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# Optimal Export Policy for a New-Product Monopoly

*By* KYLE BAGWELL*

*A new welfare-enhancing role is identified for a policy of export subsidization in a new-product industry. An export-subsidy policy promotes the (rational) perception that a high-quality export can be provided at a relatively low price. Thus, an export subsidy generates a first-order benefit to welfare by enabling a high-quality export to be sold at a less-distorted high price. The subsidy will also introduce distortions into the price of a low-quality export and the quality-selection process. Since these choices are initially undistorted, however, the export-country welfare loss arising from new distortions is of second-order importance.* (*JEL* D82, F13)

One of the key difficulties in exporting a new product is that foreign consumers may be unaware of the product's quality. Since consumers will then monitor the price of the product in order to form expectations about its quality, a firm in possession of a high-quality product may need to distort its price, lest consumers mistakenly infer that the product's quality is low. In other words, an informational externality arises, as the mere potential to produce low-quality goods may affect the profits of a high-quality exporter. The recognition of such an externality suggests a possible welfare-enhancing role for export policy in new-product industries. The purpose of this paper is to provide a formal framework with which to evaluate this possibility. In particular, conditions are given under which a specific export subsidy for a new-product monopolist raises export-country welfare.

The basic argument is easily understood. Assuming that lower-quality goods have lower marginal costs, high prices which restrict sales are especially unattractive to a monopolist with a low-quality export. Thus, a high-quality exporter uses a high, distorted (i.e., supramonopoly) price to signal its quality, while a low-quality exporter simply selects its low-quality monopoly price.[1] The key observation is that the process of quality-signaling requires the monopolist to have a lower equilibrium sales level when its quality is high. This means that a per-unit subsidy differentially benefits an exporter with a low-quality good.

Two implications follow. First, the incentive for a low-quality exporter to raise price (restrict sales) and misrepresent itself as a high-quality firm is reduced as the level of export subsidy increases. An export subsidy therefore enables a high-quality exporter to signal its quality with a lower, less-distorted price. In this way, the export subsidy generates a welfare gain. Of course, the subsidy also reduces the low-quality price; however, since this price is initially undistorted, the

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[1]The prediction that high quality is signaled with a high price is consistent with available evidence. In particular, David J. Curry and Peter C. Riesz (1988) provide some evidence that high, distorted prices are used to signal quality for relatively new high-quality products. This conclusion is corroborated in several case studies. Products such as fountain-pen ink and car wax (André Gabor and Clive Granger, 1965) as well as ballpoint pens, electric shavers, vodka, skis, and television sets (Robert D. Buzzell et al., 1972) have been successfully introduced at high prices to denote high quality.

welfare loss associated with introducing a low-quality pricing distortion is of second-order importance, at least for small subsidies.

The second implication concerns quality-choice distortions that an export subsidy induces. Since the subsidy benefits a low-quality producer most, the subsidy causes low-quality exports to be selected more often than is optimal for the exporting country. This distortion is also of second-order importance, however, since the monopolist initially selects quality in an undistorted, profit-maximizing fashion (given the equilibrium prices). Thus, in total, a small export subsidy is beneficial, because it promotes the (rational) perception that a high-quality export can be provided at a less-distorted high price.

The arguments developed here relate to two principal literatures. A number of papers in international trade have examined the possibility of strategic government intervention, following the ideas developed by James Brander and Barbara Spencer (1985). The present paper differs from the Brander-Spencer analysis in that export policy is used to alter the beliefs of foreign consumers rather than the output decisions of foreign firms. Further, while export subsidization is a "beggar-thy-neighbor" policy in the Brander-Spencer world, the lower prices that subsidization generates in the current model will raise import-country welfare.[2]

Gene M. Grossman and Henrick Horn (1988) and Robert W. Staiger and I (Bagwell and Staiger, 1989) have previously considered the role for export policy when product quality information is asymmetric in multifirm and monopoly models, respectively.[3] Both papers examine possibilities for export policy when the price of a high-quality export is pooled with that of a low-quality good and when separate prices are selected for different-quality exports. The current paper differs on two fronts. First, it is argued below that policy conclusions based on pooling equilibria may be fragile, at least in the context of a monopoly model, as such equilibria fail to be "refined" once general, downward-sloping demand functions are allowed. Second, the previous papers assume that a low-quality good is inefficient or "fly-by-night," while it is assumed here that a low-quality firm is capable of earning complete-information profits. The dismissal of fly-by-night production seems sensible in the present context, especially if one thinks of the monopoly position as being acquired as a result of a major innovation. The distinction, however, is critical. The analysis below makes it clear that an export subsidy is attractive when a separating equilibrium ensues if the output sold by a low-quality monopolist exceeds that sold by a high-quality exporter. In the previous work, however, low-quality firms make no sales in separating equilibria, which is why previous authors point to possible benefits from export taxes.

A second literature to which this paper contributes is the study of price as a signal of quality. In particular, Paul Milgrom and John Roberts (1986) and Michael H. Riordan and I (Bagwell and Riordan, 1991) have previously established that cost considerations can enable high prices to signal high quality. This paper extends this insight by considering general demand functions and endogenizing the choice of product quality.

The paper proceeds with the development of a basic model of price and quality in Section I. Possibilities for export policy are developed in Section II, and conclusions are presented in Section III.

[2]An export subsidy will also reduce the probability of a high-quality selection. This effect acts to reduce import-country welfare, *if* consumers prefer the high-price, high-quality good. Correspondingly, it is difficult to say at a general level whether an export subsidy improves global welfare.

[3]The Grossman-Horn model is in fact concerned with infant-industry protection but is easily reinterpreted in terms of export policy. See also the interesting paper by Wolfgang Mayer (1984), who focuses on export policy in the presence of country-specific quality reputations. A more extensive literature survey is provided in my discussion paper (Bagwell, 1990).

## I. A Model of Price and Quality

### A. *The Game*

Consider a monopolist exporting a new product. The firm makes a once-and-for-all choice of product quality, $q$, where $q$ may be low or high (i.e., $q \in \{L, H\}$). The product then passes through two phases. In the introductory phase of the product's life, consumers lack information about the product's quality. They therefore use the monopolist's price, $P$, to form beliefs, $b = b(P)$, as to the probability that the product is of high quality. Upon entering the mature phase, however, consumers know quality from previous experience or by reading quality reviews.

