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OPTIMAL EXPORT POLICY FOR A NEW-PRODUCT MONOPOLY

by

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Abstract: 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, when product quality is policy-sensitive, 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.

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I. Introduction

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 establish conditions under which the optimal policy is an export subsidy.

The focus of the paper is on a monopolized industry structure in which further entry is unprofitable. This is of course an extreme case, but it seems well motivated. Since new-product export industries are often characterized by large fixed costs, a concentrated market structure is certainly plausible. Furthermore, entry decisions will be "lumpy" in such a setting, and this accounts for the dismissal of the effects of export policy on marginal entrants. An alternative motivation arises if the new product represents a significant innovation. In this case, the focus on a monopoly structure is justified, at least over the short run, given the possibility of substantial diffusion lags prior to the entry of other exporters.

Two models are considered. In each case, the monopolist sells a new product whose quality may be high or low, with each type of product capable of earning complete-information profits. The monopolist sells to a general demand function and has constant costs of production which increase in quality. The models are distinguished by the extent to which quality choices are flexible. In the first model, quality is exogenous and thus insensitive to trade policy. This model is appropriate if the quality choice is made prior to the enactment of export policy. The second model allows quality to be endogenously selected in response to export policy, so as to capture any distortions in quality selections that export policy might induce.

The fundamental result is that export subsidies play a welfare-enhancing role by reducing the extent of distortion in high-quality product prices. This new function for export subsidies is easily understood. When a monopolist exports a new product, consumers will use the product's price as a signal of its quality. Since lower-quality goods are less costly to produce, high prices which restrict demand are especially unattractive to a monopolist with a low-quality good. Thus, a high-quality exporter will use a high price to signal its quality, while a low-quality exporter will simply select its low-quality, monopoly price.[1] The key observation is that the monopolist's output will depend upon its price and thus its quality. In fact, it will be shown that a monopolist necessarily sells greater equilibrium output when its product quality is low. This means that a subsidy differentially benefits an exporter with a low-quality product.

Two implications follow. First, if the monopoly has a low-quality good, then its incentive to raise price (choke off demand) and misrepresent itself as a high-quality firm is reduced as the level of export subsidy increases. An export subsidy therefore enables an exporter with a high-quality product to signal its quality with a lower, less-distorted price. In this way, the export subsidy generates a welfare gain. Of course, the subsidy will also affect the low-quality price; however, since this price is initially undistorted, the welfare loss associated with inducing a pricing distortion when the monopolist sells a low-quality good is of second order importance. In general, export subsidization is beneficial because it promotes the perception that a high-quality good can be provided at a relatively low price. This summarizes the effect of an export subsidy when quality is exogenous.

The second implication concerns quality choice distortions that an export subsidy induces when quality is policy-sensitive. Since the subsidy benefits a low-quality producer most, the subsidy will cause low-quality goods to be selected more often than is optimal for the exporting country. This quality 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 improves the welfare of the exporting country by reducing the pricing distortion associated with high-quality products.

The ideas developed here are reminiscent of the "profit-shifting" role of export subsidies described by Brander and Spencer [1985]. A first difference is that Brander and Spencer argue that strategic commitment via export subsidies can be used to alter the output decisions of foreign firms. By contrast, in the present paper, export policy is used to change the initial conditions of a signaling game, with the goal of altering the beliefs of foreign consumers. An additional difference centers on foreign welfare. Export subsidization is a "beggar-thy-neighbor" policy in the Brander-Spencer world. In the current setting, however, the lower prices that subsidization generates will increase import-country welfare.[2]

This paper relates more directly to a small but growing literature on export policy when product quality information is asymmetric. Mayer [1984] has emphasized the informational externality that emerges when compatriot exporting firms share a common reputation. This possibility seems most pertinent for firms from Newly Industrialized Countries (NICs), who may not have internationally well-established brand names. Here, if consumers' expectations are initially pessimistic, sales by any one exporter imparts a positive externality to all other exporters from the same country. An export subsidy is then called for. Some limitations of this analysis are that consumers' expectations and firms' quality choices are not modeled explicitly.

Bagwell and Staiger [1989] and Grossman and Horn [1988] consider models with firm-specific reputations.[3] Product quality is exogenous in the Bagwell-Staiger model and endogenous in the Grossman-Horn model. In each case, low-quality firms are assumed to be "fly-by-night" exporters, selling products whose quality is so low that profits could not be made in a complete-information setting.

When pooling equilibria occur, where a common price is selected independent of product quality, the equilibrium level of sales is of course independent of quality. A subsidy therefore rewards low- and high-quality firms equally. In the Bagwell-Staiger model, an export subsidy can be beneficial if equilibrium sales are initially zero, by enabling the high-quality monopoly to profitably export at the pooling price. Grossman and Horn, by contrast, have multiple firms and positive equilibrium sales prior to a subsidy. A subsidy then has no effect on the decision to produce high- or low-quality goods for any firm, since a constant subsidy is received in any case. No intervention is optimal.[4] The present paper relaxes the previous assumptions of unit capacities and inelastic demands, and demonstrates for the monopoly model that a focus on pooling equilibria is ill-advised, since such equilibria fail to be "refined" in the general demand setting.

The other possibility is a separating equilibrium, where a firm's behavior signals its quality. Here, equilibrium sales levels--and thus total subsidy receipts--will vary with product quality. In fact, if low-quality products are fly-by-night, then low-quality firms will make no equilibrium sales, and consequently a subsidy makes the high-quality strategy relatively more attractive. As Bagwell and Staiger and especially Grossman and Horn discuss, an export subsidy then might be deleterious, as a greater distortion is required from a high-quality firm in order to credibly signal quality. The present paper relaxes the assumption of fly-by-night production and allows that a low-quality exporter also makes positive sales (i.e., receives subsidies) in separating equilibria. This seems an appropriate orientation, since the possibility of fly-by-night production by an innovative monopolist does not appear fundamental.[5] The finding is that a low-quality exporter then necessarily has a larger equilibrium sales level, and it is this observation that underlies the role for export subsidies developed herein.

A final literature to which this paper contributes is the study of price as a signal of quality. In particular, Bagwell and Riordan (forthcoming) have previously argued that high prices signal high quality by restricting the level of sales. The present paper generalizes their analysis, which assumes a linear demand and does not allow quality choice.

The plan of the paper is as follows. In section II, the exogenous-quality model is solved. This model provides a simple illustration of the price distortion effect. A more complex model with endogenous quality is considered in section III, where both price and quality distortions are examined. This section may have some independent, methodological interest--the Cho-Kreps' [1987] "intuitive criterion" is used to select among equilibria in a game with both moral hazard and adverse selection. Section IV concludes. Technical proofs are collected in an appendix.

II. A Model with Exogenous Quality

We begin with a very simple game in which quality is insensitive to export policy. This game is appropriate for situations in which a commitment to quality has been made prior to the selection of export policy. Analysis of this game also improves understanding, since many of the basic insights are most cleanly expressed in this setting. We proceed below by first defining and solving the game when export policy is suppressed. This provides a framework with which to subsequently evaluate export policies.

A. The Game

Consider a monopolist exporting a new product. The quality or type of the product, t, may be low or high; thus, $t \in \{L,H\}$. Since the product is new, consumers will lack information about the product's quality. They therefore will use the monopolist's price, P, to form beliefs, b=b(P), as to the probability that the product is of high quality. The monopolist is aware of this inferential process and may distort its price accordingly.

