RAND Journal of Economics
Vol. 19, No. 3, Autumn 1988

Umbrella branding as a signal of new product quality: an example of signalling by posting a bond

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I present a signalling model in which a multiproduct firm can use its reputation as a bond for quality by using a brand name for an established product when it introduces a new experience good. As out-of-equilibrium beliefs are specified, a false signal may be taken to imply that both the established and the new product are of low quality. In contrast, the absence of a signal leaves open the possibility that one of the two products is of high quality. Hence, the signal can be credible without excessive sunk costs, as long as the bond posted is sufficiently large.

1. Introduction

■ Most signalling models in the literature have the property that, if a player is exposed as having sent a false signal, he suffers no losses beyond the cost he has already sunk into the signal. For example, the advertising models of Kihlstrom and Riordan (1984) and Milgrom and Roberts (1986) are of this type: products are of either high or low quality and if a firm signals high quality falsely, its net profits will be equal to those it would get without signalling (admitting low quality) minus the cost of the signal. In such models a signal can only be credible if it is so costly that false signals are unattractive: signalling amounts to public "burning of money." I examine what Bhattacharya (1980) calls nondissipative signals and show how they may be rendered credible by posting later sales of another product as a bond. The key mechanism at work is that sending a false signal puts the player in a worse situation from then on than if he had sent no signal. In particular, beliefs are such that a false signal is taken to imply a more unattractive probability distribution over types than no signal. Hence, credible signalling need not involve excessive sunk costs as long as the bond posted is sufficiently large.

I shall make this point in the context of a very important practical example. I consider what happens if a firm uses an established brand name in its advertising for a new experience good, e.g., Diet Coke versus Tab, where experience goods are products whose quality cannot be determined by inspection, so that consumers need to buy the product to learn its quality. This practice, called umbrella branding, has been very widely used by retailers, major consumer goods marketers, and several firms in consumer services. In a very simple model I

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I am indebted to seminar audiences at the Universities of Chicago, Northwestern, and Purdue, as well as to an Associate Editor, Kyle Bagwell, David Besanko, Alvin Klevorick, and David Sappington for detailed comments. The usual caveat applies.

find conditions under which a monopolist can use umbrella branding to send a noise-free credible signal about the quality of a new product.

The basic story is as follows.[1] Consumers are uncertain about the quality of both the old product and the new one, but they have some experience with the old product. Both products are experience goods, and the old product will be purchased again after the new one is introduced. When a firm brands a new product, it is, in effect, doing two things: it is claiming that the old and the new products are both of good quality, and it is inviting consumers to pool their experience with the two products to infer the quality of both.

In this article I provide an example for which, in equilibrium, only firms with two good quality products actually choose to use umbrella branding. Firms with a bad old product are discouraged from branding because consumers will accept the firm's invitation to use the old product for comparison purposes and will conclude that the new product is more likely to be of poor quality than an unbranded product. A firm with a good old product and a bad new product will not brand because although branding will increase sales of the new product, the poor performance of the branded new product will lead consumers to believe that the old product is also of poor quality, and thus lead to a loss of its sales.

In Section 2 I show the existence of equilibria with brand signalling and defend the out-of-equilibrium beliefs that help the firm bond itself. Concluding comments appear in Section 3.

2. A sequential equilibrium with branding

■ Following a tradition in the literature (e.g., Schmalensee, 1982), I consider an experience good whose quality is given by the probability that members of a randomly chosen production batch "work." As an example, I understand that the quality of beer to large extent can be thought of in this way. Only two qualities of product exist: "good" products of which all batches work and "bad" products of which only a fraction $\theta \in (0, 1)$ of all batches work.[2] No consumer can buy from more than one production batch at a given time, and for technological reasons each product can be produced in only one quality, known to the firm, but unknown to the consumer. In this formulation a product's reputation is given by the probability, as seen by various consumer groups, that it is "good."