The monopolist's introductory-phase profit function is described as follows. Let $D(P,b) \geq 0$ be the continuous demand function facing the exporter when it charges the price $P$ and faces the belief $b$. When $D(P,b) > 0$, assume only that it is differentiable, decreasing in $P$, and increasing in $b$. The constant unit costs of producing a product of quality $q$ are denoted by $c(q)$, where $c(H) > c(L) > 0$ captures the notion that quality is costly. With this, the introductory-phase profit function for a monopolist with quality $q$ is

$$\Pi(P, c(q), b) \equiv [P - c(q)]D(P,b).$$

It is useful to assume further both that $\Pi(P, c(q), b)$ is concave in $P$ (where demand is positive) and that a reservation price $\tilde{P} > c(H)$ exists at which $\Pi(\tilde{P}, c(q), 1) = 0$.

The exporter's introductory-phase monopoly price depends upon beliefs and costs (quality). The function $P(c(q), b)$ is thus used to denote the monopoly price of a quality-$q$ monopolist facing the belief $b$; that is, $P(c(q), b)$ is the unique maximizer of $\Pi(P, c(q), b)$. Assume that $P(c(q), b)$ is differentiable and increasing in its arguments. To avoid the possibility of fly-by-night production, assume also that

$$\Pi(P(c(q), b), c(q), b) > 0.$$

Finally, it is important to ensure that a high-quality exporter must distort its price to signal its quality. As will be seen below, this is guaranteed under the following assumption:

$$(1) \quad \Pi(P(c(H),1), c(L), 1) > \Pi(P(c(L),0), c(L), 0).$$

This assumption will be satisfied provided $c(H) - c(L)$ is not too large.

Absent the possibility of mature-phase profits, the model provides no means of motivating a high-quality selection. Since $c(H) > c(L)$, a monopolist choosing a high-quality product could always increase introductory-phase profits by maintaining its price selection and "surprising" consumers with a low-quality product. Thus, the principal role for the mature phase in this game is to provide a possible source of high-quality incentives.

The mature-phase profit function is represented quite generally as $\tilde{\Pi}(q, x)$. Recall that in this phase consumers know quality; the variable $q$ is then included to reflect the fact that costs and (complete-information) demands will differ across qualities. The variable $x$ is taken to be random, with support $[\underline{x}, \bar{x}]$ and with differentiable density and distribution functions, $f$ and $F$, respectively.

There are many interpretations for $x$. For example, it may represent the ratio of (exogenous) growth rates for high- and low-quality demand functions. A higher $x$ would then correspond to a market within which high-quality-product demand grows relatively quickly. Similarly, $x$ may describe the evolution of input prices; a large $x$ in this context means that the price of inputs used in high-quality production increases relatively slowly. These interpretations motivate the assumption that $\tilde{\Pi}(H, x) - \tilde{\Pi}(L, x)$ is differentiable and increasing in $x$.[4] Assume

[4] A referee has suggested another interpretation: $x$ may describe the ratio of setup costs for the high- and low-quality monopolist. The basic conclusions of the paper are consistent with this interpretation, provided

further that $\tilde{\Pi}(t,x)>0$ for all $t$ and $x$ and that neither quality type always yields greater future profit:

$$\tilde{\Pi}(\mathrm{H},\bar{x})-\tilde{\Pi}(\mathrm{L},\bar{x})>0$$
$$\equiv \tilde{\Pi}(\mathrm{H},\tilde{x})-\tilde{\Pi}(\mathrm{L},\tilde{x})$$
$$>\tilde{\Pi}(\mathrm{H},\underline{x})-\tilde{\Pi}(\mathrm{L},\underline{x}).$$

Here, $\tilde{x}\in(\underline{x},\bar{x})$ is the unique value of $x$ at which future high- and low-quality profits are equal.

A formal description of the game is now possible. The game begins when "nature" chooses a value for $x$ using the density $f(x)$. Quite plausibly, an exporter will have superior information about the market's evolution, and so it is assumed here that the exporter is privately informed of nature's selection. Thus, the game is characterized by incomplete information (adverse selection), and the exporter's "type" is the value of $x$ that it observes. Having learned $x$, the exporter next simultaneously chooses a price and a quality; these (pure) strategies are denoted as $P=P(x)$ and $q=q(x)$. Consumers in the initial phase observe $P$ but not $q$, indicating that the game also has imperfect information (moral hazard). Upon seeing $P$, consumers form some belief, $b=b(P)$, as to the probability that the quality selection is high.

The primary role for $x$ is to provide incentives for quality selection. Notice in particular that introductory-phase (mature-phase) profits are independent of $x$ ($P$). Thus, there is no direct interaction between $P$ and $x$. For this reason, it seems natural to focus on equilibria in which price depends on $x$ only insofar as $x$ determines quality (and thus costs). That is, attention is restricted to equilibria in which the price is the same for any two values of $x$ that induce the same quality selection.[5]

Following David M. Kreps and Robert Wilson (1982), an equilibrium for this game is a collection of strategies and beliefs, $\{\hat{P}(x),\hat{q}(x),\hat{b}(P)\}$. Consider first the requirements for equilibrium strategies. The restriction may be formalized as

$$(2)\quad \hat{P}(x_1)=\hat{P}(x_2)\quad \text{whenever } \hat{q}(x_1)=\hat{q}(x_2).$$

Next, for every $x$, the exporter's choices must be profit-maximizing, given the consumers' beliefs:

$$(3)\quad \hat{P}(x),\hat{q}(x)\in \operatorname*{argmax}_{P,q}\left[\Pi\left(P,c(q),\hat{b}(P)\right)+\tilde{\Pi}(q,x)\right].$$

Before defining Bayesian beliefs, it is convenient to note two implications of (3). First, assuming that $\tilde{\Pi}(\mathrm{H},\bar{x})-\tilde{\Pi}(\mathrm{L},\bar{x})$ and $\tilde{\Pi}(\mathrm{L},\underline{x})-\tilde{\Pi}(\mathrm{H},\underline{x})$ are sufficiently large, (3) guarantees that $\hat{q}(x)=\mathrm{H}$ for an interval of $x$ near $\bar{x}$ and $\hat{q}(x)=\mathrm{L}$ for an interval of $x$ near $\underline{x}$. Thus, both low- and high-quality products have a positive probability of selection. Second, (3) further implies that the set of $x$'s can be broken into exactly two intervals, separated by some critical $\hat{x}$, with large $x$'s generating a high-quality selection and low $x$'s inducing a low-quality selection:

LEMMA: *Given any arbitrary belief function $\hat{b}(P)$, if strategies satisfy* (3), *then there exists a unique $\hat{x}\in(\tilde{x},\bar{x})$ such that $\hat{q}(x)=\mathrm{H}$ for $x>\hat{x}$ and $\hat{q}(x)=\mathrm{L}$ for $x<\hat{x}$.*

that $\tilde{\Pi}(t,x)$ is not too negative and marginal costs continue to increase in quality.

