through market surveys, conversations with friends, and so on. The simplest way to model this information-dissemination process, which is standard in the literature,

is to assume that buyers' evaluations of the products they purchased in period t become known to all consumers before they purchase products in period $t + 1$. Thus, if a firm ever produces low quality, this becomes widely known, and the firm acquires a bad reputation. Once a firm has a bad reputation, consumers expect its products to be low quality in the future and boycott the firm. Given these expectations, it is not worthwhile for firms to produce high quality so that in equilibrium consumers' expectations are self-fulfilling. This is not the only plausible behavior of consumers in stationary equilibria: the other possibilities are discussed further below.

Consumers cannot observe quality directly. Given a knowledge of cost functions, however, they can each use the price charged and the quantity produced by a firm to check that the high quality claimed is in fact the most profitable quality. If a firm produces low quality, then it loses its reputation and cannot make any sales subsequently. Since all cash flows are in end-of-period dollars, the present value of producing low quality evaluated at the beginning of period t when the firm makes its production decision (i.e., in period $t - 1$ dollars) is therefore

$$\frac{px - f_L(x)}{1 + r} \quad (7)$$

Given stationarity, if a firm chooses to produce high quality, it maintains its reputation and receives a steady stream of profits. The present value of this stream of profits is

$$\frac{px - f_H(x)}{r} \quad (8)$$

Which is the more profitable quality choice depends on whether (7) or (8) is the larger. Since output is observable, the value of x in (7) and (8) is the same. Hence, the firm will find it more profitable to produce high quality if and only if p and x are such that

$$\frac{px - f_H(x)}{r} \geq \frac{px - f_L(x)}{1 + r} \quad (9)$$

(It is assumed throughout that if a firm is indifferent as to which quality it produces, it chooses high quality.)

Provided (9) is satisfied, consumers will expect high quality, since this maximizes the firm's profits. If (9) does not hold, consumers will expect low quality. This is so because presumably the only reason that a firm would have produced x units of output is if it intended to sell them. If (9) is not satisfied, the firm's perceived profit-maximizing choice at the time it produced the goods was low quality and so consumers will expect low quality.

The boundary values of p and x such that (9) is satisfied will be referred to as the moral hazard curve. They are important because of the moral hazard arising from quality's being unobservable. This curve is denoted $p_{MH}(x)$. Rearranging (9), we have

$$p_{MH}(x) = \frac{f_H(x) + r[f_H(x) - f_L(x)]}{x} \quad (10)$$

It can be seen that $p_{MH}(x)$ is the threshold price below which firms produce low quality. Since from (1) and (2) $f_H(x) - f_L(x) > 0$, the smaller is r , the lower is this threshold price at any x . As suggested by Shapiro (1983), this can be thought of as capturing the speed of information transmission in the market. A smaller r can result from a shorter time period, and the shorter the time period, the sooner consumers detect quality. This corresponds to better information so that the threshold price is lower.

If a firm's p and x are such that $p < p_{MH}(x)$, then consumers will not purchase its output, since they will infer that it is of low quality, and (6) implies that they are unwilling

to purchase such output. If, on the other hand, $p \geq p_{MH}(x)$, then consumers will infer that the goods are high quality. It follows from (4) and (5) that, provided they are unable to obtain a cheaper good elsewhere and provided $p \leq p_m$, they will be prepared to purchase the firm's products.

To summarize, the strategy each consumer adopts is (i) to boycott any firm which previously produced low quality, (ii) to boycott any firm with p and x such that $p < p_{MH}(x)$, and (iii) to choose randomly among the remaining firms offering the lowest price and to buy provided $p \leq p_m$.

Consider next the optimal strategy for a firm, given that consumers adopt this strategy and given the strategies of other firms. Clearly, if the firm has produced low quality in the past, it should not produce anything, since nobody will purchase its products. If a firm were to choose $p < p_{MH}(x)$ or $p > p_m$, it would again be unable to sell anything.

Since in the equilibria below all firms charge the same price, it is sufficient to consider the demand for each firm's products, given that all its competitors charge a price p^* . If a firm sets $p > p^*$, it will sell nothing: consumers will all buy from the continuum of firms with price p^* ($\leq p_m$). If $p = p^*$, then consumers choose randomly among firms with this price, and each firm will be able to sell up to σ units of the product, where σ is the ratio of the integral sum of consumers (which is exogenous) to the integral sum of firms (which is endogenous). If $p < p^*$, a firm will be able to sell as much as it likes. (If a finite group of competitors charges a price other than p^* , then the analysis will be unchanged. If a continuum of firms charges a price other than p^* , however, then the demand each firm faces will depend not only on the prices charged by competitors but also on the quantities they produce.)

To summarize, each firm's optimal strategy, given the consumers' strategies outlined above and given that other firms are charging p^* , is (a) to produce nothing if it ever previously produced low quality and (b) otherwise to produce high quality and choose p and x as follows:

$$\max_{p, x \geq 0} px - f_H(x) \tag{11}$$

subject to

$$\text{for } p < p_{MH}(x), \quad x = 0; \tag{12}$$

$$\text{for } p > p_m, \quad x = 0; \tag{13}$$

$$\text{for } p > p^*, \quad x = 0; \tag{14}$$

$$\text{for } p = p^* < p_m, \quad x \leq \sigma; \tag{15}$$

$$\text{for } p < p^* \text{ and } p_m, \quad x \leq \infty. \tag{16}$$

If the solution to this problem is such that $px - f_H(x) < 0$, then the firm chooses $x = 0$, and costs and revenues are both zero.