I consider the last two of three periods (called 0, 1, and 2) in the life of a firm. In period zero the firm sells its "old" product and develops a reputation based on that. Then in period one it sells a "new" product, which it may or may not umbrella brand. Finally, in period two it sells the old product again. Quality is exogenous but known to the firm. The probability that a given product is good is given by $\eta \in (0, 1)$ for both the old and the new product. To minimize the complexity of the algebraic expressions, I assume that the qualities of the two products are uncorrelated. The general case, where any correlation between -1 and 1 is possible, is analyzed in Wernerfelt (1986). The cost of branding is $\beta \in \mathbb{R}_+$, and the firm decides whether to brand (B) or not (N) at the start of period one. It makes pricing decisions p_1, p_2 at the start of each of the last two periods. The timing of events and decisions is summarized in Figure 1.

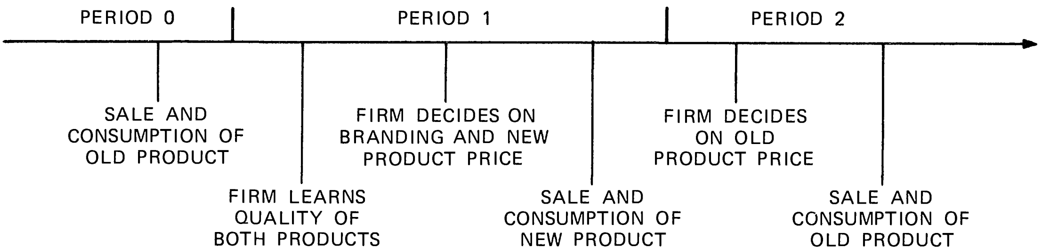
The assumption of a positive branding cost may seem unnatural. Why would it be more costly to put any particular name on the new product? Marketers do, however, ascribe a very significant indirect cost to umbrella branding. The argument is that an existing brand name identifies the product's location in attribute space and that the meaning of the name gets fuzzy, which results in "confused" consumers if it is used on different products (Kimrey, 1974; Guyon and Long, 1982). Accordingly, one would expect umbrella branding to be

[1] I am indebted to an Associate Editor for this intuitive interpretation.

[2] This formulation allows us to ignore type I errors and thus simplifies the analysis.

FIGURE 1

TIMING OF EVENTS AND DECISIONS



used more when the products are in some sense similar. In fact, the theoretical and empirical work of Sappington and Wernerfelt (1985) demonstrates the consistency of this story.

There is a unit mass of consumers who are initially identical. Faced with a price p and a reputation r, each will buy $[y(p) + z(r(p))]/p$ of the new product. Here r is the probability that the product is good. Similarly, at price p' and reputation r', demand for the old product is $\alpha[y(p') + z(r'(p'))]/p'$, $\alpha \in \mathbb{R}_+$.[3] Note that r may depend on p. That is, I am not requiring prices to be pooled. In fact, it is possible that price instead of branding can be used to signal the quality of one or both products. Note further that, for the purpose of expositional simplicity, I have used the same $y(\cdot)$ and $z(\cdot)$ for both products. Assume that z is positive and increasing in r and that y is concave, differentiable, and maximized for a finite positive price. If we assume that production is costless and take r as fixed, we can find the complete information monopoly price p^* from $\partial y(p^*)/\partial p = 0$ and profits from sale of the new product (with reputation r) as $y(p) + z(r(p))$, whereas the corresponding profits from the old product are $\alpha[y(p) + z(r(p))]$. For simplicity we assume that consumers do not communicate; each one's probability assessment will be a function of his prior, the branding decision of the firm, and the consumer's own purchasing experience.

I shall establish the existence of a sequential equilibrium (Kreps and Wilson, 1982) in which all firms charge p^* for both products, and a firm with two good products always brands while no other type of firm will brand. The equilibrium is supported by the out-of-equilibrium beliefs that: (i) if a firm brands and supplies a new product that does not work, then that firm has two bad products; (ii) if a firm brands and supplies an old product that does not work, then that firm has a good new product with probability ψ; and (iii) if a firm fails to charge p^*, then that firm has a good old and a bad new product with probability ϕ, a bad old and a good new product with probability μ, and two bad products with probability $1 - \phi - \mu$. It is the beliefs (i) and (ii) that are so costly to the sender of a false signal. I shall justify these later.