The monopolist's profit function is described as follows. Let D(P,b) be the demand function facing the exporter when it charges the price P and faces the belief b. Assume only that D(P,b) is differentiable, decreasing in P, and increasing in b. Let c(t) denote the constant unit costs of producing a product of quality t. We shall ignore fixed costs, by assuming they have been sunk previously. To capture the notion that quality is costly, assume c(H) > c(L) > 0. With this, the profit function for a monopolist of type t is given by:

$$\Pi(P,c(t),b) \equiv (P - c(t))D(P,b)$$

Observe that future profits (once quality is known) are ignored in this framework; this omission is without loss of generality when quality is exogenous. The model is amended to allow for future profits and endogenous quality in the next section.

The exporter's monopoly price will depend upon beliefs and costs (quality). To assure existence of such prices, assume $\Pi(P,c(t),b)$ is concave in P. It is also convenient to assume that a reservation price $\tilde{P} > c(H)$ exists at which $\Pi(\tilde{P},c(t),1) = 0$. Let us use P(c(t),b) to denote the monopoly price of a type-t monopolist facing the belief b, that is, P(c(t),b) is the unique maximizer of $\Pi(P,c(t),b)$. Assume P(c(t),b) is differentiable in its arguments. To avoid the possibility of fly-by-night production, assume also that $\Pi(P(c(t),b),c(t),b) > 0$.

Under these assumptions, it is a straightforward matter to verify that P(c(H),b) > P(c(L),b); that is, monopoly prices are increasing in costs.

Furthermore, if D(P,b) increases strongly enough in b, then P(c(t),b) is increasing in b.[6] Let us assume this property as well. Finally, we shall also assume that:

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

This means that a low-quality exporter would select the complete-information, high-quality monopoly price if it could thereby fool consumers. If this property were to fail, the analysis would be trivial, as an exporter with a high-quality product could signal its quality without distorting its price. The assumption will be satisfied provided c(H) - c(L) is not too large.

Formally, this situation is modeled as a standard, incomplete-information game. Let "nature" choose quality to be high or low, and let $b^{o} \in (0,1)$ be the prior probability that nature selects t=H. The monopolist is then privately informed as to nature's selection. An intuitive interpretation is that the exporter receives some signal of a future parameter state, and chooses quality prior to the resolution of parameter uncertainty. From this perspective, b^{o} represents the probability that the exporter receives a signal leading it to select high quality.

Let P(t) denote a pricing strategy for a type-t monopolist and b(P) denote a belief function for consumers. Using the sequential equilibrium concept [Kreps and Wilson, 1982], a combination of strategies and beliefs, $\{\hat{P}(H),\hat{P}(L),\hat{b}(P)\}$, forms an <u>equilibrium</u> if:

(E1) <u>Strategies are optimal given beliefs</u>

$$\hat{P}(t) \in \underset{P}{argmax}\, \Pi(P,c(t),\hat{b}(P))$$

(E2) Beliefs are Bayes-Consistent

(i) $\hat{P}(H) = \hat{P}(L)$ implies $\hat{b}(\hat{P}(H)) = b^{\circ}$

(ii) $\hat{P}(H) \neq \hat{P}(L)$ implies $\hat{b}(\hat{P}(H)) = 1 > 0 = \hat{b}(\hat{P}(L))$

Thus, whatever its type, the exporter must price so as to maximize profits, given the consumers' posterior belief function. Furthermore, beliefs must exhibit rational expectations, whether a pooling equilibrium ($\hat{P}(H) = \hat{P}(L)$) or a separating equilibrium ($\hat{P}(H) \neq \hat{P}(L)$) occurs. Notice that beliefs are not restricted off-the-equilibrium path (i.e., for $P \notin \{\hat{P}(L), \hat{P}(H)\}$), where Bayes' rule is inapplicable. As is well known, the arbitrariness of disequilibrium beliefs generate a multiplicity of equilibria.

A literature on refining equilibria with plausible standards on disequilibrium beliefs had thus emerged. We shall follow Cho and Kreps in focusing on intuitive equilibria.[7] A disequilibrium price P is said to be equilibrium dominated for a monopolist of type t if:

$$\max_{b} \Pi(P, c(t), b) < \Pi(\hat{P}(t), c(t), \hat{b}(\hat{P}(t))$$

In other words, a price P is equilibrium dominated, if, under the best possible belief, the monopolist earns less with this price than it would have earned by maintaining the equilibrium. For our game, it is straightforward to show that P is equilibrium dominated exactly when:

(2) $\Pi(P, c(t), 1) < \Pi(\hat{P}(t), c(t), \hat{b}(\hat{P}(t)))$.[8]

With this, an equilibrium is said to be <u>intuitive</u> if:

(E3) $\hat{b}(P) = 1(0)$ if $P \notin \{\hat{P}(L), \hat{P}(H)\}$ is equilibrium dominated for a low-quality (high-quality) monopolist and not equilibrium dominated for a high-quality (low-quality) monopolist.

The idea is that if a consumer sees a deviation which could only possibly improve upon equilibrium profit for a monopolist of one particular type, then the consumer should believe that the monopolist is indeed that type.

B. <u>The Unique Intuitive Equilibrium</u>

Consider now the possibility of a separating equilibrium. A first observation is that the low-quality exporter does not distort its price; i.e., $\hat{P}(L) = P(c(L),0)$. To see this, suppose instead that $\hat{P}(L) \neq P(c(L),0)$. But in that case:

$$\Pi(\hat{P}(L), c(L), 0) < \Pi(P(c(L),0), c(L), 0) \leq \Pi(P(c(L),0), c(L), \hat{b}(P(c(L),0)))$$

where the last inequality holds since $P(c(L),0) > c(L)$ and demand increases in b. It follows that the monopolist with a low-quality product would deviate to P(c(L),0). $\hat{P}(L) \neq P(c(L),0)$ violates (E1) in a separating equilibrium.

The low-quality exporter thus earns $\Pi(P(c(L),0),c(L),0)$ profit in a separating equilibrium. Clearly, such an exporter will accept this return only if higher profits cannot be achieved by mimicking the high-quality price and inducing the belief that quality is high. We are thus led to consider prices which will not be mimicked. To this end, define $\underline{P}$ and $\overline{P}$, with $\underline{P} < P(c(L),1) < \overline{P}$, as the roots to the following "no mimic" equation:

(3) $\quad \Pi(P,c(L),1) = \Pi(P(c(L),0),c(L),0)$

In any separating equilibrium, $\hat{P}(H) \notin (\underline{P},\overline{P})$ is necessary, lest mimicry occur. Notice that $\tilde{P} > \overline{P} > P(c(H),1)$ under (1) and our positive profit assumption. Further $c(L) < \underline{P} < P(c(L),0)$ is easily established. These relationships are captured in figure 1.

The focal separating equilibria can now be described.

<u>Theorem 1</u>: In any intuitive separating equilibrium, $\hat{P}(H) = \overline{P}$ and $\hat{P}(L) = P(c(L),0)$.

Thus, the high-quality exporter signals its quality with the high price, $\overline{P}$, while the low-quality exporter does not distort its price.