It can easily be seen that, given this firm strategy, the consumer's strategy outlined above is an optimal response. If any other strategy were adopted, the consumer would either be no better off or would be strictly worse off. For example, suppose strategy (i) were changed to not boycotting firms which had previously produced low quality. Then, given firms' strategies, the consumer's utility would be unchanged, and similarly for other changes in (i). If strategy (ii) was altered by changing the criterion $p < p_{MH}(x)$ say, then the consumer would either reject the high-quality goods available at a price below p_m and, from (4) and (5), would be strictly worse off, or would still accept them and would be no better off, and similarly for other changes in (ii) and for changes in strategy (iii).

To reach equilibrium it is also necessary that the optimal solution to (11) be such that

$$p = p^* = p_e, \tag{17}$$

$$x = \sigma = x_e, \tag{18}$$

where p_e and x_e are the equilibrium values of price and quantity. There must also be no strict incentive for firms to enter or to leave the industry

$$p_e = \frac{rI + f_H(x_e)}{x_e}. \tag{19}$$

This zero-profit condition together with (18) determines the equilibrium ratio (σ) of consumers to firms.

So far it has been assumed that strategies are constrained to be stationary. Even if consumers and firms are free to choose nonstationary strategies, however, those considered clearly remain equilibrium strategies.

The only difference between (11) and the firm's problem in the case where quality is observable is the moral hazard constraint (12). Given stationarity, this means it is possible to use the moral hazard (*MH*) curve (10) in a variant of the standard cost diagram to analyze the types of equilibria that can arise: for a firm to be able to sell its output, any (p, x) it chooses must lie on or above $p_{MH}(x)$ in Figure 1. The diagram's other curves are the usual long-run average cost (*AC*) curve $p_{AC}(x)$, which is given by the values of p and x such that (19) is satisfied, and the marginal cost (*MC*) curve

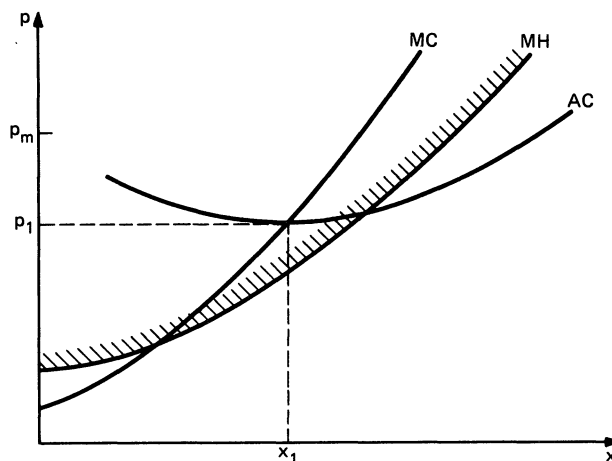
$$p_{MC}(x) = f'_H(x). \tag{20}$$

It is helpful to start by considering the price firms would charge and the quantity they would produce in the first-best stationary equilibrium that would occur if quality were observable. In this case firms would produce the high-quality good at the level of output, x_1 , which minimizes long-run average cost and would set a price, p_1 , equal to both marginal and average cost in the usual way (see Figure 1). For ease of exposition, it is assumed that consumers are willing to purchase the product at this price. That is, using (5), we have

$$p_1 \leq p_m. \tag{21}$$

The first question in determining the nature of equilibrium when quality is unobservable is whether (p_1, x_1) is above or below the moral hazard curve. It can easily be seen that both possibilities can occur: Figure 1 illustrates the case where it is above

FIGURE 1
FIRST-BEST STATIONARY EQUILIBRIUM AT (p_1, x_1)



(e.g., $f_H = 2x^2 + 2x$; $f_L = x^2 + x$; $r = .1$; $I = 10$), and Figure 2 depicts the case where it is below (e.g., $f_H = 2x^2 + 2x + 6$; $f_L = x^2 + x + 1$; $r = .1$; $I = 10$). If (p_1, x_1) is above the moral hazard curve, it is immediate that it remains an equilibrium.

If (p_1, x_1) lies below the moral hazard curve, then whether a second-best equilibrium exists depends on the shape of the moral hazard curve and its intersection with the average cost curve. The slope of the moral hazard curve can be examined by differentiating (10):

$$\frac{dp_{MH}(x)}{dx} = \frac{r}{x} [f'_H(x) - f'_L(x)] + \frac{f'_H(x) - p_{MH}(x)}{x}. \tag{22}$$

For x such that $p_{MH}(x) \leq f'_H(x)$, (2) implies that the slope of p_{MH} must be positive, but for $p_{MH}(x) > f'_H(x)$ either sign is possible. Hence, when it is below the marginal cost curve, the moral hazard curve must be upward sloping, but when it is above it can slope downwards.

The values of x at which the moral hazard and average cost curves cross can be determined by solving (10) and (19) simultaneously:

$$f_H(x) - f_L(x) - I = 0. \tag{23}$$

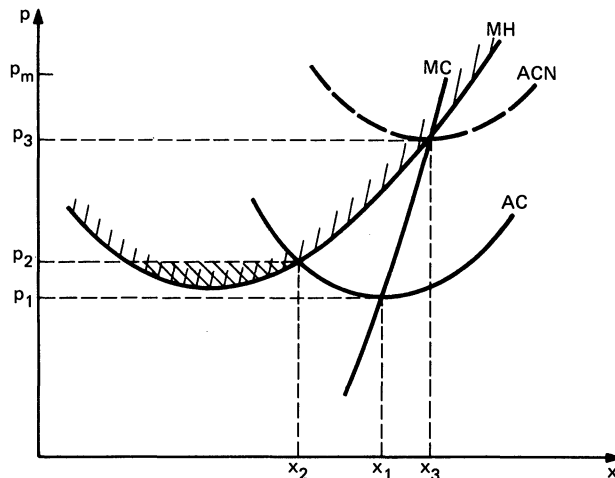
It follows from this and (2) that if the curves intersect, this intersection, which is denoted (p_2, x_2) , must be unique. The difference between the slopes of the two curves at such points is

$$\left. \frac{dp_{MH}(x)}{dx} \right|_{MH=AC} - \left. \frac{dp_{AC}(x)}{dx} \right|_{MH=AC} = \frac{r}{x} [f'_H(x) - f'_L(x)] > 0. \tag{24}$$

Since (2) implies that the difference in these slopes is positive, the moral hazard curve must always cut the average cost curve from below, if they intersect.