[5]The restriction does preclude a variety of equilibria. For example, the restriction is inconsistent with equilibria in which a low-quality monopolist sometimes selects its monopoly price and sometimes selects a higher, pooling price while a high-quality monopolist sometimes picks the pooling price and sometimes picks an even higher, separating price. The arguments developed in this paper, however, may be extended to establish that all equilibria failing the restriction also fail the "intuitive criterion" (In-Koo Cho and David M. Kreps, 1987). Thus, the restriction may be regarded as a natural requirement, which in addition serves to simplify exposition.

Intuitively, $\hat{x} > \tilde{x}$, since at $x = \tilde{x}$ mature-phase profits are quality-independent. Thus, $\hat{q}(\tilde{x}) = \mathbf{L}$ must occur, given that profits are higher for low-quality production in the introductory phase. A complete proof is straightforward and is provided in my discussion paper (Bagwell, 1990).[6]

Using (2) and the lemma, a simple representation of Bayesian beliefs may now be provided:

(4) if $x_1 < \hat{x} < x_2$, then

(i) $\hat{P}(x_1) = \hat{P}(x_2)$ implies

$$\hat{b}\big(\hat{P}(x_1)\big) = 1 - F(\hat{x})$$

(ii) $\hat{P}(x_1) \neq \hat{P}(x_2)$ implies

$$\hat{b}\big(\hat{P}(x_1)\big) = 0 < 1 = \hat{b}\big(\hat{P}(x_2)\big).$$

Thus, whether *pooling* $[\hat{P}(x_1) = \hat{P}(x_2)]$ or *separation* $[\hat{P}(x_1) \neq \hat{P}(x_2)]$ occurs, beliefs exhibit rational expectations. An *equilibrium* for this game is now defined as a set of strategies and beliefs satisfying (2), (3), and (4).

As beliefs are unrestricted for off-the-equilibrium-path prices [$P$ such that for all $x$, $P \neq \hat{P}(x)$], a wide variety of equilibria exist. Thus, following Cho and Kreps (1987), it is important to refine the equilibrium concept and define "intuitive" equilibria for the new game. To this end, a strategy $(P, q)$ is said to be *equilibrium-dominated* for $x$ (i.e., a monopolist with information $x$) if $P$ is off the equilibrium path and

$$\max_b \left[\Pi(P, c(q), b) + \tilde{\Pi}(q, x)\right] < \Pi\big(\hat{P}(x), c(\hat{q}(x)), \hat{b}\big(\hat{P}(x)\big)\big) + \tilde{\Pi}(\hat{q}(x), x)$$

where the right-hand side of this expression is simply $x$'s equilibrium profit. It is now useful to impose a minor restriction on the strategy space by eliminating any strategy in which $P < c(q)$. Notice that any such strategy is strictly dominated by a strategy in which $P > c(q)$.[7] With this, it is straightforward to see that $(P, q)$ is equilibrium-dominated for $x$ exactly when

(5) $$\Pi(P, c(q), 1) + \tilde{\Pi}(q, x) < \Pi\big(\hat{P}(x), c(\hat{q}(x)), \hat{b}\big(\hat{P}(x)\big)\big) + \tilde{\Pi}(\hat{q}(x), x).$$

The philosophy here is that consumers should believe that equilibrium-dominated strategies are never selected, as a firm could never improve upon equilibrium profit with such a strategy. If consumers reason in this fashion, then the observation of a disequilibrium price $P$ that is (i) equilibrium-dominated for all $x$ in conjunction with a particular quality choice and (ii) not equilibrium-dominated for some $x$ in conjunction with the alternative quality choice must convince consumers that the latter quality choice has been made (and that one of the corresponding $x$'s has been generated). In this way, the process of eliminating equilib-

[6] Thus, if strategies satisfy (3), then the probability that consumers attach to a high-quality selection (prior to observing prices) is endogenous and equal to $1 - F(\hat{x}) \in (0, 1)$. This feature of the model is distinct from models with only incomplete or imperfect information. In the traditional incomplete-information model, the prior probability of a high-quality selection is exogenously given by "nature." By contrast, if the model had only imperfect information as to the quality choice, then in equilibrium consumers would correctly anticipate the quality choice, and so the prior probability of a high-quality selection would be degenerate at zero or unity.

[7] This follows since future profits are independent of current prices. The extra restriction is required for equivalence with (5), since otherwise (5) might hold for some pair $(P, q)$ that is not equilibrium-dominated. This occurs only when $\tilde{\Pi}(q, x) > \tilde{\Pi}(\hat{q}(x), x)$.

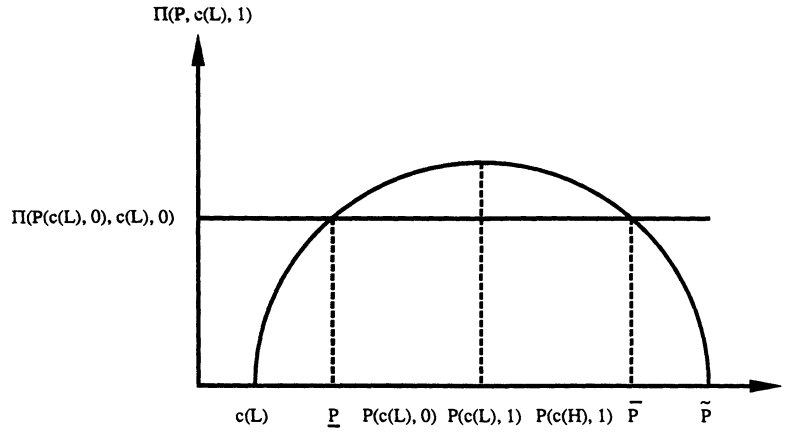


FIGURE 1. INTRODUCTORY-PHASE PRICES AND PROFITS

rium-dominated strategies can place structure on disequilibrium beliefs. Formally, an equilibrium is now said to be *intuitive* if

(6) if, for all $x$, $P \neq \hat{P}(x)$, then

(i) $(P,\mathrm{L})$ is equilibrium-dominated for all $x$ while $(P,\mathrm{H})$ is not implies $\hat{b}(P)=1$

(ii) $(P,\mathrm{H})$ is equilibrium-dominated for all $x$ while $(P,\mathrm{L})$ is not imples $\hat{b}(P)=0$.