The formal proof of this theorem is provided in the appendix, but the core intuition is aptly captured in figure 2. Using (2) and (3), observe first that any $P \notin [\underline{P},\overline{P}]$ is equilibrium dominated for the low-quality monopolist, since such prices always yield profit below $\Pi(P(c(L),0),c(L),0)$. Further, as the low-quality monopolist is indifferent between $\underline{P}$ and $\overline{P}$, the high-quality monopolist must prefer to signal with $\overline{P}$. This is because demand is lower at the higher price, and higher-cost, higher-quality firms are more tolerant of demand reductions than are lower-cost, lower-quality firms. Putting all of this together and using (E3), it is now a simple matter to show that "intuitive deviations" can be used to destroy any separating equilibrium in which $\hat{P}(H) \neq \bar{P}$.[9]

Next, it is established that the intuitive separating equilibrium does in fact exist.

Theorem 2: There exists an intuitive separating equilibrium in which $\hat{P}(H) = \bar{P}$ and $\hat{P}(L) = P(c(L),0)$.

As discussed more fully in the appendix, the key difficulty in establishing existence is in proving that the high-quality monopolist is unwilling to deviate. In particular, if consumers are pessimistic, then the best deviant price for this exporter is P(c(H),0), and so existence requires $\Pi(\bar{P},c(H),1) \geq \Pi(P(c(H),0),c(H),0)$. This inequality actually follows from a "single-crossing property" of the model. To understand, consider the isoprofit curves plotted in figure 3, where:

$$\Pi(P,c(t),b) = \Pi(P(c(t),0),c(t),0) \equiv \bar{\Pi}^t$$

Intuitively, these curves indicate a tradeoff between the extent of price distortion, $|P - P(c(t),b)|$, and the level of beliefs. Higher distortion levels are tolerated only if an offsetting increase in b is granted.

The two curves are easily related. Using only the assumptions that c(H) > c(L) and D(P,b) increases in b, it is straightforward to confirm that the slope of the low-quality isoprofit curve exceeds that of the high-quality isoprofit curve at any point at which the isoprofit curves intersect.[10] The low-quality monopolist is less desirous of price increases (demand reductions) and therefore requires a more favorable adjustment in b in order to maintain indifference. The isoprofit curves thus cross only once. Further, as is evident from figure 3, $\Pi(\bar{P},c(H),1) \geq \Pi(P(c(H),0),c(H),0)$ then follows.

Thus, a very focal equilibrium exists in which high prices are used to signal high quality. The plausibility of this equilibrium is further strengthened with the next theorem, which establishes the nonexistence of intuitive pooling equilibria.

Theorem 3: There does not exist an intuitive pooling equilibrium.

Once more, a formal proof is contained in the appendix, but the result is easily understood as an implication of the single-crossing property of the model. Since a high-quality exporter will tolerate a greater price increase (demand reduction) in exchange for a given belief increase than will a low-quality exporter, the former can break pooling equilibria under (E3) by deviating to a price sufficiently high that a low-quality firm would lose from such a deviation even when b=1 follows.[11] Figure 4 illustrates this process in the context of isoprofit curves for a particular pooling equilibrium. In this figure, P' (plus ϵ) is the deviant price and $\bar{\Pi}^t = \Pi(P^p,c(t),b^0)$.

To summarize, there exists exactly one intuitive equilibrium for the exogenous quality game, which is characterized by an upward distortion in the high-quality price and no distortion in the low-quality price.

C. Optimal Export Policy

Consider now the possibility that the government may subsidize or tax the new export good. Denote an export policy by $s \in \mathbf{R}$, where s > 0 (s < 0) corresponds to an export subsidy (tax). Let us assume that the government does not know quality when s is selected; thus, subsidization cannot be made on a quality contingent basis.[12]

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

It follows that a unique intuitive equilibrium exists for any export policy s. Letting $\hat{P}(t,s)$ denote the equilibrium pricing strategy of an exporter of type t, we can characterize the focal equilibrium as follows: $\hat{P}(H,s) = \bar{P}(s)$ and $\hat{P}(L,s) = P(c(L,s),0)$, where $\bar{P}(s) > P(c(H,s),1)$ solves:[13]

$$(4) \qquad \Pi(P,c(L,s),1) = \Pi(P(c(L,s),0),c(L,s),0) \quad .$$

Note that $\bar{P}(s) = \bar{P}$ when $s = 0$.

Export-country welfare is defined as the expected value of producer surplus plus government revenue. Letting $\bar{W}(s)$ denote the welfare for the exogenous quality game, we have:

$$(5) \qquad \begin{aligned} \bar{W}(s) &= b^0\Pi(\hat{P}(H,s),c(H,s),1) + (1 - b^0)\Pi(\hat{P}(L,s),c(L,s),0) \\ &\quad - b^0 sD(\hat{P}(H,s),1) - (1 - b^0)sD(\hat{P}(L,s),0) \end{aligned}$$

Simple rearranging gives:

(6) $\bar{W}(s) = b^0\Pi(\hat{P}(H,s),c(H),1) + (1-b^0)\Pi(\hat{P}(L,s),c(L),0)$

It is important to understand (6). The direct effect of a subsidy is simply a transfer from the government to the monopoly and has no welfare implications. The subsidy may have an indirect effect on equilibrium prices, however, and it is through this channel that a role for policy may emerge.

We are now ready to determine optimal export policy. Letting subscripts denote partial derivatives, observe that:

(7) $\bar{W}_s(s) = b^0\Pi_p(\hat{P}(H,s),c(H),1)\hat{P}_s(H,s) + (1-b^0)\Pi_p(\hat{P}(L,s),c(L),0)\hat{P}_s(L,s)$

Next, since $\Pi_p(\hat{P}(L,s),c(L,s),0) = 0$, we have that:

(8) $\Pi_p(\hat{P}(L,s),c(L),0) = -sD_p(\hat{P}(L,s),0)$

Combining (7) and (8) gives:

(9) $\bar{W}_s(s) = b^0\Pi_p(\hat{P}(H,s),c(H),1)\hat{P}_s(H,s) - (1 - b^0)sD_p(\hat{P}(L,s),0)\hat{P}_s(L,s)$

In general, it is of interest to know the sign of $\bar{W}_s(s)$ when s = 0. If $\bar{W}(s)$ is concave, this will indicate whether the optimal policy is a subsidy, a tax, or no intervention. Further, whether or not $\bar{W}_s(s)$ is concave, it is desirable to know the affect of small subsidies on welfare. Using (9):

(10) $\bar{W}_s(s)|_{s=0} = b^0\Pi_p(\hat{P}(H,s),c(H),1)\hat{P}_s(H,s)|_{s=0}$

This expression is easily understood. A small subsidy has no first order effect on low-quality profits, since the low-quality monopolist is then pricing very close to its true (undistorted) monopoly price. The high-quality price, however, is distorted and the subsidy can have a first order effect here, as (10) illustrates.

To gain some further intuition, note that $\hat{P}(H,s) = \bar{P}(s) > P(c(H),1)$ if s is close to zero. Concavity of profits then gives that $\Pi_P(\hat{P}(H,s),c(H),1) < 0$ when s is 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 $\hat{P}_s(H,s) < 0$ for s near zero.

We have now to compute $\hat{P}_s(H,s)$. Using (4), we get:

$$(11) \quad \hat{P}_s(H,s) = \frac{D(\hat{P}(L,s),0) - D(\hat{P}(H,s),1)}{\Pi_P(P(H,s),c(L,s),1)}$$

Note that the denominator in (11) is negative since $\hat{P}(H,s) > P(c(L,s),1)$. The desirability of an export subsidy therefore hinges precisely upon whether the high-or-low-quality monopolist sells more in equilibrium:

$$(12) \quad sign\, \bar{W}_s(s)|_{s=0} = sign\{D(\hat{P}(L,s),0) - D(\hat{P}(H,s),1)\}|_{s=0}$$

This result has a simple intuition. If a subsidy is to reduce the high-quality price, then it must be that, after the subsidy is imposed, the low-quality monopolist becomes less willing to mimic the original, high-quality price. 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 $D(\hat{P}(L,s),0) - D(\hat{P}(H,s),1) > 0$ when $s = 0$, 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, thereby raising welfare.