These results imply that a number of possibilities exist in addition to those shown in Figures 1 and 2. First, values of (p_2, x_2) may not exist. If $f_H(0) - f_L(0) > I$, the moral hazard curve lies everywhere above the average cost curve and no stationary equilibrium exists. It is also possible for the average cost curve to be everywhere below the moral hazard curve (e.g., $f_H = x^2 + 2x + \tanh x$; $f_L = x^2 + 2x$; $r = .1$; $I = 2$) so that (p_1, x_1) is an equilibrium. When the curves do intersect, however, the uniqueness of (p_2, x_2) and (24) imply that if (p_2, x_2) is to the right of (p_1, x_1) (i.e., $x_1 < x_2$), then (p_1, x_1) must be

FIGURE 2
SECOND-BEST STATIONARY EQUILIBRIUM AT (p_2, x_2)



above the moral hazard curve and is an equilibrium. It can be seen from (23) that this is more likely, the higher is I . If (p_2, x_2) is to the left of (p_1, x_1) (i.e., $x_1 > x_2$), then (p_1, x_1) must be below the moral hazard curve. In such cases, in addition to the possibility illustrated in Figure 2, (22) means that the moral hazard curve may be downward sloping at (p_2, x_2) as shown in Figure 3 (e.g., $f_H = 2x^2 + 2x + 8$; $f_L = x^2 + x$; $r = .1$; $I = 14$) or may even have multiple turning points, as illustrated in Figure 4 (e.g., $f_H = x^4 - 8x^3 + 25x^2 + 121x$; $f_L = 2x^3 + 2x^2 + x$; $r = 1$; $I = 133$).

It is easiest to start by considering what happens in situations such as that in Figure 2 where $p_2 \leq p_m$ and the moral hazard curve is upward sloping for $x \geq x_2$. In this case it can be shown that the unique stationary equilibrium is at (p_2, x_2) . This is done in two steps: it is first shown that no other values of p and x can be equilibria, and it is then demonstrated that (p_2, x_2) is an equilibrium.

Only p and x which lie on the average cost curve and on or above the moral hazard curve can be equilibria. But it is clear that those p and x such that $p > p_2$ and $x < x_2$ for which this is the case cannot be equilibria: if in the maximization problem (11) $p^* > p_2$, any firm could always do better than $(p^*, g(p^*))$ (where $g(p)$ is the inverse of $p_{AC}(x)$) by choosing an alternative p and x such that $p < p^*$ and $x > g(p)$. The alternative would still give the firm the correct incentives to produce high quality, but would result in higher profits.

It remains to show that (p_2, x_2) is an equilibrium. Consider a firm's problem (11) if $p^* = p_2$, and suppose that $\sigma = x_2$. It follows from (14) that the firm will choose $p \leq p_2$. To maximize profits at price p_2 the firm should produce the most it can sell, $x_2 = \sigma$, since $f_H(x)$ is convex and $p_2 > f'_H(x_2)$. It can be seen from Figure 2 that, at any price below p_2 , the firm is constrained by the moral hazard curve to selling less than x_2 , and its profits will be lower than at (p_2, x_2) . Thus, the optimal price and output combination for the firm is (p_2, x_2) and this is an equilibrium.

If quality were observable, (p_2, x_2) would not be an equilibrium because each firm would have an incentive to cut its price and increase output and profits. When quality is unobservable, a firm has no such incentive because of the moral hazard constraint (12). Profits can only be increased when $p < p_2$ if $x > x_2$, but in this case consumers would infer that the firm's products are low quality, so they would refuse to buy them. The demand for a firm's products thus depends on its price and level of output in an unusual way. If it raises its price above p_2 , it loses all its business; if it lowers price below p_2 and tries to sell more than x_2 , it also loses all its business. The only (p, x) where sales are

FIGURE 3
MORAL HAZARD CURVE DOWNWARD SLOPING AT (p_2, x_2)

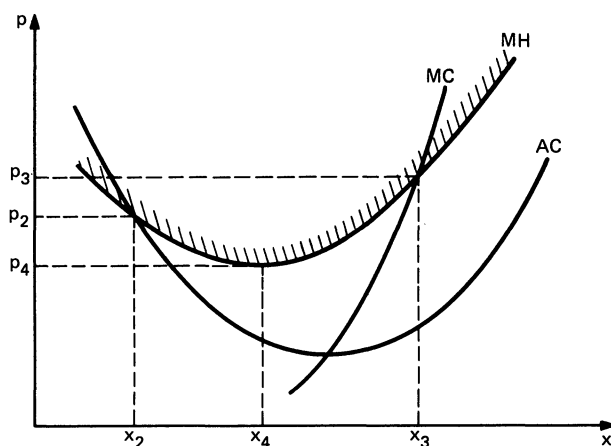
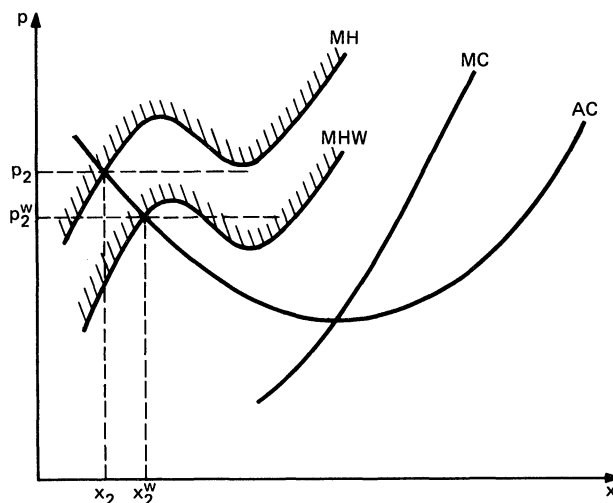