### B. *The Unique Intuitive-Equilibrium Outcome*

Before stating the main theorem of the section, it is necessary to define $\underline{P}$ and $\bar{P}$, with $\underline{P} < P(c(\mathrm{L}),1) < \bar{P}$, as the roots to the following equation:

(7) $$\Pi(P,c(\mathrm{L}),1) = \Pi(P(c(\mathrm{L}),0),c(\mathrm{L}),0).$$

Notice that $\tilde{P} > \bar{P} > P(c(\mathrm{H}),1)$ under the positive-profit assumption and (1). Further, $c(\mathrm{L}) < \underline{P} < P(c(\mathrm{L}),0)$ is easily established. These relationships are depicted in Figure 1.

THEOREM: *There exists a unique intuitive-equilibrium outcome, and in it* $\hat{P}(x)=\bar{P}$ *and* $\hat{q}(x)=\mathrm{H}$ *for* $x > \hat{x}$, *and* $\hat{P}(x)=P(c(\mathrm{L}),0)$ *and* $\hat{q}(x)=\mathrm{L}$ *for* $x < \hat{x}$, *where* $\hat{x} \in (\underline{x},\bar{x})$ *uniquely satisfies*

(8) $$\Pi(\bar{P},c(\mathrm{H}),1)+\tilde{\Pi}(\mathrm{H},\hat{x}) \equiv \Pi(P(c(\mathrm{L}),0),c(\mathrm{L}),0)+\tilde{\Pi}(\mathrm{L},\hat{x}).$$

Thus, in the focal equilibrium of the game, a firm that chooses to provide a high-quality export distorts its price upward $[\bar{P} > P(c(\mathrm{H}),1)]$, while a firm that exports a low-quality good chooses the complete-information monopoly price $[P(c(\mathrm{L}),0)]$ and, hence, does not distort its price.

To prove the theorem, it is useful to collect some observations about (intuitive) separating equilibria. A first observation is that, in any separating equilibrium, the low-quality monopolist does not distort its price. To see this, suppose that a separating equilibrium exists with some associated $\hat{x}$ and that $\hat{P}(x_1) \neq \underline{P}(c(\mathrm{L}),0)$ for $x_1 < \hat{x}$; (4) then ensures that $\hat{b}(\hat{P}(x_1))=0$, from which it follows that a monopolist with information $x_1$ would improve total profits by continuing to produce the low-quality export, but at the deviant price $P(c(\mathrm{L}),0)$. Mature-phase profits are unaltered by such a devia-

tion, while introductory-phase profits rise:

$$\begin{aligned}&\Pi(\hat{P}(x_1), c(\mathrm{L}), 0)\\ &\quad < \Pi(P(c(\mathrm{L}),0), c(\mathrm{L}), 0)\\ &\quad \le \Pi(P(c(\mathrm{L}),0), c(\mathrm{L}), \hat{b}(P(c(\mathrm{L}),0))).\end{aligned}$$

It may be concluded that the introductory-phase profit earned by a low-quality exporter in any separating equilibrium is $\Pi(P(c(\mathrm{L}),0), c(\mathrm{L}), 0)$.

A second observation is that the price selected by the high-quality exporter cannot fall in the set $(\underline{P}, \bar{P})$ in any separating equilibrium. The central idea is that the high-quality price must be sufficiently high or low that it does not invite mimicry by a low-quality exporter. To see this, suppose a separating equilibrium exists with some corresponding $\hat{x}$ and that $\hat{P}(x_2) \in (\underline{P}, \bar{P})$ for $x_2 > \hat{x}$. From (4), it must be that $\hat{b}(\hat{P}(x_2)) = 1$; but then, as illustrated in Figure 1, a low-quality exporter would be better off to deviate to the strategy $(\hat{P}(x_2), \mathrm{L})$, thus fooling introductory-phase consumers and leaving mature-phase profits unaltered.

These two observations place some structure on separating-equilibrium prices, but they do not indicate whether a high-quality selection will be signaled with a low price $(\hat{P}(x_2) \le \underline{P})$ or a high price $(\hat{P}(x_2) \ge \bar{P})$. To understand this issue better, it is important first to determine the preferred separating price for a high-quality exporter. Since (1) ensures that $\underline{P} < P(c(\mathrm{H}),1) < \bar{P}$, some distortion in the high-quality price is clearly necessary for separation. A high-quality exporter will desire to minimize this distortion, leading to the following comparison:

$$\begin{aligned}(9)\quad &\Pi(\bar{P}, c(\mathrm{H}), 1) - \Pi(\underline{P}, c(H), 1)\\ &= \Pi(\bar{P}, c(\mathrm{H}), 1) - \Pi(\underline{P}, c(\mathrm{H}), 1)\\ &\quad - \Pi(\bar{P}, c(\mathrm{L}), 1) + \Pi(\underline{P}, c(\mathrm{L}), 1)\\ &= (c(\mathrm{H}) - c(\mathrm{L}))(D(\underline{P}, 1) - D(\bar{P}, 1))\\ &> 0.\end{aligned}$$

Thus, the preferred separating price is the high price, $\bar{P}$. This preference is easily understood. As the low-quality monopolist is indifferent between $\underline{P}$ and $\bar{P}$, the high-quality monopolist must prefer to signal with $\bar{P}$. This is because demand is lower at the higher price, and higher-cost firms are more tolerant of demand reductions.

With this result in place, the third observation—that the high-quality price is $\bar{P}$ in any intuitive separating equilibrium—may be established. Suppose a separating equilibrium exists with corresponding $\hat{x}$ and that $\hat{P}(x_2) \ne \bar{P}$ for $x_2 > \hat{x}$. From (9), for $\varepsilon$ sufficiently small, the strategy $(\bar{P} + \varepsilon, \mathrm{H})$ is not equilibrium-dominated for $x_2$. By contrast, the strategy $(\bar{P} + \varepsilon, \mathrm{L})$ is equilibrium-dominated for all $x$. The simple idea is that a monopolist with information $x$ always has the option of pursuing the low-quality equilibrium strategy, $(P(c(\mathrm{L}),0), \mathrm{L})$; hence, a strategy like $(\bar{P} + \varepsilon, \mathrm{L})$, which can never improve upon the low-quality equilibrium strategy, must be equilibrium-dominated for all $x$. However, then (6) gives $\hat{b}(\bar{P} + \varepsilon) = 1$, and so a monopolist with information $x_2$ would deviate to $(\bar{P} + \varepsilon, \mathrm{H})$, thereby increasing introductory-phase profits without altering mature-phase profits.