Use $\pi(i, j, A)$ to denote the profits due to reputation above zero for a firm with an old product of type i, a new product of type j, and branding strategy A. Further, let g and b denote good and bad products, respectively. We assume that the profit functions satisfy all participation constraints so that we are left with the incentive-compatibility requirements:

$$(gg): \quad \pi(g, g, B) > \pi(g, g, N)$$

$$(gb): \quad \pi(g, b, N) > \pi(g, b, B)$$

$$(bg): \quad \pi(b, g, N) > \pi(b, g, B)$$

$$(bb): \quad \pi(b, b, N) > \pi(b, b, B).$$

[3] Because all consumers always buy some of the good, there is no incentive to buy for purposes of information-gathering alone.

Define $x(r) \equiv z(r) - z(0)$. I show in the Appendix that the above constraint set reduces to

$$x(1)(1 + \alpha) - \beta > x\left(\frac{\eta\theta}{\eta + \theta}\right) + \alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) \tag{1}$$

$$x(1)(1 + \theta\alpha) - \beta < x\left(\frac{\eta\theta}{\eta + \theta}\right) + \theta\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) + (1 - \theta)\alpha x\left(\frac{\eta}{\eta + \theta(1 - \eta)}\right) \tag{2}$$

$$x(1)\theta(1 + \alpha) + (1 - \theta)x(\psi') - \beta < \theta x\left(\frac{\eta\theta}{\eta + \theta}\right) + (1 - \theta)x(\eta) + \theta\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right)$$

$$\text{for some} \quad \psi' \in [0, 1]. \tag{3}$$

Given these conditions, there exists a sequential equilibrium in which only firms with two good products brand, provided that prices are pooled. Since prices were held constant at p^* in the above, these arguments also apply to simultaneous price-branding deviations. I show in the Appendix that pure price signalling is also excluded.

Conditions (1)–(3) are difficult to evaluate because the underlying space consists of four parameters (α, β, η, θ) and one function ($x(\cdot)$). But it is easy to find examples for which they are statisfied. To this end, suppose that $\psi = \eta$ and that $x(\cdot)$ and η are such that $x(1) = 1$ and $\pi(g, g, N) = 3/2$. In this case the three inequalities are satisfied for $\theta = 1/2$, $\alpha = 2$, and $\beta = 1$. It is difficult to say "how often" these conditions will be satisfied. They get weaker if we include more periods, but remain complicated and nontrivial. Still, the purpose of this article is only to establish the feasibility of noise-free branding signals. The frequency with which this strategy can work is an empirical question. It is, nevertheless, possible to characterize circumstances under which (1)–(3) will tend to hold. The conditions roughly imply that umbrella branding is more likely to work when quality differences are large (θ small), bad products are rare (η large), and the old product is important (α large). Intuitively, these circumstances increase the cost of being identified as a *b,b* type, which again is what sustains the equilibrium against false signals.

Summarizing, there exist examples in which umbrella branding can serve as a nondissipative signal of quality.

Proposition 1. Given (1)–(3), there is a sequential equilibrium in which prices are pooled at p^* and only firms with two good products brand.

The out-of-equilibrium beliefs that: (i) a firm that both brands and supplies a failing new product is of the *b,b* type, (ii) a firm that both brands and supplies a failing old product is of the *b,b* or *b,g* type, and (iii) a firm that prices at $\tilde{p} \neq p^*$ is not of the *g,g* type, are clearly crucial for our equilibrium and the firm's ability to post a bond by signalling. In particular, it is principally by exposing itself to (i) that the firm posts a bond.