FIGURE 4
MORAL HAZARD CURVE WITH MULTIPLE TURNING POINTS AND THE EFFECT OF WARRANTIES



positive are illustrated in Figure 2 by the diagonally hatched area. It is this property of demand that makes (p_2, x_2) an equilibrium.

The demonstration that (p_2, x_2) is an equilibrium depends on two features of Figure 2. The first of these is that $p_2 \leq p_m$. If $p_2 > p_m$, consumers will not find purchase of the product worthwhile, and equilibrium will involve none of its being produced.

The other important feature is that there are no values of (p, x) with $p < p_2$ that lie on or above the moral hazard curve and that result in a higher discounted stream of profits than (p_2, x_2) . If this were not so, (p_2, x_2) could not be an equilibrium. Consider, for example, the situation illustrated in Figure 3 where the moral hazard curve is downward sloping at (p_2, x_2) : taking other firms' prices as p_2 in every period, a firm can choose a slightly lower price and an output above x_2 that has both the correct quality incentives and higher profits. By a similar argument, no other values of (p, x) that lie on the average cost curve and on or above the moral hazard curve can be an equilibrium, so no stationary equilibrium exists. In addition to the situation depicted in Figure 3, this result will also hold whenever either (a) there is a point on the moral hazard curve with price below p_2 that lies above the average cost curve or (b) the moral hazard curve lies everywhere above the average cost curve.

This discussion of equilibrium is summarized by the following proposition.

Proposition 1. (i) If $p_1 \geq p_{MH}(x_1)$, (p_1, x_1) is a stationary equilibrium. (ii) If $p_1 < p_{MH}(x_1)$ and $p_{MH}(x)$ intersects with $p_{AC}(x)$, then (p_2, x_2) is a stationary equilibrium, provided $p_2 \leq p_m$ and there are no values of $p_{MH}(x)$ such that $p_{AC}(x) < p_{MH}(x) < p_2$. If these conditions are satisfied except $p_2 > p_m$, equilibrium involves none of the good's being produced. At (p_2, x_2) price is greater than marginal cost. (iii) In all other cases no stationary equilibrium exists.

The proposition shows conditions under which stationary equilibrium exists and the types of equilibria that are possible. If a firm produces low quality, it loses its good reputation and has to leave the market. In type-(i) equilibria this penalty is sufficient at the first-best price and quantity (p_1, x_1) to make high-quality production worthwhile for firms.

In type-(ii) equilibria the penalty of exclusion is insufficient at price p_1 and output x_1 to ensure good quality. Raising the price in every period makes high quality relatively

more attractive. This is so because for firms producing high quality and maintaining their reputation, revenue is raised in every period, whereas for those producing low quality, revenue is only increased in one period. In addition, in cases such as that illustrated in Figure 2, restricting output also makes low quality relatively less attractive: this is so because the excess of price over marginal cost is greater for low than for high quality, and for outputs between x_2 and x_1 , this effect predominates over the greater increase in average fixed costs for high quality that is caused by a reduction in x . An increase in price from p_1 and a reduction in output from x_1 , can thus lead to an equilibrium where firms have the correct incentives to produce high quality, but earn zero profits.

Klein and Leffler (1981) consider the case where consumers can only observe prices and firms are price-takers that perceive that they can sell as much as they want at the going price. Their analysis can, however, be adapted to the situation here, where each firm's price and output are observable so that it is restricted by the moral hazard curve (10). In contrast to above, the correct incentives are obtained by increasing price from the first-best level p_1 and increasing quantity from x_1 so that the marginal cost of high quality is kept equal to price. The lowest price at which firms will produce high quality is then at the intersection of the moral hazard and marginal cost curves: this is denoted (p_3, x_3) and is illustrated in Figure 2. The problem is that the price premium at p_3 results in positive profits. For this price premium to be consistent with the free-entry condition, Klein and Leffler introduce the notion of nonprice competition. This involves firms' investing in the firm-specific assets that provide the greatest service value to consumers. The important feature of these investments is that the utility consumers receive from them does not justify their cost, since otherwise they would be undertaken anyway, and their cost would be included in I and $f_H(x)$. They involve a distortion and would not be made if quality were observable. The effect of these investments is to shift the average cost curve upwards. For zero profits, the degree of nonprice competition must be such that the new average cost curve passes through (p_3, x_3) : this is illustrated in Figure 2 by the dotted curve ACN .

In the model considered above, however, it can be seen that (p_3, x_3) in Figure 2 cannot be an equilibrium. Suppose a firm were to reduce its expenditures associated with nonprice competition, lower its price, and choose its quantity so that $p \geq p_{MH}(x)$. Since nonprice competition involves expenditures that give consumers less utility than their cost justifies, it will be possible to choose such a change that makes both consumers and firms better off, so (p_3, x_3) cannot be an equilibrium. In fact, it is always the case when output is observable, that equilibrium will not involve nonprice competition. This is so since (2) and (22) imply that the moral hazard curve must be upward sloping at any intersection with the marginal cost curve, and a similar argument to that above will always hold. It is shown below in Section 4, however, that equilibrium with nonprice competition can exist if output is unobservable.