It is worth emphasizing the process through which the high price $\bar{P}$ is used to signal high quality. The key point is that high prices restrict sales and thereby deter mimicry by the low-quality exporter. In fact, using (7) and $\bar{P} > P(c(\mathrm{L}),0)$, it is immediate that

$$(10)\quad D(P(c(\mathrm{L}),0),0) > D(\bar{P},1).$$

Intuitively, if a low-quality monopolist is to be indifferent between various price–belief combinations, then the higher-price possibilities must generate lower sales. Using the first and third observations, it follows that a high-quality exporter signals its quality by restricting its sales to a level lower than that of a low-quality exporter in any intuitive separating equilibrium. This finding will prove crucial when export policy analysis is addressed.

A fourth and final observation is that $\hat{x}$ is defined by (8) in any intuitive separating equilibrium. The high-price, high-quality

strategy is chosen precisely when it yields greater total profit than the low-price, low-quality strategy. Together, these observations establish that the only possible intuitive separating equilibrium outcome is that described in the theorem.

There are two remaining issues in completing the proof of the theorem. The first concerns the existence of an intuitive pooling equilibrium. It is established in the Appendix that such equilibria do not exist. The basic insight is that pooling equilibria fail to be intuitive, since a high-quality exporter can profitably distinguish itself with a deviation to a higher price and the concomitant lower sales volume.[8] The final issue involves the existence of an intuitive separating equilibrium. For example, it must be proved that the high-quality exporter is willing to incur the distortion associated with separation. Fortunately, as shown in the Appendix, the high-quality exporter is indeed willing to separate, and moreover, the outcome described in the theorem can be supported by an intuitive separating equilibrium.

Thus, the model admits a single intuitive-equilibrium outcome, and this outcome is characterized by an upward distortion in the high-quality price and no distortion in the low-quality price.[9] The distorted high-quality price deters a low-quality firm from misrepresenting itself as a high-quality firm, while the variability of mature-phase profits causes the monopolist sometimes to select a high-quality product.

[8]The nonexistence of intuitive pooling equilibria contrasts with the findings reported in Bagwell and Staiger (1989) and Grossman and Horn (1988). The special assumption of previous work appears to be that demand is perfectly inelastic, since this precludes a demand-reducing deviation for a high-quality firm. More generally, as I emphasize in my discussion paper (Bagwell, 1990), when demand is downward-sloping, a "single crossing property" holds for the product-quality model, and this in turn ensures that intuitive pooling (separating) equilibria do not (do) exist.

[9]If the low-quality good were fly-by-night, then the existence of a separating equilibrium would require explicit inclusion of an entry fee. In any intuitive separating equilibrium, only the high-quality monopolist would enter, and a distorted, high price would once more signal quality.

## II. Optimal Export Policy

Consider now the possibility that the government may subsidize or tax the new export. Denote an export policy by $s \in \mathbb{R}$, where $s > 0$ ($s < 0$) corresponds to an introductory-phase, specific export subsidy (tax). It is assumed that the government does not know quality or $x$ when $s$ is selected.[10]

Formally, a subsidy is modeled as a reduction in production costs: the unit cost of production when quality is $q$ and policy is $s$ is given by $c(q,s) \equiv c(q) - s$. Clearly, the assumptions and theorem discussed above apply as well to this set of cost functions, provided that consumers observe $s$ and that $c(\mathrm{L}) \geq s$. Note in particular that $c(\mathrm{H},s) - c(\mathrm{L},s) = c(\mathrm{H}) - c(\mathrm{L}) > 0$. In general, one can view $s$ as a suppressed parameter in the above analysis.

A unique intuitive-equilibrium outcome therefore exists for a given $s$. This equilibrium is characterized by $\hat{P}(x) = \bar{P}(s)$ and $\hat{q}(x) = \mathrm{H}$ for $x > \hat{x}(s)$ and by $\hat{P}(x) = P(c(\mathrm{L},s),0)$ and $\hat{q}(x) = \mathrm{L}$ for $x < \hat{x}(s)$, where $\bar{P}(s) > P(c(\mathrm{H},s),1)$ and $\hat{x}(s)$ are respectively defined by

$$(11)\quad \Pi\big(\bar{P}(s), c(\mathrm{L},s), 1\big) \equiv \Pi\big(P(c(\mathrm{L},s),0), c(\mathrm{L},s), 0\big)$$

$$(12)\quad \Pi\big(\bar{P}(s), c(\mathrm{H},s), 1\big) + \tilde{\Pi}(\mathrm{H}, \hat{x}(s)) \equiv \Pi\big(P(c(\mathrm{L},s),0), c(\mathrm{L},s), 0\big) + \tilde{\Pi}(L, \hat{x}(s)).$$

Note that $\bar{P}(s) = \bar{P}$ when $s = 0$. In order to simplify notation, $\hat{P}(\mathrm{H},s) \equiv \bar{P}(s)$ and $\hat{P}(\mathrm{L},s) \equiv P(c(\mathrm{L},s),0)$ are used to represent

[10]This is a plausible assumption. In Grossman and Horn (1988) and in Bagwell and Staiger (1990), it is also assumed that the government is uninformed of quality. Notice further that there is no need to consider mature-phase subsidies, assuming that the government is unable to commit to such a subsidy during the introductory phase. Once the mature-phase is entered, quality is known, and no role for a subsidy arises.

the high- and low-quality equilibrium prices, respectively.

Export-country welfare is defined as the expected value of producer surplus plus government revenue. Letting $W(s)$ denote export-country welfare,

$$W(s) = \int_{\underline{x}}^{\hat{x}(s)} f(x)\left[\Pi\left(\hat{P}(\mathrm{L},s),c(\mathrm{L},s),0\right) + \tilde{\Pi}(\mathrm{L},x) - sD\left(\hat{P}(\mathrm{L},s),0\right)\right] dx + \int_{\hat{x}(s)}^{\bar{x}} f(x)\left[\Pi\left(\hat{P}(\mathrm{H},s),c(\mathrm{H},s),1\right) + \tilde{\Pi}(\mathrm{H},x) - sD\left(\hat{P}(\mathrm{H},s),1\right)\right] dx.$$

Simple rearranging gives

$$(13)\quad W(s) = \int_{\underline{x}}^{\hat{x}(s)} f(x)\left[\Pi\left(\hat{P}(\mathrm{L},s),c(\mathrm{L}),0\right) + \tilde{\Pi}(\mathrm{L},x)\right] dx + \int_{\hat{x}(s)}^{\bar{x}} f(x)\left[\Pi\left(\hat{P}(\mathrm{H},s),c(\mathrm{H}),1\right) + \tilde{\Pi}(\mathrm{H},x)\right] dx.$$

Thus, the direct effect of a subsidy is simply a transfer from the government to the monopoly and has no welfare implications. Equivalently, welfare calculations are made relative to an unsubsidized cost function.