These out-of-equilibrium beliefs can be defended by an equilibrium dominance type of argument that is related to the notion of strategic stability introduced by Kohlberg and Mertens (1986) and the implications of this equilibrium concept emphasized by Cho and Kreps (1987). Specifically, I require that out-of-equilibrium signals (a) are not interpreted as coming from types for which the equilibrium dominates any interpretation of the signal (Cho and Kreps, 1987), but (b) possibly could come from any type for which some interpretation of the signals is preferable to the equilibrium. Because "possibly" may refer to any probability of (0, 1], condition (b) is not very demanding.

In the Appendix I show that conditions (1), (3), and (4) and (5) below guarantee that our equilibrium is unique in the class of equilibria that satisfy (a) and (b):

$$x(1)(1 + \alpha) - \beta < x\left(\frac{\eta\theta}{\theta + \eta}\right) + \theta\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) + (1 - \theta)\alpha x\left(\frac{\eta}{\eta + \theta(1 - \eta)}\right) \tag{4}$$

$$x(1)(1 + \theta\alpha) - \beta > \theta x\left(\frac{\eta\theta}{\theta + \eta}\right) + (1 - \theta)x(\eta) + \theta^2\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right)$$
$$+ \theta(1 - \theta)\alpha x\left(\frac{\eta}{\eta + \theta(1 - \eta)}\right). \quad (5)$$

Although these conditions are complicated, they can be consistent. As a brief, incomplete, check on this, note that if $\psi' = \eta$, we can write (1), (3), (4), and (5) as

$$x(1)(1 + \alpha) - \beta/\theta < x\left(\frac{\eta\theta}{\theta + \eta}\right) + \alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) < x(1)(1 + \alpha) - \beta < x\left(\frac{\eta\theta}{\theta + \eta}\right)$$
$$+ \theta\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) + (1 - \theta)\alpha x\left(\frac{\eta}{\eta + \theta(1 - \nu)}\right) < x(1)(1/\theta + \alpha) - \beta/\theta - (1 - \theta)/\theta x(\eta).$$

Given the assumptions on the parameters and $x(\cdot)$, these inequalities can be consistent.

Hence, the equilibrium beliefs supporting the equilibrium in Proposition can sometimes be given a systematic foundation.

Proposition 2. Given (1), (3), (4), and (5), the equilibrium in which only firms with two good products brand is the only equilibrium in which firms separate on branding that satisfies our dominance criterion.

The intuition behind the result is that the posted bond is bigger if the old product is good. Firms with bad old products are therefore "more likely" to cheat, and out-of-equilibrium beliefs reflect that. In contrast, firms avoid precisely identifying themselves if they refrain from branding.

Summarizing, under the stated assumptions, there is only one reasonable equilibrium with brand signalling. In principle, other instruments such as prices could be used to signal quality. But the branding signal seems to be a natural way of tying the products together to generate the appropriate beliefs.

3. Conclusion

■ The purpose of this article was to show the *possibility* of signalling by posting a bond in the context of umbrella branding. Because this signal is nondissipative, it is an efficient vehicle for communication. It is therefore not surprising that umbrella branding is so commonly observed.

Three comments are in order. First, although the model is very stylized, the intuition seems quite robust, and I conjecture that analogous equilibria exist in a wider class of games. Second, umbrella branding could also serve as a nondissipative signal in a supergame model in which the firm introduces a possibly infinite stream of new products. The present set-up, however, only requires two products. Third, a key component in my construction is that the reputation of the old product is put at risk. In many practical examples this is not a reasonable assumption for all consumers. If one has been drinking Coca-Cola for twenty years, it is not likely that a bad experience with Diet Coke will change one's mind. In any real market, however, there is a continuing turnover of consumers due to demographic shifts and changing tastes. Hence, there will always be some consumers for whom the quality of the old product is unsettled, and it is sales to these customers that are at stake when the firm uses umbrella branding.

It is instructive to compare the model with that of Klein and Leffler (1981). In their model quality is endogenous, and the firm dares not cheat consumers today with low quality products for fear that they will not buy in the future. The idea is, therefore, that the firm bonds current good behavior by carrying many products. In the present model quality is exogenous, and the firm bonds its current honesty with its reputation for future honesty.