In Shapiro's (1983) article, consumers are less sophisticated than in the model here. They do not deduce quality from the price and output of the firm; instead they buy goods at the market price with the expectation that a firm's quality will be the same as its quality in the last period. Firms initially acquire a good reputation by selling high-quality products at the minimum-quality price in the first period they produce. The price-quality schedule is such that this initial loss when acquiring a reputation is equal to the present value of the profits required in each subsequent period to ensure that a firm has the correct incentives to continue producing high quality. In contrast, in the model considered here the free-entry condition is satisfied because firms earn zero profits (where profits are defined by taking into account the cost of the initial unrecoverable investment I) in every period, including the first in which the firm produces.

When Proposition 1 (iii) is applicable, it is not possible to reconcile the price premium with the free-entry condition, and no stationary equilibrium exists. The reason

for this is that reducing output does not make low quality relatively less attractive. Consider, for example, the situation illustrated in Figure 3 which arises when the fixed costs of high quality $f_H(0)$ are much greater than the fixed costs of low quality $f_L(0)$. Here reductions in output make low quality relatively more attractive because of the greater increase in the average fixed costs of high quality. For outputs between x_2 and x_1 this more than offsets the effect of the greater excess of price over marginal cost for low quality, which predominates in type-(ii) equilibria.

The notion of reputation used above was that of self-fulfilling expectations. As Dybvig and Spatt (1983) have stressed in the context of a monopolistic model, a standard problem with this is that there exist many equilibria of this type. For example, it was assumed in (7) that once a firm had produced low quality and acquired a bad reputation, consumers expected low quality in every period after that. If, however, consumers expected that the firm would produce low quality for a finite number of periods but that it would then reacquire a good reputation, these expectations might also give rise to a self-fulfilling equilibrium. Similarly, for firms with a good reputation, the quality expected depended on which yielded higher profits. Consumers could, however, expect just low quality in some periods and this might also give rise to a self-fulfilling equilibrium.

One reason for focusing on the pattern of expectations underlying (7) and (8) is that it corresponds most closely to the assumptions of Klein and Leffler (1981) and Shapiro (1983) and so facilitates a comparison of results. More importantly though, the equilibrium considered is the best in the sense that it Pareto dominates the other possible equilibria of the type described. Firms are indifferent among all equilibria since the free-entry condition ensures that their wealth is the same in all of them. Consumers are better off, however, in the equilibrium considered because it involves the strongest response by consumers to quality reduction, and firms produce high quality in every period. Any of the other equilibria described involves either a weaker response to quality reduction which increases (7) or a smaller reward for maintaining a good reputation which reduces (8). The result of either of these is to increase the threshold price $p_{MH}(x)$ for every x . It follows that the equilibrium price in cases where the moral hazard constraint binds will also be higher and consumers will be worse off.

When deriving the proposition, we assumed that consumers knew the structure of the model. It can be seen this is not necessary: in type-(ii) equilibria it is sufficient for consumers to know the equilibrium price p_2 and quantity x_2 that give firms the correct incentives. Provided they boycott firms with $p < p_2$ and $x > x_2$ (but their strategies are otherwise as above), their behavior will support the equilibria described.

4. Firms' outputs unobservable

■ In the previous section x was taken to be observable. In many situations of interest this will not be the appropriate assumption. In this section we consider the effect of taking x to be unobservable.

If x cannot be observed by consumers, then firms which decide to produce the low-quality good may no longer be restricted to producing the same level of output as they would if they were producing high quality. Consumers know this, however, and have enough information, given prices, to work out firms' optimal outputs and the incentives they have. They are therefore still able to infer quality indirectly.

Consider first the situations arising in Proposition 1 (i) where (p_1, x_1) lies above the old moral hazard curve (10). If every firm charged p_1 , then no firm could sell more than x_1 , since the ratio of consumers to firms limits demand at each firm. At price p_1 no firm has any incentive to produce low quality, since at the low volume of x_1 it is not worth foregoing future business for the one-shot gain. Consumers can work this out and would patronize any of the stores charging p_1 . Suppose, however, that one firm attempted to

undercut its rivals. Such an action would be rational only if that firm wished to expand its output; but such an output expansion would, in turn, be rational only if the firm wished to produce low quality, since (p_1, x_1) is on the marginal cost curve for high quality. Consumers could therefore identify the intentions of the firms undercutting p_1 and boycott that firm. As a result, no firm has any incentive to deviate from (p_1, x_1) , and it remains an equilibrium.

Similarly, if the conditions for Proposition 1 (ii) are satisfied, (p_2, x_2) is again the equilibrium (provided $p_2 \leq p_m$), even though x is unobservable. Whereas in the case where output is observable each firm restricted its own output, and price was above marginal cost, here each firm's sales are restricted by the market. At p_2 the ratio of consumers to firms is such that it is only possible to sell x_2 whether high or low quality is produced. Given that it can only sell x_2 , a firm has an incentive to produce high quality. Consumers can work this out and would be willing to patronize any of the firms charging p_2 . Suppose, however, that one firm attempted to undercut its rivals so as to expand output. The firm would then earn less by producing the optimal amount of high-quality output forever than it would earn producing the optimal amount of low-quality output for a single period. Consumers can calculate this, however, and would boycott the firm undercutting p_2 . As a result, no firm has any incentive to deviate from (p_2, x_2) , and it remains an equilibrium.