We now establish that the low-quality monopolist indeed does have greater sales in equilibrium, that is, $D(\hat{P}(L,s),0) - D(\hat{P}(H,s),1) > 0$. This follows directly from (4), which gives that $\Pi(\hat{P}(H,s),c(L,s),1) = \Pi(\hat{P}(L,s),c(L,s),0)$, and from the fact that $\hat{P}(H,s) > \hat{P}(L,s)$. If the low-quality exporter is indifferent between mimicking and not, and if the price associated with mimicry is higher, then the demand corresponding to not mimicking (maintaining the equilibrium) must be larger. This in particular holds when $s = 0$. We may conclude that a slight subsidy differentially rewards the low-quality equilibrium strategy, thus lowering the high-quality pricing distortion and raising export-country welfare.[14]

III. <u>A Model of Endogenous Quality</u>

If product quality is selected or adjusted after the enactment of export policy, then the policy may induce a distortion in quality selection. To explore this possibility, we must develop a richer model in which quality is endogenous. As before, the export policy variable is initially suppressed, and an explicit analysis of export policy is given subsequently.

A. The Game

We begin with the observation that the low-quality exporter earns more than the high-quality exporter in the exogenous quality game. This follows because the lower-quality product is less costly to produce and because the low-quality exporter has the option to mimic the high-quality price:

$$\Pi(\hat{P}(L), c(L), 0) = \Pi(\hat{P}(H), c(L), 1) > \Pi(\hat{P}(H), c(H), 1)$$

Thus, if this game is to be amended to allow for quality choice, then some means to motivate a high-quality product selection must be included.

A realistic source of high-quality incentives comes with the addition of a second stage to the original game. In particular, the total profit to a monopolist whose quality is t is $\Pi(P, c(t), b) + \tilde{\Pi}(t, x)$, where x is some random variable, with support $[\underline{x}, \overline{x}]$ and differentiable density and distribution functions, f and F, respectively. Thus, the profit function used in the previous model corresponds to a first-period profit function in the new model. We will maintain all assumptions previously placed on this function. The second-stage profit function, $\tilde{\Pi}(t, x)$, corresponds to a mature phase of the product's life cycle. In this phase, consumers know quality from previous experience. The variable t is included in $\tilde{\Pi}(t, x)$ to reflect the fact that costs and (complete-information) demands will differ across qualities. Thus, even though high-quality exporters earn less in the introductory phase of a product's life, they may earn more in the mature phase. This provides a natural way to model a possible incentive for high-quality production.

There are many interpretations for the variable 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 increase relatively slowly. These interpretations motivate the assumption that $\tilde{\Pi}(H,x) - \tilde{\Pi}(L,x)$ is differentiable and increasing in x. Assume further that $\tilde{\Pi}(t,x) > 0$ for all t and x and that neither quality type always yields greater future profit:

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

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

The endogenous quality game may now be described. The game begins when "nature" chooses a value for x using the density f(x). It is plausible that the exporter has superior information about the market's evolution, and so let us assume 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 now the value of x which it observes. Having learned x, the exporter next simultaneously chooses a price and a quality; these strategies are denoted as P = P(x) and t = t(x). Product quality is fixed throughout the introductory and mature phase. Consumers in the initial phase observe P but not t, 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.

In this game, the role of x is to provide incentives for quality selection. Notice in particular that introductory profits are independent of x. Similarly, mature phase profits are assumed to be independent of the introductory price P. Thus, there is no meaningful interaction between P and x, besides the fact that optimal introductory pricing may depend upon the quality selection (i.e., production costs).[15] For this reason, it seems natural to focus upon equilibria in which price depends on x only insofar as x determines quality. That is, we shall consider equilibria in which the price is the same for any two values of x which induce the same quality selection. In addition to being plausible, this restriction simplifies the subsequent analysis and enables us to maintain emphasis on the extent to which price signals quality.[16]

An equilibrium for this game is again a collection of strategies and beliefs, $\{\hat{P}(x),\hat{t}(x),\hat{b}(P)\}$. Let us begin with equilibrium strategies. The restriction may be formalized as:

$$\text{(R)} \quad \hat{P}(x_1) = \hat{P}(x_2) \text{ whenever } \hat{t}(x_1) = \hat{t}(x_2) \quad .$$

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

$$\text{(E1)}' \quad \hat{P}(x),\hat{t}(x) \in \underset{P,t}{argmax}\ \Pi(P,c(t),\hat{b}(P)) + \tilde{\Pi}(t,x) \quad .$$

Before defining Bayesian-beliefs, it is convenient to note two implications of (E1)'. First, let us assume that $\tilde{\Pi}(H,\overline{x}) - \tilde{\Pi}(L,\overline{x})$ and $\tilde{\Pi}(L,\underline{x}) - \tilde{\Pi}(H,\underline{x})$ are large. (E1)' then guarantees that $\hat{t}(x) = H$ for an interval of x near $\overline{x}$ and $\hat{t}(x) = L$ for an interval of x near $\underline{x}$. Thus, both low-and-high-quality products have a positive probability of selection. Second, (E1)' also gives the following lemma, which shows that the set of x can be broken into two intervals, with large x's generating a high-quality selection and low x's inducing a low-quality selection.

<u>Lemma 1</u>: Given any arbitrary belief function $\hat{b}(P)$, if strategies satisfy (E1)', then there exists a unique $\hat{x} \in (\tilde{x},\overline{x})$ such that $\hat{t}(x) = H$ for $x > \hat{x}$ and $\hat{t}(x) = L$ for $x < \hat{x}$.

Intuitively, $\hat{x} > \tilde{x}$ since at $x = \tilde{x}$ mature-phase profits are quality-independent. Thus, $\hat{t}(\tilde{x}) = L$ must occur given that profits are higher for low-quality production in the introductory phase. A complete proof is found in the appendix.

We may now use (R) and Lemma 1 to provide a simple representation of Bayesian beliefs:

(E2)' If $x_1 < \hat{x} < x_2$, then:

(i) $\hat{P}(x_1) = \hat{P}(x_2)$ implies $\hat{b}(\hat{P}(x_1)) = 1 - F(\hat{x})$

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

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 collection of strategies and beliefs satisfying
(R), *(E1)*´, and *(E2)*´.