It is now convenient to define $b^0(s) \equiv 1 - F(\hat{x}(s))$ as the (endogenous) prior probability of high quality. With this, (13) may be rewritten as

$$(14)\quad W(s) = \left(1 - b^0(s)\right)\Pi\left(\hat{P}(\mathrm{L},s),c(\mathrm{L}),0\right) + b^0(s)\Pi\left(\hat{P}(\mathrm{H},s),c(\mathrm{H}),1\right) + \int_{\underline{x}}^{F^{-1}(1-b^0(s))} f(x)\tilde{\Pi}(\mathrm{L},x)\,dx + \int_{F^{-1}(1-b^0(s))}^{\bar{x}} f(x)\tilde{\Pi}(\mathrm{H},x)\,dx.$$

This formulation clearly shows that a subsidy may affect equilibrium prices and the probability of a high-quality selection; it is through these indirect channels that a role for policy may emerge.

As (14) indicates, export-country welfare is ultimately determined by the probability of a high-quality selection and the low- and high-quality prices. Thus, as a general matter, welfare may be written alternatively in the form $\tilde{W}(b^0, P^{\mathrm{L}}, P^{\mathrm{H}})$, where of course in the focal equilibrium $b^0 = b^0(s)$, $P^{\mathrm{L}} = \hat{P}(\mathrm{L},s)$, and $P^{\mathrm{H}} = \hat{P}(\mathrm{H},s)$; that is,

$$(15)\quad W(s) \equiv \tilde{W}\left(b^0(s), \hat{P}(\mathrm{L},s), \hat{P}(\mathrm{H},s)\right).$$

Optimal export policy may now be determined. Letting subscripts denote partial derivatives, observe that

$$(16)\quad W_s(s) \equiv \tilde{W}_{b^0}(\cdot)b_s^0(s) + \tilde{W}_{P^{\mathrm{L}}}(\cdot)\hat{P}_s(\mathrm{L},s) + \tilde{W}_{P^{\mathrm{H}}}(\cdot)\hat{P}_s(\mathrm{H},s).$$

In general, it is of interest to evaluate this expression when $s = 0$. If $W(s)$ is concave, this will indicate whether the optimal policy is a subsidy, a tax, or no intervention. Further, whether or not $W(s)$ is concave, it is desirable to know the effect of a small subsidy on welfare.

To begin, consider the effect of a subsidy on the high-quality price. Using (14) and (15) gives

$$(17)\quad \left[\tilde{W}_{P^{\mathrm{H}}}(\cdot)\hat{P}_s(\mathrm{H},s)\right]\Big|_{s=0} = \left[b^0(s)\Pi_P\left(\hat{P}(\mathrm{H},s),c(\mathrm{H}),1\right)\hat{P}_s(\mathrm{H},s)\right]\Big|_{s=0}.$$

This expression is easily understood. Note that $\hat{P}(\mathrm{H},s) \equiv \bar{P}(s) > P(c(\mathrm{H}),1)$ if $s$ is close to zero. Concavity of profits then gives that $\Pi_P(\hat{P}(\mathrm{H},s),c(\mathrm{H}),1) < 0$ for $s$ near zero. This means that (unsubsidized) high-quality profits would increase if price were distorted less. Thus, welfare increases with a small subsidy if the high-quality price thereby declines, that is, if $\hat{P}_s(\mathrm{H},s) < 0$ for $s$ near zero.

The next task is to compute $\hat{P}_s(\mathrm{H}, s)$. Using (11) yields

$$(18)\quad \hat{P}_s(\mathrm{H}, s) = \frac{D\big(\hat{P}(\mathrm{L}, s), 0\big) - D\big(\hat{P}(\mathrm{H}, s), 1\big)}{\Pi_P\big(\hat{P}(\mathrm{H}, s), c(\mathrm{L}, s), 1\big)}.$$

Note that the denominator in (18) is negative since $\hat{P}(\mathrm{H}, s) > P(c(\mathrm{L}, s), 1)$. The welfare effect of the change in high-quality price induced by an export subsidy therefore hinges precisely on whether the high- or low-quality monopolist sells more in equilibrium:

$$(19)\quad \operatorname{sign}\big[\tilde{W}_{P\mathrm{H}}(\cdot)\hat{P}_s(\mathrm{H}, s)\big]\big|_{s=0} = \operatorname{sign}\big[D(\hat{P}(\mathrm{L}, s), 0) - D(\hat{P}(\mathrm{H}, s), 1)\big]\big|_{s=0}.$$

This result has a simple intuition. If a subsidy is to reduce the high-quality price, then it must be that the low-quality monopolist becomes less willing to mimic the original high-quality price after the subsidy is imposed. In other words, the subsidy must introduce some slack into the signaling process, enabling the high-quality exporter to signal its quality with a lower price. Now, if $D(\hat{P}(\mathrm{L}, s), 0) - D(\hat{P}(\mathrm{H}, s), 1) > 0$ at $s = 0$, then equilibrium sales are highest for the low-quality monopolist. Equivalently, the low-quality monopolist sells more units under its equilibrium strategy than when it mimics the high-quality price. A slight subsidy to all units sold would thus reduce the attractiveness of the mimic strategy. This would in turn make possible a lower high-quality price, contributing to a rise in welfare. Recall now from (10) that the low-quality monopolist indeed does have greater sales in equilibrium. Thus, a slight per-unit subsidy differentially rewards the low-quality strategy, thereby lowering the high-quality pricing distortion and raising export-country welfare.[11]

[11]Note that sales are largest for the high-quality firm when the low-quality good is fly-by-night, as is assumed in previous work. In this case, a subsidy differentially rewards the high-quality strategy, forcing a greater distortion in the high-quality price. See also footnote 9.

Consider next the effect of the subsidy on the low-quality price. Using (14) and (15), this is given by

$$(20)\quad \big[\tilde{W}_{P\mathrm{L}}(\cdot)\hat{P}_s(\mathrm{L}, s)\big]\big|_{s=0} = \big[(1 - b^0(s))\Pi_P(\hat{P}(\mathrm{L}, s), c(\mathrm{L}), 0)\hat{P}_s(\mathrm{L}, s)\big]\big|_{s=0}$$

but of course $\Pi_P(\hat{P}(\mathrm{L}, s), c(\mathrm{L}), 0) = 0$ at $s = 0$, since $\hat{P}(\mathrm{L}, s) \equiv P(c(\mathrm{L}, s), 0)$. A small subsidy will reduce the low-quality price but has no first-order effect on unsubsidized, low-quality profits, since the low-quality monopolist is then pricing very close to its true (undistorted) monopoly price, $P(c(\mathrm{L}), 0)$.