The main difference in the analysis where x is unobservable is that the circumstances in which no equilibrium exists are altered. In situations such as that illustrated in Figure 3 equilibrium now exists. At p_2 consumers know each firm can sell only $x_2 = \sigma$ regardless of its quality choice. When a firm cuts its price below p_2 , consumers will assume in calculating the profit stream for each quality choice that the respective levels of output are such that price is equal to the respective marginal cost. Since in Figure 3 the moral hazard curve is above the high-quality marginal cost curve at $p_2 - \epsilon$ ($\epsilon > 0$), it follows that even if the firm only produces x such that $f'_H(x) = p_2 - \epsilon$, it would be better off producing low quality. In fact, with low quality it would choose x such that $f'_L(x) = p_2 - \epsilon$, and its profits would be even higher. Hence, consumers will not be willing to purchase at prices below p_2 and no firm has an incentive to undercut its rivals. In the new information environment, (p_2, x_2) becomes an equilibrium. This argument will not hold in all the situations arising in Proposition 1 (iii), however. It is possible to construct examples where even at output levels equating marginal cost and price, high quality is more profitable at prices slightly below p_2 (e.g., $f_H = 2x^2 + 2x + 10$; $f_L = 2x^2 + x$; $r = .1$; $I = 12$). In such cases no stationary equilibrium exists as before.

Proposition 2. When firms' outputs are unobservable: (i) If $p_1 \geq p_{MH}(x_1)$, (p_1, x_1) is a stationary equilibrium. (ii) If $p_1 < p_{MH}(x_1)$ and $p_{MH}(x)$ intersects with $p_{AC}(x)$, (p_2, x_2) is a stationary equilibrium, provided $p_2 \leq p_m$, and for $p < p_2$, high quality is less profitable than low quality when outputs are such that $f'_q(x) = p$ ($q = H, L$). If all these conditions are satisfied except $p_2 > p_m$, equilibrium involves none of the good's being produced. At (p_2, x_2) price is greater than marginal cost. (iii) In all other cases no stationary equilibrium exists.

Klein and Leffler (1981) also consider the case where output is unobservable, but their analysis differs because it is assumed that firms are price-takers and each perceives that it can always sell as much as it wants at the going price. This means that even at p_3 , a firm does not have an incentive to produce high quality. In evaluating the profits from low quality, a firm conjectures a level of output such that $f'_L(x) = p_3$ which is greater than x_3 . This means low quality once is more profitable than high quality forever. The equilibrium price in their model is therefore above p_3 and is the lowest price where each firm perceives that high quality forever is at least as profitable as low quality once. The profits that arise at this price are then dissipated through nonprice competition so that there is no entry.

It is again possible to use Klein and Leffler's notion of nonprice competition in the model here, where each firm correctly perceives that to sell more than σ units of output, it is necessary to cut price below that of its rivals. In Section 3, where firms' output was observable, it was argued that no equilibrium could exist in which there is nonprice competition. If output is unobservable, this is no longer true. For example (p_3, x_3) in Figure 2 is now an equilibrium. Before, a firm could increase its profits and make consumers better off by simultaneously lowering its nonprice competition expenditures and its price, and choosing an output that showed consumers that the firm still had incentives for high quality. When output is unobservable though, consumers will assume that the firm chooses its output to equate marginal cost and price. If price is lowered from p_3 , this means that optimal production of low quality for one period becomes more profitable than optimal production of high quality forever, so that a price-cutting firm no longer has the correct incentives. Hence (p_3, x_3) will be an equilibrium.

In fact, (p_3, x_3) is not the only equilibrium which involves nonprice competition. For every degree of nonprice competition less than that at (p_3, x_3) there is a corresponding average cost curve. In Figure 2 these lie between AC and ACN . The intersection of each of these with the moral hazard curve will also be an equilibrium: any firm that cut its price would again have an incentive to produce low quality. It follows that there is a continuum of equilibria that lie along the moral hazard curve between (p_2, x_2) and (p_3, x_3) which correspond to different degrees of nonprice competition.

In the case shown in Figure 2 it can be seen that (p_2, x_2) Pareto dominates all the other equilibria. Firms earn zero profits in all the equilibria, and so are indifferent between them. The expenditures associated with nonprice competition yield utility to consumers, but never enough to compensate for their cost. This implies that the equilibrium consumers will prefer most is at (p_2, x_2) , where price is lowest and their utility highest. The Pareto-dominating equilibrium will not always be at (p_2, x_2) however. In the case shown in Figure 3 the equilibrium with the lowest price and highest utility occurs at (p_4, x_4) , where there is some nonprice competition. It is the case, though, that because of the upward slope of the moral hazard curve at its intersection with the marginal cost curve (implied by (2) and (22)), the Pareto-dominating equilibrium will never be at (p_3, x_3) .

Finally, as in Section 3, it is not necessary for equilibrium that consumers know the entire structure of the model. In equilibria where the moral hazard constraint binds, it is sufficient that they are aware of the threshold price p_2 and boycott firms with $p < p_2$.

5. Warranties

■ In the previous sections it was assumed that goods were such that there was no scope for the use of warranties. With many services assessments of quality are subjective, and this is the appropriate assumption. For manufactured goods, however, quality is often associated with whether the product breaks. This is objectively observable, so warranties are feasible. The purpose of this section is to consider the effect of allowing for this possibility. If a product is of low quality, it now breaks, and this is observable. It is also assumed, once again, that firms' levels of output are observable.

It is clear that, if whenever a product fails, the firm has to make a warranty payment that is greater than the cost savings of producing the low-quality good, the firm will have the correct incentives, and the first-best is obtainable. With many products, however, there is a second moral hazard: goods break not only if they are of low quality, but also if consumers do not look after them properly, and this level of care is unobservable. In such cases warranties may not enable the first-best to be obtained: the payment necessary for the firm to have the correct incentives can destroy consumers' incentives to look after the product. Reputation then has a role to play as in Section 3.