As before, beliefs are unrestricted for off-the-equilibrium path prices (P such that for all x, $P \neq \hat{P}(x)$). Thus, it is important to define intuitive equilibria for the new game. If P is a disequilibrium price, then a strategy (P,t) is equilibrium dominated for x (i.e., a monopolist with information x) if:

$$\max_b \Pi(P,c(t),b) + \tilde{\Pi}(t,x) < \Pi(\hat{P}(x),c(\hat{t}(x)),\hat{b}(\hat{P}(x))) + \tilde{\Pi}(\hat{t}(x),x)$$

Let us now impose a minor restriction on the strategy space by eliminating any strategy in which $P < c(t)$. Notice that any such strategy is strictly dominated by a strategy in which $P > c(t)$.[17] With this, it is straightforward to see that (P,t) is equilibrium dominated for x exactly when:

$$(13) \quad \Pi(P,c(t),1) + \tilde{\Pi}(t,x) < \Pi(\hat{P}(x),c(\hat{t}(x)),\hat{b}(\hat{P}(x))) + \tilde{\Pi}(\hat{t}(x),x)$$

Now, if consumers believe that equilibrium dominated strategies are never selected, then the observation of a disequilibrium price P which is equilibrium dominated for all x in conjunction with a particular quality choice and which is 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 equilibrium dominated strategies can place structure on disequilibrium beliefs even when the monopolist is in possession of two dimensions of private information. Formally, an equilibrium is now said to be <u>intuitive</u> if:

$(E3)'$ $\hat{b}(P) = 1(0)$ if, for all x, $P \neq \hat{P}(x)$, and if the strategy (P,L) ((P,H)) is equilibrium dominated for every x while the strategy (P,H) ((P,L)) is not.

B. <u>The Unique Intuitive Equilibrium</u>

We begin with separating equilibria, where $\hat{x} \in (\tilde{x},\overline{x})$ exists such that $\hat{P}(x_1) \neq \hat{P}(x_2)$, $\hat{t}(x_1) = L$ and $\hat{t}(x_2) = H$ for $x_1 < \hat{x} < x_2$. The next theorem demonstrates that the focal separating equilibrium for the endogenous quality model is similar to that found in the exogenous quality model. In both cases, an exporter with a high-quality product signals its quality by restricting demand with the high price $\overline{P}$, as defined in (3), while an exporter with a low-quality product does not distort its price.

<u>Theorem 4</u>: In any intuitive separating equilibrium, $\hat{P}(x) = \overline{P}$ and $\hat{t}(x) = H$ for $x > \hat{x}$, $\hat{P}(x) = P(c(L),0)$ and $\hat{t}(x) = L$ for $x < \hat{x}$, and $\hat{x} \in (\tilde{x},\overline{x})$ is uniquely defined by:

$$(14) \quad \tilde{\Pi}(H,\hat{x}) - \tilde{\Pi}(L,\hat{x}) = \Pi(P(c(L),0),c(L),0) - \Pi(\overline{P},c(H),1)$$

To understand this theorem, observe first that a monopolist who chooses to produce a low-quality good selects the low-quality monopoly price, P(c(L),0), in any separating equilibrium. It follows that any strategy (P,L) with $P \notin [\underline{P},\overline{P}]$ is equilibrium dominated for every x. The idea is that a monopolist with information x always has the option of pursuing the low-quality equilibrium strategy, so that any price-quality combination which is always inferior to this strategy must be equilibrium dominated. Using (E3)', it is then not difficult to argue that a monopolist choosing a high-quality product signals its choice with its preferred signaling price, $\overline{P}$. This price is again just high enough to deter a monopolist with a low-quality product from misrepresenting itself. Next, while a low-quality producer makes more introductory-phase profit, the future profit associated with high-quality production eventually compensates as x rises. The critical $\hat{x}$ just balances the lower introductory-phase profits for a high-quality selection with the greater mature-phase profits. These basic points are illustrated in Figure 5; a full proof is found in the appendix.

The next step is to show existence.

Theorem 5: There exists an intuitive separating equilibrium in which $\hat{P}(x) = \overline{P}$ and $\hat{t}(x) = H$ for $x > \hat{x}$, and $\hat{P}(x) = P(c(L),0)$ and $\hat{t}(x) = L$ for $x < \hat{x}$, with $\hat{x} \in (\tilde{x},\overline{x})$ defined by (14).

Existence is an implication of the single crossing property discussed previously. This enables the definition of a price $\overline{P}$ which is attractive only to a firm choosing high quality. Once $\overline{P}$ is so defined, the incentive for an exporter to maintain its quality and deviate in its price is removed. The critical value $\hat{x}$ is then defined to ensure that the firm is also unwilling to deviate in its quality selection. A complete proof is given in the appendix.

The remaining task is to further strengthen the plausibility of the intuitive separating equilibrium by demonstrating that pooling equilibria, where $\hat{P}(x_1) = \hat{P}(x_2)$ for all x_1 and x_2, are never intuitive.

Theorem 6: There does not exist an intuitive pooling equilibrium.

This theorem builds on the intuition developed for the proof of Theorem 3. In particular, pooling equilibria are unintuitive since a high price can always be found which could never improve upon equilibrium profits when the price is accompanied by a low-quality selection. The existence of such a price derives from the single-crossing aspect of the underlying model, as discussed more fully in the appendix.

Thus, the endogenous quality model admits a single intuitive equilibrium, and this equilibrium is characterized by distorted, high-quality prices and undistorted, low-quality prices.

C. Optimal Export Policy

Let us again suppose that the government can enact an export policy s. We shall maintain the assumption that the policy cannot be contingent upon quality, since the government does not know quality when s is selected. Assume further that the government is also uninformed of x at the time at which policy is decided. This seems a plausible assumption, since the new-product monopolist quite reasonably has some information about probable market evolution which the government does not.

The subsidy is once more modeled as a reduction in production costs: $c(t,s) = c(t) - s$. Let us now assume, however, that the subsidy is only temporary; that is, the subsidy applies only in the introductory phase. This, too, seems plausible. Once the mature phase is entered, quality information is commonly known and there is no longer any reason for a subsidy. Thus, the exporter's profit function may be written as:

$$\Pi(P, c(t,s), b) + \tilde{\Pi}(t,x)$$

Clearly, all previous theorems apply to this set of cost functions.

A unique intuitive equilibrium therefore exists for a given s. This equilibrium is characterized by $\hat{P}(x) = \overline{P}(s)$ and $\hat{t}(x) = H$ for $x > \hat{x}(s)$, where $\overline{P}(s)$ is defined by (4), and $\hat{P}(x) = P(c(L,s),0)$ and $\hat{t}(x) = L$ for $x < \hat{x}(s)$, where $\hat{x}(s)$ is defined by:

$$(15)\quad \tilde{\Pi}(H,\hat{x}(s)) - \tilde{\Pi}(L,\hat{x}(s)) = \Pi(P(c(L,s),0),c(L,s),0) - \Pi(\overline{P}(s),c(H,s),1) \quad .$$

In order to relate the results to those in the exogenous quality game, let us use $\hat{P}(H,s) \equiv \overline{P}(s)$ and $\hat{P}(L,s) \equiv P(c(L,s),0)$ to represent the prices selected by a monopolist who chooses high and low quality, respectively.

The first task is to sign the direction of quality distortion induced by a subsidy. Does an export subsidy increase, decrease, or not change the probability of a high-quality selection? To answer this, we must compute $\hat{x}_s(s)$. Implicitly differentiating (15) and using (11), one obtains:

$$(16)\quad \hat{x}_s(s) = \frac{\hat{P}_s(H,s)\ [\Pi_P(\hat{P}(H,s),c(L,S),1) - \Pi_P(\hat{P}(H,s),c(H,S),1)]}{\Pi_x(H,\hat{x}(s)) - \Pi_x(L,\hat{x}(s))}$$

The bracketed term is negative, since a higher-quality firm values a price increase more. Using (11):

(17) $sign\ \hat{x}_s(s) = sign\{D(\hat{P}(L,s),0) - D(\hat{P}(H,s),1)\}$.

Thus, arguing as in the previous section, 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 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 $\hat{P}_s(H,s) < 0$)). The key 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., (11) is derived from (4)). 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.