Finally, the effect of a subsidy on the quality-selection process must be examined. Using (14) and (15), one can easily derive that

$$(21)\quad \big[\tilde{W}_{b^0}(\cdot)b_s^0(s)\big]\big|_{s=0} = \Big[\big\{\Pi\big(\hat{P}(\mathrm{H}, s), c(\mathrm{H}), 1\big) + \tilde{\Pi}(H, \hat{x}(s)) - \Pi\big(\hat{P}(\mathrm{L}, s), c(\mathrm{L}), 0\big) - \tilde{\Pi}(\mathrm{L}, \hat{x}(s))\big\}b_s^0(s)\Big]\Big|_{s=0}$$

but this, too, is zero, by the definition of $\hat{x}(s)$ given in (12). Again, the result is intuitive. For $s$ near zero, the monopolist's comparison of subsidized low- and high-quality profits is nearly identical to a social planner's comparison of unsubsidized low- and high-quality profits. Thus, for the given equilibrium prices, quality selections are undistorted when $s = 0$. A small subsidy will induce only a second-order welfare loss from introducing distortions in the quality-selection process.

Summarizing, (16), (19), (20), and (21) imply that

$$(22)\quad \operatorname{sign}\big[W_s(s)\big]\big|_{s=0} = \operatorname{sign}\Big[D\big(\hat{P}(\mathrm{L}, s), 0\big) - D\big(\hat{P}(\mathrm{H}, s), 1\big)\Big]\Big|_{s=0} > 0.$$

$$(23) \qquad \hat{x}_s(s) = \frac{\hat{P}_s(\mathrm{H},s)\left[\Pi_P(\hat{P}(\mathrm{H},s),c(\mathrm{L},s),1) - \Pi_P(\hat{P}(\mathrm{H},s),c(\mathrm{H},s),1)\right]}{\tilde{\Pi}_x(\mathrm{H},\hat{x}(s)) - \tilde{\Pi}_x(\mathrm{L},\hat{x}(s))}$$

A small export subsidy reduces the distortion in the high-quality price, which provides a first-order benefit to export-country welfare and introduces distortions into the low-quality price and the product-quality selection process, which generate only second-order losses to export-country welfare. It may be concluded that a small export subsidy raises export-country welfare.[12,13]

Finally, as a practical matter, it may be important to determine whether a subsidy increases or decreases the probability of high-quality selection. Certainly, this issue is important to foreign consumers and hence to import-country welfare, for example. This section is thus concluded with the demonstration that $b_s^0(s) < 0$ (i.e., an export subsidy decreases the probability of a high-quality export).

To see this, note that $b_s^0(s) = -f(\hat{x}(s))\hat{x}_s(s)$ so that $b_s^0(s)$ and $\hat{x}_s(s)$ take opposite signs. Next, implicitly differentiating (12) and using (18) yields equation (23), above. The bracketed term in (23) is negative, since a higher-cost firm values a price increase more. Using (18) then gives

$$(24) \quad \mathrm{sign}[\hat{x}_s(s)] = \mathrm{sign}\left[D(\hat{P}(\mathrm{L},s),0) - D(\hat{P}(\mathrm{H},s),1)\right].$$

Thus, arguing as above, it follows that $\hat{x}_s(s) > 0$, since equilibrium sales must be larger under the low-quality pricing strategy. A subsidy therefore causes a distortion into low-quality production (i.e., a subsidy raises the probability that a low-quality good will be produced).

This result may appear immediate, since the total subsidy receipt is necessarily greater under the high-sales, low-quality strategy. On the other hand, however, the subsidy does have a first-order indirect effect on high-quality profits by reducing the extent of pricing distortion [recall that $\hat{P}_s(\mathrm{H},s) < 0$)]. The critical point is that the size of this latter effect is in fact determined by the willingness of a low-quality monopolist to mimic higher prices [i.e., (18) is derived from (11)]. Since a lower-cost, lower-quality monopolist is more attracted to price reductions than is a higher-cost, higher-quality monopolist, the extent of the reduction in a high-quality monopolist's pricing distortion is severely limited.

## III. Conclusion

This paper considers the role for specific export subsidies as a means to enhance export-country welfare in a new-product industry. Export subsidies reduce the prices of low- and high-quality exports and increase the probability of a low-quality export. The key finding is that only the high-quality price is initially distorted, as a consequence of product quality signaling. The low-quality price and the product-selection process are undistorted in the absence of policy. Thus, an export subsidy provides a first-order benefit to export-country welfare by reducing

[12]This conclusion also holds if the export country uses ad valorem subsidies. The key point is that a low-quality exporter has greater equilibrium total revenue than does a high-quality exporter; thus, a small ad valorem subsidy is especially beneficial to a low-quality monopolist, and so high quality may be signaled with a less-distorted, high price.

[13]It is important to consider whether signaling costs might be reduced without government intervention. For example, a monopolist might increase its expected profit by choosing a cost technology with low marginal and high fixed costs, if it is assumed that (i) the cost-technology selection is commonly known to precede the monopolist's observation of $x$ and (ii) foreign consumers observe the cost-technology selection. These are unattractive assumptions, however, as it seems much more reasonable to posit that the export-country government lacks information about $x$ and selects an export policy that is observable to foreign consumers.

the distortion in high-quality prices and causes only second-order losses to welfare by introducing distortions in low-quality prices and the selection of quality.

There are several extensions that might be considered. One possibility is to extend the model to allow for a continuum of quality types. The basic results derived above should hold in such a model, provided that marginal cost is increasing in quality and all qualities are capable of earning complete-information profits.[14]

Second, it would be interesting to extend the model to a multiperiod framework. A reasonable assumption is that the fraction of consumers who are informed of a product's quality is initially very low and then increases gradually through time. In Bagwell and Riordan (1991), we employ this assumption and demonstrate that a high-quality monopolist can signal quality with a high price that becomes less distorted as the market evolves. In the current context, the important point is that the high-quality price may be distorted upward over a considerable period of time. This in turn implies a possible role for a somewhat persistent export-subsidy program.

A third and very important extension is to examine modeling structures in which a low price signals a high-quality export. Suppose, for example, that the design and R&D costs associated with a high-quality export are large but that the marginal costs of high-quality production are relatively small. In this case, a low price and the corresponding large sales volume will signal high quality, and so it follows that an export subsidy will necessitate an even greater pricing distortion. A role for export policy still exists in this situation, but the optimal policy is now an export *tax*. Thus, while there is a robust role for export policy in markets with asymmetric information, the optimal policy is not always an export subsidy.[15] This example suggests that export subsidies are best suited for industries in which product quality is especially sensitive to the quality of raw materials, as one can reasonably expect marginal costs to increase with product quality in such industries.