Suppose the model is changed so that there are two unobservable levels of care and

maintenance consumers can adopt: good (G) and bad (B). Let $U_{qc}(p)$ be the utility from a product of quality q looked after with care c ($c = G, B$). Similarly to before

$$U'_{qc}(p) < 0; \quad U''_{qc}(p) \geq 0, \quad (25)$$

$$U_{HG}(p_m) = U_0, \quad (26)$$

$$U_{Lc}(0) < U_0. \quad (27)$$

We assume that it is worthwhile for consumers to look after high-quality products if there is no warranty:

$$U_{HG}(p) > U_{HB}(p). \quad (28)$$

The product always breaks unless it is of high quality and well maintained. If the warranty payment is denoted w (≥ 0), consumers will only look after products properly if

$$U_{HG}(p) \geq U_{HB}(p - w). \quad (29)$$

(When indifferent, consumers look after the product.) It follows from (25) and (28) that (29) can alternatively be written in the form

$$w \leq w(p), \quad (30)$$

where

$$w(p) > 0. \quad (31)$$

As far as the properties of $w(p)$ are concerned, implicitly differentiating (30) (with an equality) gives

$$\frac{dw(p)}{dp} = \frac{U'_{HB}(p - w) - U'_{HG}(p)}{U'_{HB}(p - w)}. \quad (32)$$

If the utility function is separable in the level of care and price, (25) implies that this derivative must be nonnegative. With nonseparability, however, either sign is possible.

As outlined above, the problem when there are two moral hazards is that (30) may be inconsistent with the requirement that w be sufficiently large for firms to have the right incentives, and an analysis similar to that of Section 3 should be made. Once again, the consumer's strategy is considered first and the firm's second.

The analysis of consumer strategy is similar to that presented before. The main difference is the effect of warranties on a firm's incentives. If the firm produces low quality, it has to make warranty payments, and it loses its reputation so that the present value of its stream of profits is

$$\frac{px - f_L(x) - wx}{1 + r}. \quad (33)$$

It can be seen that the warranty payments are like an increase in $f_L(x)$ and reduce the profits from producing low quality. If $w \leq w(p)$ and the firm produces high quality every period, it never has to make a warranty payment, and the present value of its stream of profits at the beginning of period t (i.e., in period $t - 1$ dollars) is the same as in (8). For the firm to have the right incentives it is necessary that

$$\frac{px - f_H(x)}{r} \geq \frac{px - f_L(x) - wx}{1 + r}. \quad (34)$$

If $w > w(p)$, the firm must always make warranty payments, and the condition for high quality to be more profitable is

$$\frac{px - f_H(x) - wx}{r} \geq \frac{px - f_L(x) - wx}{1 + r}. \quad (35)$$

The optimal strategy for each consumer is now to (i) boycott any firm if it has produced low quality in the past, (ii) boycott any firm either if $w \leq w(p)$ and (34) is not satisfied or if $w > w(p)$ and (35) is not satisfied, and (iii) choose randomly among the remaining firms whose p and w are such that the utility obtained is the highest, given that it is only worthwhile looking after the product if $w \leq w(p)$, and to buy, provided this utility is not below U_0 .

As for each firm's optimal strategy, it will never involve producing high quality and setting $w > w(p)$. If the firm did this, it would have to make warranty payments to every customer, and its net price would $p - w$. If it lowered both p and w by the same amount so $(p - w)$ and consumer's utility were unaffected, (28) implies that the firm would eventually reach a price where (30) was satisfied and consumers looked after their products. Firms would then not have to pay the warranty and so would be better off. Thus, it will always be optimal for a firm to set w so that (30) is satisfied.

The firm's optimal strategy is therefore (a) to produce nothing if it has ever previously produced low quality and (b) otherwise to produce high quality and choose p , x , and w as follows:

$$\max_{p, x, w \geq 0} px - f_H(x), \quad (36)$$

subject to (30), (34), and (13)–(16). If the solution to this is such that $px - f_H(x) < 0$, the firm sets $x = 0$ and incurs no costs.

As before, each consumer and firm strategy is optimal, with other firms' and consumers' strategies taken as given. The other conditions for equilibrium are again (17)–(19).

In this case the analysis of the types of equilibria is slightly more complex owing to the additional constraint (30). But this complexity can be eliminated because it is always optimal for the firm to set $w = w(p)$. To see this, suppose to the contrary $w < w(p)$ at the optimal solution to (36). Now the only place in the firm's problem, other than (30), where w appears is (34). Suppose (34) does not bind at the optimum being considered, then increasing w until $w = w(p)$, while holding p and x constant, would just reduce the right-hand side of (34), and the firm would be indifferent to the change. The only other possibility is that (34) binds. In this case, increasing w would result in (34)'s being satisfied with a strict inequality. It would then be possible to change p and x to increase profits without violating the constraint, so that the initial situation with $w < w(p)$ could not have been a maximum. Hence, it is optimal for the firm to set $w = w(p)$.

Substituting $w = w(p)$ in (34) gives the moral hazard curve, which here is denoted $p_{MHW}(x)$ and is implicitly defined by

$$p_{MHW} + rw(p_{MHW}) = \frac{f_H(x) + r[f_H(x) - f_L(x)]}{x}. \quad (37)$$

This can be used in conjunction with the average and marginal cost curves as in Section 3.

If (p_1, x_1) is above $p_{MHW}(x)$, this will be the equilibrium. If it is below, a stationary equilibrium may or may not exist, depending on the form of the moral hazard curve and its intersections with the average cost curve. The analysis of this case differs from that in Section 3, because the results derived in (22)–(24) no longer hold. In particular the moral hazard and average cost curves now intersect at values of x such that

$$f_H(x) - f_L(x) - w(p_{AC}(x))x - I = 0. \quad (38)$$

In contrast to (23), this together with (32) implies that there is not necessarily a unique point of intersection. If there are multiple intersections, then equilibrium can only exist at the one with the lowest price: this intersection will be referred to as (p_2^w, x_2^w) .