With this insight at hand, we may now consider the welfare effects of an export policy. Let exporter-country welfare now be defined by:

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

$$+ \int_{\hat{x}(s)}^{\bar{x}} f(x)[\Pi(\hat{P}(H,s),c(H,s),1) + \tilde{\Pi}(H,x) - sD(\hat{P}(H,s),1)]\,dx \quad .$$

After rearranging, the direct transfer effect of the subsidy drops out:

$$
(18)\quad
\begin{aligned}
W(s) = &\int_{\underline{x}}^{\hat{x}(s)} f(x)[\Pi(\hat{P}(L,s),c(L),0) + \tilde{\Pi}(L,x)]\,dx \\
&+ \int_{\hat{x}(s)}^{\bar{x}} f(x)[\Pi(\hat{P}(H,s),c(H),1) + \tilde{\Pi}(H,x)]\,dx
\end{aligned}
\quad .
$$

To better relate the results with those obtained in the previous section, let us define $b^0(s) \equiv 1 - F(\hat{x}(s))$ to denote the (endogenous) prior probability of high quality. Observe that $b_s^0(s) < 0$ since $\hat{x}_s(s) > 0$: a subsidy reduces the probability of high quality. With this, (18) may be rewritten as:

$$
(19)\quad
\begin{aligned}
W(s) = &(1 - b^0(s))\Pi(\hat{P}(L,s),c(L),0) + b^0(s)\Pi(\hat{P}(H,s),c(H),1) \\
&+ \int_{\underline{x}}^{\hat{x}(s)} f(x)\tilde{\Pi}(L,x)\,dx + \int_{\hat{x}(s)}^{\bar{x}} f(x)\tilde{\Pi}(H,x)\,dx
\end{aligned}
\quad .
$$

Comparing with (6), we see that W(s) differs from $\bar{W}(s)$ only in that b^0 is a function of s and second-period profits are included.

The next step is to compute the effect of an export subsidy. Using (7) and (15), one can obtain:

$$
(20)\quad
\begin{aligned}
W_s(s) = &\bar{W}_s(s) + b_s^0(s)[\Pi(\hat{P}(H,s),c(H),1) - \Pi(\hat{P}(L,s),c(L),0) \\
&+ \Pi(\hat{P}(L,s),c(L,s),0) - \Pi(\hat{P}(H,s),c(H,s),1)]
\end{aligned}
\quad .
$$

Here, $\bar{W}_s(s)$ is understood to be evaluated with $b^0 = b^0(s)$. Simple rearranging gives:

$$
(21)\quad W_s(s) = \bar{W}_s(s) + sb_s^0(s)[D(\hat{P}(L,s),0) - D(\hat{P}(H,s),1)] \quad .
$$

Recall that $b_s^0(s) < 0$ and that equilibrium sales are largest for a low-quality exporter. It follows from (21) that subsidies are now less attractive than when quality is exogenous. This simply reflects the fact that subsidies distort the quality selection, causing a low-quality product to be selected more often than is optimal.

It is again useful to consider a small subsidy. Using (12) and (21):

$$(22) \quad sign\, W_s(s)|_{s=0} = sign\, \bar{W}_s(s)|_{s=0} = sign\{D(\hat{P}(L,s),0) - D(\hat{P}(H,s),1)\}|_{s=0} \quad .$$

Thus, if W(s) is concave, optimal export policy again involves an export subsidy. In any case, a small export subsidy is welfare improving.

This is easily understood. From (21), it is apparent that any quality distortion induced by a small subsidy is of second order importance. Intuitively, 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 associated distortions in quality selection. By contrast, even when s = 0, the high-quality price is distorted. A subsidy could therefore provide a first order welfare benefit if it reduced the extent of distortion in the high-quality price. Finally, as argued above, a small subsidy will in fact reduce this pricing distortion, precisely because equilibrium sales levels--and thus total subsidy receipts--are largest for a low-quality exporter. We may conclude that a small export subsidy raises export-country welfare, whether or not quality is policy-sensitive.

IV. Conclusion

This paper considers the role for 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. When the choice of product quality is sensitive to export policy, export subsidies also increase the probability of a low-quality export. These results are implications of the finding that equilibrium sales levels--and thus total subsidy receipts--are necessarily largest for a low-quality exporter.

The fundamental conclusion is that export subsidies are welfare-enhancing for the exporting country. This conclusion holds whether product quality is insensitive to export policy, as Bagwell and Staiger assume, or responsive to export policy, as Grossman and Horn suggest. The key point is that only the high-quality price is initially distorted, as a consequence of product quality signaling. The low-quality price and the selection of product quality (when quality is endogenous) are undistorted in the absence of policy. Thus, an export subsidy provides a first order benefit to export-country welfare by reducing the distortion in high-quality prices and causes only second order losses to welfare by introducing distortions in low-quality prices and, where appropriate, quality selection.

This basic argument is not specific to the two-quality-type model. Ramey [1987] and Fertig [1988] have analyzed a monopoly model with a continuum of exogenous quality types, where all qualities are efficient (capable of earning positive profits when quality is known or signaled). Assuming that marginal cost is increasing in quality, they show that prices are distorted upward for all but the lowest-quality exporter in the unique separating equilibrium. Furthermore, equilibrium sales levels are decreasing in quality. Thus, as above, an export subsidy differentially rewards lower-quality, higher-sales strategies, which should in turn reduce the pricing distortion required to signal quality.

The possibility of fly-by-night (i.e., inefficient) product qualities does not appear especially relevant for an innovative monopolist. Such a firm has little incentive to forsake future sales with fly-by-night production. Nevertheless, it is of some interest to consider the role of export policy when the monopolist chooses amongst a continuum of qualities in a two-phase model, with lower-quality products being inefficient. A tradeoff may arise in this setting, since an export subsidy increases the distortion required to separate from the possibility of a fly-by-night selection, as Grossman and Horn argue, and yet reduces the distortion needed for separation amongst efficient product qualities, as discussed above. A reasonable conjecture is that the optimal policy might rule out fly-by-night production and also reduce the pricing distortion associated with efficient product qualities. This can be accomplished with a combination policy, where a minimum export quality standard is imposed and an export subsidy is provided to any product meeting this standard.

Finally, it has been assumed throughout that consumers understand the relation between marginal cost and product quality and that consumers observe the level of export subsidies. Interesting future work might explore the extent to which these strong assumptions can be relaxed. Work by Davis [1990] suggests that the basic results may go through if consumers lack precise information about marginal costs, but do recognize that higher-quality products tend to have higher marginal costs.[18] Similarly, it seems that a role for export subsidies will remain, if consumers know that the product has been targeted for a subsidization policy but can only estimate the exact subsidy level. 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.

Notes

1. The prediction that high quality is signaled with a high price is consistent with available evidence. In particular, Curry and Riesz [1988] provide some evidence that high prices are used to signal quality for relatively new, high-quality products, while Monroe and Krishnan [1985] discuss experimental evidence of consumer beliefs which associate high prices with high quality.

2. The associated reduction in the probability of a high-quality selection may reduce import-country welfare, however, if consumers prefer the high-quality good at the equilibrium prices.

3. The Grossman-Horn model is in fact concerned with infant-industry protection, but is easily reinterpreted in terms of export policy. (This interpretation is discussed further by Grossman [1989] and Skeath [1990].) See Chen [1989] for an extension of a Grossman-Horn model that finds some support for R & D subsidies.

4. Export subsidization is in fact harmful in the Grossman-Horn model because it invites less-efficient, lower-quality entrants. Moreover, if consumer welfare is considered, then an export tax is (socially) optimal.