Beyond the specifics of the model, the results suggest the existence of reputational economies of scope. In a more realistic environment, with quality a question of degree rather than kind, it would be quite difficult to write a satisfactory leasing contract for a brand name, especially with limited liability. Accordingly, I would expect such market failures to give rise to multiproduct firms, built around their reputations. This could provide another rationale for the existence of chain stores and conglomerates. Alternatively, one might expect to see very detailed contracts as, for example, those of McDonald's. Yet another possibility is that some independent certification service would be used.

The fact that a reputation from one market can be valuable (used or leased) in another has implications for competition in the first market. In particular, it may pay for a firm to accept negative profits in the first market to maximize its reputational advantages in other markets.[4] Investigation of the welfare implications of this is an important goal of future research.

Most important, however, in this article I have demonstrated the possibility of signalling by posting a bond. Because the signal sender never defaults on the bond in equilibrium, this class of signals is more attractive than those in the literature that are based on demonstrated waste of money.

Appendix

■ Three proofs follow.

Proof that incentive compatibility constraints (gg), (gb), (bg), and (bb) reduce to (1)–(3). Assume that prices are pooled at p^*, and denote by $r_{ij}(A, v_0)$ $(i, j = g, b; A = B, N; v_0 = w, f)$ the probability, as seen by a consumer at the start of the first period, that a firm has an old product of type i and a new product of type j, given that it charges p^*, that it uses branding strategy A, and that its product in period zero worked (w) or failed (f). From our assumptions, this gives the posterior probabilities:

$$r_{gg}(B, w) = 1$$

$$r_{bg}(N, w) = \theta\eta[\theta + \eta]^{-1}$$

$$r_{gb}(N, w) = \eta[\theta + \eta]^{-1}$$

$$r_{bb}(N, w) = \theta(1 - \eta)[\theta + \eta]^{-1}$$

$$r_{bg}(N, f) = \eta$$

$$r_{bb}(N, f) = 1 - \eta.$$

For example, consider $r_{gb}(N, w)$. Given N, only gb, bg, and bb are possible. $\text{Prob}(gb) = \eta(1 - \eta)$ and $\text{Prob}(w|gb) = 1$. Further, $\text{Prob}(bg) = \eta(1 - \eta)$, $\text{Prob}(w|bg) = \theta$, $\text{Prob}(bb) = (1 - \eta)^2$, and $\text{Prob}(w|bb) = \theta$. We then find that $r_{gb}(N, w) = \eta(1 - \eta)[\eta(1 - \eta) + \theta\eta(1 - \eta) + \theta(1 - \eta)^2]^{-1}$ which reduces to the expression above.

Similarly, if we let $s_{ij}(A, v_0, v_1)$ $(i, j = g, b; A = B, N; v_0, v_1 = w, f)$ denote the analogous probability assessment at the start of the second period, given the history (A, v_0, v_1), we obtain

$$s_{gg}(B, w, w) = 1$$

$$s_{bg}(N, w, w) = s_{gb}(N, w, w) = \eta[2\eta + \theta(1 - \eta)]^{-1}$$

$$s_{bb}(N, w, w) = \theta(1 - \eta)[2\eta + \theta(1 - \eta)]^{-1}$$

$$s_{bg}(N, f, w) = s_{gb}(N, w, f) = \eta[\eta + \theta(1 - \eta)]^{-1}$$

$$s_{bb}(N, f, w) = s_{bb}(N, w, f) = \theta(1 - \eta)[\eta + \theta(1 - \eta)]^{-1}.$$

Now denote the profits due to reputation above zero of a firm with an old product of type i, a new product of type j, and branding strategy A, by $\pi(i, j, A)$. Using $x(r) \equiv z(r) - z(0)$, we find that

[4] This intermarket externality may have effects quite similar to those of intertemporal externalities such as learning curves or brand loyalty.