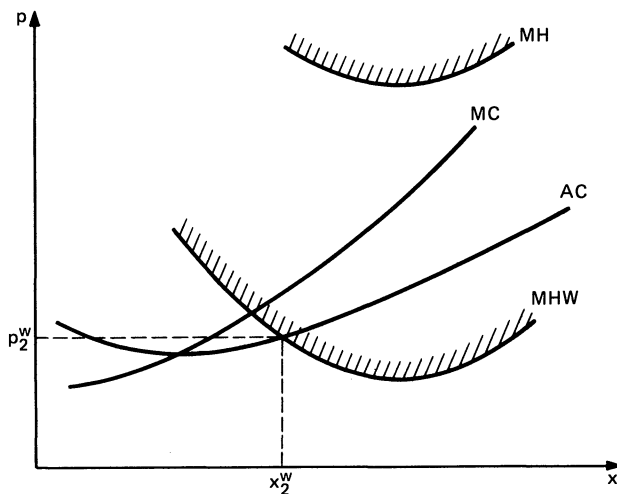
Without warranties all second-best equilibria involved price's being greater than marginal cost. With warranties, however, equilibria can exist where price is below marginal cost (e.g., $f_H = 11x^2 + 2x + 39$; $f_L = 10x^2 + x$; $r = 1$; $I = 1$; $U_{HG} = 25 - p$; $U_{HB} = 3 - p$). This is illustrated in Figure 5. Firms would like to cut output, but are unable to because this would change their incentives. At a lower output the present value of profits from producing low quality are greater than those from producing high quality. Consumers are aware of this and would be unwilling to buy, because from (27), no matter what their maintenance behavior, they would be worse off. As in Section 3, it is essential for equilibrium that the moral hazard curve is such that no point on it which is above the average cost curve has a price less than or equal to p_2^w , because otherwise firms could cut output and increase profits without destroying their incentives for high quality.

Apart from this difference, the analysis of equilibrium is similar to that presented previously. If, for example, the moral hazard curve with warranties is like the *MH* curve shown in Figure 3, no equilibrium exists.

Proposition 3. With partial warranties: (i) If $p_1 \geq p_{MHW}(x_1)$, (p_1, x_1) is a stationary equilibrium. (ii) If $p_1 < p_{MHW}(x_1)$ and $p_{MHW}(x)$ intersects with $p_{AC}(x)$, a stationary equilibrium exists at (p_2^w, x_2^w) , provided $p_2^w \leq p_m$ and there are no values of $p_{MHW}(x)$ such that $p_{MC}(x) < p_{MHW}(x) < p_2^w$ if $x_2^w < x_1$, or $p_{AC}(x) < p_{MHW}(x) \leq p_2^w$ if $x_2^w > x_1$. If all these conditions are satisfied except $p_2^w > p_m$, equilibrium involves none of the good's being produced. Equilibrium at (p_2^w, x_2^w) can involve price greater than marginal cost; it can also involve price below marginal cost. (iii) In all other cases no stationary equilibrium exists.

A comparison of Propositions 1 and 3 shows that in otherwise identical situations, the nature of equilibrium is altered by warranties. In particular, the circumstances in which equilibrium is first-best, second-best, and nonexistent change. Since (31) implies that $p_{MHW}(x)$ lies everywhere below $p_{MH}(x)$, equilibrium is first-best in a wider set of situations. A second-best equilibrium may exist with warranties, where without them it did not. The case shown in Figure 5 is an example of this: without warranties the moral hazard curve and average cost curve do not intersect, but with them they do. The reverse is also possible, as illustrated in Figure 4: introducing warranties results in a lower moral hazard curve and no equilibrium exists because at (p_2^w, x_2^w) it is now possible for firms to

FIGURE 5
STATIONARY EQUILIBRIUM WITH PRICE BELOW MARGINAL COST AT (p_2^w, x_2^w)



cut prices and to increase output and profits, while still having the correct incentives for high quality. If second-best equilibria do exist both with and without warranties, however, it follows from the uniqueness implied by (23), (24), and the fact $p_{MH}(x)$ is everywhere below $p_{MH}(x)$ that the equilibrium price must be lower with warranties than without warranties.

It has so far been assumed in this section that output is observable. As in Section 4, the case where it is unobservable will be similar. The main difference here will be that equilibria with price below marginal cost will not exist: consumers know firms would always cut output below the required level.

Finally, if warranties can be paid to third parties, then the first-best is attainable, even if there are two moral hazards. Since the warranties are not paid to consumers, their incentives are not distorted, so the level of payments can always be made sufficiently high for firms to have the correct incentives. This type of arrangement is seldom observed, however. Presumably one of the reasons for this is that it is difficult for consumers to establish that third parties are in fact third parties and have no ties to the firm. In addition, warranties often have an important risk-sharing role which has not been considered here at all (Heal, 1977).

6. Concluding remarks

■ A simple model has been developed to investigate the role of reputation in ensuring that, when quality is unobservable, firms only sell high-quality goods at high-quality prices. In contrast to Klein and Leffler (1981), we invoke no mechanism for nonprice competition; in addition, consumers are taken to be more sophisticated than in Shapiro's (1983) model. The main result is that, despite the competitive nature of the model, equilibria can exist in which price is not equal to marginal cost. If no warranties are feasible, price can be above marginal cost. Each firm does not cut its price, because this would change its incentives, and consumers would refuse to buy its products. If warranties are feasible, there is the additional possibility that equilibria can exist with price below marginal cost: each firm does not cut its output, because this would again change its incentives and result in no sales.

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