5. This issue is discussed more fully in a concluding section.

6. $D_{Pb}(P,b) \geq 0$ is sufficient for P(c(t),b) to increase in b, where subscripts denote partial derivatives.

7. An alternative refinement is to eliminate dominated strategies (Milgrom and Roberts, 1986). This refinement is sufficient for all of the results on separating equilibria.

8. This is a consequence of the fact that demand increases in b. Along with the positive-profit assumption, this monotonicity ensures that $\Pi(\hat{P}(t), c(t), \hat{b}(\hat{P}(t))) > 0$ (lest a deviation occur to P(c(t),0), which is sure to give positive profits). The relevant case therefore has $\Pi(P, c(t), 1) > 0$, and monotonicity ensures that b=1 is the best belief in this case.

9. If the low-quality good is fly-by-night, then the existence of a separating equilibrium requires explicit inclusion of fixed costs to entry and future (mature-phase) profits for the high-quality monopolist. When intuitive separating equilibria do exist, only the high-quality monopolist enters and a distorted, high price is again used to signal quality.

10. Formally, if $b = b(P,\overline{\Pi}^t,c(t))$ devotes the isoprofit curve for the type-t monopolist, then $b_p = -\Pi_p/\Pi_b$, where $\Pi_b > 0$ when $P > c(t)$. Furthermore, one can show easily that b_p is decreasing in c(t).

11. The nonexistence of intuitive pooling equilibria contrasts with the findings of Bagwell and Staiger and also Grossman and Horn. The divergence does not stem from different assumptions about the efficiency of the low-quality good, as the proof of Theorem 3 is readily confirmed to hold even when the low-quality good is fly-by-night. Rather, 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.

12. This is a plausible an important assumption. Bagwell and Staiger and Grossman and Horn also assume that government is uninformed of quality.

13. The definition of $P(c(t,s),b)$ is exactly analogous to that of $P(c(t),b)$; namely, $P(c(t,s),b)$ uniquely maximizes $\Pi(P,c(t,s),b)$.

14. Note that sales are largest for the high-quality firm when the low-quality good is fly-by-night. In this case, a subsidy differentially rewards the high-quality strategy, forcing an even greater distortion in the high-quality price. See also note 9.

15. It is now straightforward to see that Theorems 1, 2, and 3 hold exactly as stated when the exogenous quality game is amended to include a mature-phase profit function.

16. This restriction is without loss of generality when x takes a finite number of values. A sketch follows. First, if prices but not qualities vary over a range of x's in equilibrium, then the monopolist must be indifferent over the various prices for any x in this range. Second, this greatly restricts the set of possible equilibrium prices. At most one (two) price is (prices are) selected <u>only</u> by a monopolist who chooses a low-quality (high-quality) product. Further, at most one price is selected which is sometimes paired with a low-quality product and sometimes paired with a high-quality product. With the set of possible equilibrium prices thus reduced to four, the third observation is that disequilibrium prices are plentiful, so that the intuitive criterion may be used as it is subsequently in the text. It seems prudent to impose the restriction directly and avoid an explicit representation of this sketch.

17. This follows since future profits are independent of current prices. The extra restriction is required for equivalence with (13), since otherwise (13) might hold for (P,t) that is not equilibrium dominated. This occurs only when $\Pi(t,x) > \Pi(\hat{t}(x),x)$.

18. See Judd and Riordan [1987] for an alternative model of price as a signal of quality when production costs are privately known.

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Appendix

Proof of Theorem 1: From (2) and (3), the set of P such that $P \notin [\underline{P},\overline{P}]$ is exactly the set of P which are equilibrium dominated for the low-quality monopolist. Thus, $\hat{P}(H) < \underline{P}$ ($\hat{P}(H) > \overline{P}$) is impossible when beliefs satisfy (E3), since a deviation to $\hat{P}(H) + \epsilon$ ($\hat{P}(H) - \epsilon$) could benefit only a high-quality monopolist. Also, as discussed, $\hat{P}(H) \notin (\underline{P},\overline{P})$, lest (E1) be violated for the low-quality monopolist. Hence, $\hat{P}(H) \in \{\underline{P},\overline{P}\}$.

Next, note that:

$$
\begin{aligned}
&\Pi(\overline{P},c(H),1) - \Pi(\underline{P},c(H),1) \\
&= \Pi(\overline{P},c(H),1) - \Pi(\underline{P},c(H),1) - \Pi(\overline{P},c(L),1) + \Pi(\underline{P},c(L),1) \\
&= (c(H) - c(L))\,(D(\underline{P},1) - D(\overline{P},1)) \\
&> 0
\end{aligned}
\tag{A1}
$$

Thus, $\hat{P}(H) = \underline{P}$ is impossible under (E3), since a deviation to $\overline{P} + \epsilon$ could benefit only the high-quality monopolist. It must be that $\hat{P}(H) = \overline{P}$. Q.E.D.

Proof of Theorem 2: Suppose first that $\Pi(\overline{P},c(H),1) \geq \Pi(P(c(H),0),c(H),0)$. Put b(P) = 1 for all $P \notin [\underline{P},\overline{P})$ and b(P) = 0 otherwise. Set $\hat{P}(H) = \overline{P}$ and $\hat{P}(L) = P(c(L),0)$. It is now straightforward to verify that (E1), (E2), and (E3) hold.

Next, it is shown that the supposition holds. Note first that:

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

Using (3) and the definition of $\tilde{P}$, it is clear that $P^* \in (\bar{P},\tilde{P})$ must exist at which:

$$\Pi(P(c(H),0),c(L),0) = \Pi(P^*,c(L),1)$$

(Figure 1 may be helpful.) Further, since $\bar{P} > P(c(H),1)$, it must be that $\Pi(\bar{P},c(H),1) > \Pi(P^*,c(H),1)$. With all of this, it follows that:

$$\begin{aligned}
&\Pi(\bar{P},c(H),1) - \Pi(P(c(H),0),c(H),0) \\
&= \Pi(\bar{P},c(H),1) - \Pi(P(c(H),0),c(H),0) - \Pi(P^*,c(L),1) + \Pi(P(c(H),0),c(L),0) \\
\text{(A2)}\quad &> \Pi(P^*,c(H),1) - \Pi(P(c(H),0),c(H),0) - \Pi(P^*,c(L),1) + \Pi(P(c(H),0),c(L),0) \\
&= (c(H) - c(L))(D(P(c(H),0),0) - D(P^*,1)) \\
&> 0
\end{aligned}$$

where the final inequality follows from the definition of P^* and the fact that $P^* > P(c(H),0)$. Q.E.D.

<u>Proof of Theorem 3</u>: Suppose to the contrary that $\hat{P}(H) = \hat{P}(L) \equiv P^P$. Defection will occur to $P(c(t),0)$ unless:

$$\Pi(P^P,c(t),b^0) \geq \Pi(P(c(t),0),c(t),\hat{b}(P(c(t),0))) \geq \Pi(P(c(t),0),c(t),0) > 0$$

Thus, positive profits are earned. It follows that:

$$\Pi(P^P,c(L),1) > \Pi(P^P,c(L),b^0) > \Pi(\tilde{P},c(L),1) = 0$$

which implies the existence of $P' > \max[P^P, P(c(L),1)]$ such that $\Pi(P',c(L),1) = \Pi(P^P,c(L),b^0)$. This is illustrated in figure 6 for various P^P. Observe that:

$$\begin{aligned}
&\Pi(P',c(H),1) - \Pi(P^P,c(H),b^0)\\
&= \Pi(P',c(H),1) - \Pi(P^P,c(H),b^0) - \Pi(P',c(L),1) + \Pi(P^P,c(L),b^0)\\
&= (c(H) - c(L))(D(P^P,b^0) - D(P',1))\\
&> 0
\end{aligned} \tag{A3}$$

where the last inequality follows from the definition of P' and the fact that $P' > P^P$. But then a deviation to $P' + \epsilon$ induces $\hat{b}(P' + \epsilon) = 1$ under (E3). The high-quality monopolist therefore undertakes the deviation, destroying the equilibrium. Q.E.D.