$$\pi(g, g, B) = x(1)(1 + \alpha) - \beta$$

$$\pi(g, g, N) = x\left(\frac{\eta\theta}{\theta + \eta}\right) + \alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right)$$

$$\pi(g, b, B) = x(1)(1 + \alpha\theta) - \beta$$

$$\pi(g, b, N) = x\left(\frac{\eta\theta}{\theta + \eta}\right) + \theta\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) + (1 - \theta)\alpha x\left(\frac{\eta}{\eta + \theta(1 - \eta)}\right)$$

$$\pi(b, g, B) = x(1)\theta(1 + \alpha) + (1 - \theta)x(\psi) - \beta$$

$$\pi(b, g, N) = \theta x\left(\frac{\eta\theta}{\theta + \eta}\right) + (1 - \theta)x(\eta) + \theta\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right)$$

$$\pi(b, b, B) = x(1)\theta(1 + \theta\alpha) + (1 - \theta)x(\psi) - \beta$$

$$\pi(b, b, N) = \theta x\left(\frac{\eta\theta}{\theta + \eta}\right) + (1 - \theta)x(\eta) + \theta^2\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) + \theta(1 - \theta)\alpha x\left(\frac{\eta}{\eta + \theta(1 - \eta)}\right).$$

Since $\pi(b, b, N) > \pi(b, g, N)$ and $\pi(b, b, B) < \pi(b, g, B)$, incentive-compatibility constraint (bb) is not binding. Hence, the incentive-compatibility requirements reduce to (1)–(3). *Q.E.D.*

Proof that we can rule out pure price signals. Price signals involve deviations from p^* and will thus carry a, perhaps infinitesimal, cost. Given this, firms with two good products have no incentive to deviate from p^* in the equilibrium derived in the text. They are already identified. The other types of firms are more interesting.

If we let $\pi(i, j, \tilde{p})$ denote the profits to a firm with an old product of type i, a new product of type j, and the price (for the new product) $\tilde{p} \neq p^*$, we find:

$$\sup\pi(g, b, \tilde{p}) = x\left(\frac{\theta\mu}{\phi + \theta(1 - \phi)}\right) + \theta\alpha x\left(\frac{\phi}{\theta + (1 - \theta)(\phi + \mu)}\right) + (1 - \theta)\alpha x\left(\frac{\phi}{\phi + (1 - \theta)(1 - \phi - \mu)}\right)$$

$$\sup\pi(b, g, \tilde{p}) = \theta x\left(\frac{\theta\mu}{\phi + \theta(1 - \phi)}\right) + (1 - \theta)x\left(\frac{\mu}{1 - \phi}\right) + \theta\alpha x\left(\frac{\phi}{\theta + (1 - \theta)(\phi + \mu)}\right)$$

$$\sup\pi(b, b, \tilde{p}) = \theta x\left(\frac{\theta\mu}{\phi + \theta(1 - \theta)}\right) + (1 - \theta)x\left(\frac{\mu}{1 - \phi}\right) + \theta^2\alpha x\left(\frac{\phi}{\theta + (1 - \theta)(\phi + \mu)}\right)$$
$$+ \theta(1 - \theta)\alpha x\left(\frac{\phi}{\phi + (1 - \theta)(1 - \phi - \mu)}\right).$$

Hence, we need to assume that for some $(\mu', \phi') \in \{[0, 1 - \phi'], [0, 1 - \mu']\}$:

$$x\left(\frac{\eta\theta}{\eta + \theta}\right) + \theta\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) + (1 - \theta)\alpha x\left(\frac{\eta}{\eta + \theta(1 - \eta)} > x\left(\frac{\theta\mu'}{\phi' + \theta(1 - \phi')}\right) + \theta\alpha x\left(\frac{\phi'}{\theta + (1 - \theta)(\phi' + \mu')}\right)$$
$$+ (1 - \theta)\alpha x\left(\frac{\phi'}{\phi' + (1 - \theta)(1 - \phi' - \mu')}\right)$$