Finally, it has been assumed throughout that consumers observe the level of export subsidies. It would be interesting to relax this strong assumption.[16] One intriguing possibility is that consumers may associate a particular country with the frequent subsidization of exports, while not knowing exactly which products are actually subsidized. In this setting, a country's reputation for export subsidization might be beneficial, since it promotes the (rational) perception that high-quality products can be exported from this country at relatively low prices.

## APPENDIX

It is first shown that intuitive pooling equilibria do not exist. Suppose that $\hat{P}(x_1) = \hat{P}(x_2) = P^{\mathrm{P}}$ with $\hat{q}(x_1) = \mathrm{L}$ and $\hat{q}(x_2) = \mathrm{H}$. Note that introductory-phase profits must be positive for every $x$, lest a deviation occur to $(P(c(\hat{q}(x)),0),\hat{q}(x))$ which ensures positive introductory-phase profits and maintains mature-phase profits. This in turn implies that $P' > \max[P^{\mathrm{P}}, P(c(\mathrm{L}),1)]$ can be found for which

$$(\mathrm{A1}) \quad \Pi(P', c(\mathrm{L}), 1) = \Pi(P^{\mathrm{P}}, c(\mathrm{L}), \hat{b}(P^{\mathrm{P}})).$$

[14]This conjecture draws from Garey Ramey's (1987) findings. He analyzes a continuum-type monopoly model and shows that prices are distorted upward for all but the lowest-quality monopolist. He also finds that equilibrium sales levels are again decreasing in quality. If one goes further and assumes that lower-quality types are fly-by-night, a trade-off arises, since an export subsidy reduces (increases) the distortion required for separation among efficient types (from inefficient types). A good conjecture is that the optimal policy then combines an export subsidy with a minimum-quality standard for exports. The standard eliminates the possibility of fly-by-night exports but does presume partial quality observability.

[15]An export tax might also emerge in alternative games. For example, if the exporter is signaling its marginal cost to foreign entrants, along the line of Milgrom and Roberts (1982), then an export tax reduces the pricing distortion of the low-cost exporter.

[16]Similarly, the assumption that consumers know marginal cost levels is strong. Work by Scott Davis (1990) suggests that the basic conclusions may go through if consumers lack precise information about marginal costs but recognize that higher-quality products tend to have higher marginal costs.

Following the procedure used in (9), (A1) may be added to the left-hand side below to give

$$\begin{aligned}(\text{A2})\quad &\Pi(P',c(\text{H}),1)-\Pi(P^{\text{P}},c(\text{H}),\hat{b}(P^{\text{P}}))\\ &=[c(\text{H})-c(\text{L})](D(P^{\text{P}},\hat{b}(P^{\text{P}}))\\ &\quad -D(P',1))\\ &>0\end{aligned}$$

where the final inequality follows from $P' > P^{\text{P}}$ and (A1).

Using (A2), the strategy $(P'+\varepsilon,\text{H})$ for $\varepsilon$ small and positive is clearly not equilibrium-dominated for $x_2$. Observe, however, that the strategy $(P'+\varepsilon,\text{L})$ is equilibrium-dominated for every $x$. Again, the idea is that a monopolist with information $x$ has the option of using the low-quality equilibrium strategy, $(P^{\text{P}},\text{L})$, and so a strategy such as $(P'+\varepsilon,\text{L})$, which by (A1) is always inferior to the low-quality equilibrium strategy, must be equilibrium-dominated for all $x$. Thus, it follows from (6) that $\hat{b}(P'+\varepsilon)=1$; but then (A2) indicates that $x_2$ deviates to $(P'+\varepsilon,\text{H})$, which increases (does not alter) introductory-phase (mature-phase) profits.

Next, the existence of an intuitive separating equilibrium is established. To begin, specify beliefs by putting $\hat{b}(P)=1$ for $P\notin[\underline{P},\bar{P})$ and $\hat{b}(P)=0$ otherwise. These beliefs satisfy (4) and (6), if the low-quality (high-quality) price is $P(c(\text{L}),0)$ $(\bar{P})$. With $\hat{x}$ defined by (8), it is clear from (7) that $x_1<\hat{x}$ will not deviate in price alone. Using (9), the only possible price deviation that might be attractive to $x_2>\hat{x}$ is $P(c(\text{H}),0)$.

To examine this possibility, note that it is straightforward to establish the existence of a price $P^*\in(\bar{P},\tilde{P})$ at which

$$\begin{aligned}(\text{A3})\quad &\Pi(P(c(\text{H}),0),c(\text{L}),0)\\ &\quad=\Pi(P^*,c(\text{L}),1).\end{aligned}$$

Using once more the procedure used in (9), (A3) may be added to the second difference below to give

$$\begin{aligned}(\text{A4})\quad &\Pi(\bar{P},c(\text{H}),1)\\ &\quad -\Pi(P(c(\text{H}),0),c(\text{H}),0)\\ &>\Pi(P^*,c(\text{H}),1)\\ &\quad -\Pi(P(c(\text{H}),0),c(\text{H}),0)\\ &=[c(\text{H})-c(\text{L})][D(P(c(\text{H}),0),0)\\ &\quad -D(P^*,1)]>0\end{aligned}$$

where the final inequality follows from $P^* > P(c(\text{H}),0)$ and (A3). Thus, $x_2$ will not deviate to the strategy $(P(c(\text{H}),0),\text{H})$.

It remains to show that the monopolist also has no incentive to deviate in quality (and perhaps price as well). For $x_1\le\hat{x}$, the best deviation of form $(P',\text{H})$ against the above beliefs is $(\bar{P},\text{H})$. [This uses (A4).] However,

$$\begin{aligned}&\tilde{\Pi}(\text{H},x_1)-\tilde{\Pi}(\text{L},x_1)\\ &\quad\le\tilde{\Pi}(\text{H},\hat{x})-\tilde{\Pi}(\text{L},\hat{x})\\ &\quad=\Pi(P(c(\text{L}),0),c(\text{L}),0)\\ &\quad\quad-\Pi(\bar{P},c(\text{H}),1)\end{aligned}$$

so this deviation is nonimproving. Finally, for $x_2>\hat{x}$, a best deviation of form $(P',\text{L})$ is $(P(c(\text{L}),0),\text{L})$. An exactly related argument reveals that this deviation is also nonimproving.

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