$$\theta x\left(\frac{\eta\theta}{\eta + \theta}\right) + (1 - \theta)x(\eta) + \theta\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) > \theta x\left(\frac{\theta\mu'}{\phi' + \theta(1 - \phi')}\right) + (1 - \theta)x\left(\frac{\mu'}{1 - \phi'}\right)$$
$$+ \theta\alpha x\left(\frac{\phi'}{\theta + (1 - \theta)(\phi' + \mu')}\right)$$

$$\theta x\left(\frac{\eta}{\eta + \theta}\right) + (1 - \theta)x(\eta) + \theta^2\alpha x\left(\frac{\eta}{2\eta + \theta(1 - \eta)}\right) + \theta(1 - \theta)\alpha x\left(\frac{\eta}{\eta + \theta(1 - \eta)}\right) > \theta x\left(\frac{\theta\mu'}{\phi' + \theta(1 - \phi')}\right)$$
$$+ (1 - \theta)x\left(\frac{\mu'}{1 - \phi}\right) + \theta^2\alpha x\left(\frac{\phi'}{\theta + (1 - \theta)(\phi' + \mu')}\right) + \theta(1 - \theta)\alpha x\left(\frac{\phi'}{\phi' + (1 - \theta)(1 - \phi' - \mu')}\right).$$

Since we can set $\mu' = \phi' = 0$, these conditions are not binding. *Q.E.D.*

Proof that (1), (3), (4), and (5) guarantee uniqueness under the refinement. We shall initially establish uniqueness in the set of equilibria in which prices are pooled. We shall then show that the equilibrium still exists when we allow price signalling and impose our equilibrium refinements.

Consider the disequilibrium information set in which a firm brands and supplies a failing new product. The best a g,b type can earn by branding, given any out-of-equilibrium beliefs, is $x(1)(1 + \alpha) - \beta$, which results if the old product is given a reputation one. Hence, if we replace (2) by

$$x\left(\frac{\eta\theta}{\theta+\eta}\right) + \theta\alpha x\left(\frac{\eta}{2\eta+\theta(1-\eta)}\right) + (1-\theta)\alpha x\left(\frac{\eta}{\eta+\theta(1-\eta)}\right) > x(1)(1+\alpha) - \beta, \tag{4}$$

we have a condition under which branding is dominated for g,b types relative to the equilibrium. Similarly, the best a b,b type can achieve by branding, given any beliefs, is $x(1)(1+\theta\alpha) - \beta$. Hence, if we assume

$$\theta x\left(\frac{\eta\theta}{\eta+\theta}\right) + (1-\theta)x(\eta) + \theta^2\alpha x\left(\frac{\eta}{2\eta+\theta(1-\eta)}\right) + \theta(1-\theta)\alpha x\left(\frac{\eta}{\eta+\theta(1-\eta)}\right) < x(1)(1+\theta\alpha) - \beta, \tag{5}$$

consumers should infer that branding in connection with a failing new product signals the b,b type.[5]

Second, in the case in which a firm brands and supplies a failing old product, we wish to show that for some beliefs both b,g and b,b types find branding attactive. As an example of such beliefs, we again set the reputation of the new product equal to one. In this case b,g and b,b types will get $x(1)(1+\theta\alpha) - \beta$, so that if we assume

$$\theta x\left(\frac{\eta}{\eta+\theta}\right) + (1-\theta)x(\eta) + \theta\alpha x\left(\frac{\eta}{2\eta+\theta(1-\eta)}\right) < x(1)(1+\theta\alpha) - \beta$$

and (5) above, we have a set of conditions under which consumers should infer that branding in connection with a failing old product signals either the b,b or b,g type. Since the latter constraint is weaker than (5), it is not binding.

The above arguments show that our equilibrium is reasonable in the class of equilibria in which prices are pooled and only g,g types brand. Under the stated assumptions it is also unique in that class since the opposite out-of-equilibrium beliefs have been shown to be incompatible with our dominance criterion.

To begin thinking about other equilibria, still keeping prices pooled, we first consider what will turn out to be the most difficult case, namely that where g,g and (perhaps only some) b,b types brand. In this situation g,b types will not brand if

$$x(r_{gg}(B, w)) + \theta\alpha x(s_{gg}(B, w, w)) - \beta < x(r_{bg}(N, w)) + \theta\alpha x(s_{gb}(N, w, w)) + (1-\theta)\alpha x(s_{gb}(N, w, f)),$$

while b,b types will brand or randomize if

$$x(r_{gg}(B, w)) + \theta\alpha x(s_{gg}(B, w, w)) - \beta/\theta$$
$$\geqslant x(r_{bg}(N, w)) + \frac{1-\theta}{\theta}x(r_{bg}(N, f)) + \theta\alpha x(s_{gb}(N, w, w)) + (1-\theta)\alpha x(s_{gb}(N, w, f)).$$

Since the latter constraint has a larger right-hand side and a smaller left-hand side than the former, such an equilibrium cannot exist.

Next consider the case where g,g and b,g types brand. In this situation b,b types will have "too much" to gain from b₁anding and another inconsistency in the incentive-compatibility constraints will appear. Similar contradictions result from the conjecture that g,g types plus any two of the three other types brand. Finally, the cases where g,g types do not brand, but some other type or types do, will not work, essentially because these firms will be paying to identify themselves as low-quality producers. Since mixed strategies require equalities instead of inequalities in the above, these arguments also exclude all mixed strategy equilibria in this class.

We finally need to see whether the equilibrium refinement invalidates the equilibrium once we allow price signalling. Since price signalling is costly, firms of the g,g type will have no incentive to deviate by charging prices other than p^*. Our refinement requires that there exist beliefs (ϕ_1, μ_1), (ϕ_2, μ_2), and (ϕ_3, μ_3) such that firms of the g,b, and b,g, and the b,b types, respectively, could benefit from charging prices other than p^*, should these beliefs obtain. Hence, we need:

$$x\left(\frac{\eta\theta}{\eta+\theta}\right) + \theta\alpha x\left(\frac{\eta}{2\eta+\theta(1-\eta)}\right) + (1-\theta)\alpha x\left(\frac{\eta}{\eta+\theta(1-\eta)}\right) < x\left(\frac{\theta(1-\phi_1)}{\phi_1+\theta(1-\phi_1)}\right) + \theta\alpha x(\phi_1) + (1-\theta)\alpha x(1),$$
$$\text{for some} \quad \phi_1 \in [0, 1]$$

$$\theta x\left(\frac{\eta\theta}{\eta+\theta}\right) + (1-\theta)x(\eta) + \theta\alpha x\left(\frac{\eta}{2\eta+\theta(1-\eta)}\right) < \theta x\left(\frac{\theta(1-\phi_2)}{\phi_2+\theta(1-\phi_2)}\right) + (1-\theta)x(1) + \theta\alpha x(\phi_2),$$
$$\text{for some} \quad \phi_2 \in [0, 1]$$

$$\theta x\left(\frac{\eta\theta}{\eta+\theta}\right) + (1-\theta)x(\eta) + \theta^2\alpha x\left(\frac{\eta}{2\eta+\theta(1-\eta)}\right) + (1-\theta)\theta\alpha x\left(\frac{\eta}{\eta+\theta(1-\eta)}\right)$$
$$< \theta x\left(\frac{\theta(1-\phi_3)}{\phi_3+\theta(1-\phi_3)}\right) + (1-\theta)x(1) + \theta^2\alpha x(\phi_3) + \theta(1-\theta)\alpha x(1), \quad \text{for some} \quad \phi_3 \in [0, 1].$$

[5] Since Cho and Kreps used only the first part of the above argument, these conditions are not equivalent to theirs.

These are satisfied if for $i = 1, 2, 3$

$$\frac{\eta}{2\eta + \theta(1-\eta)} < \phi_i < \frac{\eta + \phi(1-\eta)}{2\eta + \theta(1-\eta)}. \qquad Q.E.D.$$

The equilibrium refinement, therefore, does not invalidate the equilibrium if we allow price signalling.

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