<u>Proof of Lemma 1</u>: Assume to the contrary that $\hat{t}(x_1) = H$ and $\hat{t}(x_2) = L$ with $x_2 > x_1$. Let $\hat{b}_i \equiv \hat{b}(\hat{P}(x_i))$ where $\hat{b}(P)$ is some arbitrary belief function, and let $\hat{P}_i \equiv \hat{P}(x_i)$, for i = 1, 2. Then (E1)' implies:

$$\tilde{\Pi}(H,x_1) - \tilde{\Pi}(L,x_1) \geq \Pi(\hat{P}_2,c(L),\hat{b}_2) - \Pi(\hat{P}_1,c(H),\hat{b}_1)$$

$$\Pi(\hat{P}_2,c(L),\hat{b}_2) - \Pi(\hat{P}_1,c(H),\hat{b}_1) \geq \tilde{\Pi}(H,x_2) - \tilde{\Pi}(L,x_2)$$

But this contradicts $x_2 > x_1$, given that $\tilde{\Pi}(H,x) - \tilde{\Pi}(L,x)$ increases in x. Since $\hat{t}(x) = L(H)$ for x near $\underline{x}$ $(\bar{x})$, we see that $\hat{x} \in (\underline{x},\bar{x})$ must exist below (above) which $\hat{t}(x) = L(H)$. The last step is to show that $\hat{x} > \tilde{x}$. This follows since $\tilde{\Pi}(L,\tilde{x}) = \tilde{\Pi}(H,\tilde{x})$ and $c(L) < c(H)$ guarantees that $\hat{t}(x) = L$ for x near $\tilde{x}$ under (E1)'. Q.E.D.

Proof of Theorem 4: First, we show $\hat{P}(x_1) = P(c(L),0)$ *when* $\hat{t}(x_1) = L$ in a separating equilibrium. Otherwise, $\hat{b}(\hat{P}(x_1)) = 0$ by *(E2)*´ and:

$$\Pi(\hat{P}(x_1),c(L),0) + \tilde{\Pi}(L,x_1) < \Pi(P(c(L),0),c(L),0) + \tilde{\Pi}(L,x_1)$$
$$\leq \Pi(P(c(L),0),c(L),\hat{b}(P(c(L),0))) + \tilde{\Pi}(L,x_1)$$

and so x_1 would deviate to $(P,t) = (P(c(L),0),L)$, contradicting *(E1)*´.

Next, observe that $\hat{P}(x_2) \notin (\underline{P},\overline{P})$ for any x_2 such that $\hat{t}(x_2) = H$. Otherwise, $\hat{b}(\hat{P}(x_2)) = 1$ by *(E2)*´ and:

$$\Pi(\hat{P}(x_2),c(L),1) + \tilde{\Pi}(L,x_1) > \Pi(P(c(L),0),c(L),0) + \tilde{\Pi}(L,x_1)$$

and so x_1, where $\hat{t}(x_1) = L$, would deviate to $(P,t) = (\hat{P}(x_2),L)$, contradicting *(E1)*´.

It is useful to note that (P,L) with $P \notin [\underline{P},\overline{P}]$ is equilibrium dominated for every x in any separating equilibrium. This is because:

$$\Pi(\hat{P}(x),c(\hat{t}(x)),\hat{b}(\hat{P}(x))) + \tilde{\Pi}(\hat{t}(x),x) \geq \Pi(P(c(L),0),c(L),0)) + \tilde{\Pi}(L,x)$$

since x always has the option of choosing $(P(c(L),0),L)$, thereby receiving $b = 0$ under *(E2)*´. The conclusion then follows from the definition of $\underline{P}$ and $\overline{P}$ as given in (3) and from the fact that $\underline{P} < P(c(L),1) < \overline{P}$.

Next, it is shown that $\hat{P}(x_2) = \overline{P}$ for any x_2 such that $\hat{t}(x_2) = H$ in any intuitive separating equilibrium. Observe that $\hat{P}(x_2) > \overline{P}$ ($\hat{P}(x_2) < \underline{P}$) is impossible under $(E3)'$, since a deviation to $\hat{P}(x_2) - \epsilon$ ($\hat{P}(x_2) + \epsilon$) and t = H is not equilibrium dominated for x_2, whence $\hat{b}(\hat{P}(x_2) - \epsilon) = 1$ ($\hat{b}(\hat{P}(x_2) + \epsilon) = 1$). x_2 would then deviate, contradicting $(E1)'$. Further, $\hat{P}(x_2) = \underline{P}$ is also impossible under $(E3)'$. Using (A1), a deviation to $(\overline{P} + \epsilon, H)$ would not be equilibrium dominated for x_2. Thus, $(E3)'$ would give $\hat{b}(\overline{P} + \epsilon) = 1$ and by (A1) x_2 would deviate, contradicting $(E1)'$.

Finally, Lemma 1 indicates that $\hat{x} \in (\tilde{x}, \overline{x})$ exists. To characterize $\hat{x}$, let us first define x^* by:

$$\tilde{\Pi}(H, x^*) - \tilde{\Pi}(L, x^*) = \Pi(P(c(L), 0), c(L), 0) - \Pi(\overline{P}, c(H), 1)$$

Suppose $\hat{x} > x^*$. Then $\hat{t}(x^* + \epsilon) = L$ and $\hat{P}(x^* + \epsilon) = P(c(L), 0)$. But since $\tilde{\Pi}(H, x) - \tilde{\Pi}(L, x)$ is increasing in x, the above equality indicates that $x^* + \epsilon$ would deviate to $(P, t) = (\overline{P}, H)$, contradicting $(E1)'$. A similar contradiction occurs if $\hat{x} < x^*$. Thus, $\hat{x} = x^*$. Q.E.D.

<u>Proof of Theorem 5</u>: Put $\hat{b}(P) = 1$ for $P \notin [\underline{P}, \overline{P})$ and $\hat{b}(P) = 0$ otherwise. Set $\hat{P}(x) = \overline{P}$ and $\hat{t}(x) = H$ when $x > \hat{x}$, and $\hat{P}(x) = P(c(L), 0)$ and $\hat{t}(x) = L$ when $x \leq \hat{x}$. Clearly, (R) and $(E2)'$ are satisfied. Next, if $(E1)'$ holds so that the equilibrium exists, then $(E3)'$ will also hold; that is, the equilibrium will be intuitive. This is because (P,L) with disequilibrium $P \notin [\underline{P}, \overline{P})$ is then

equilibrium dominated for every x, while (P,L) with $P \in [\underline{P},\overline{P})$ is not (e.g., $\underline{x}$).

It remains to show that $(E1)'$ holds. Consider first $x \leq \hat{x}$. Given the above beliefs, there is no deviation in price alone which improves profit. Consider then a deviation of form (P',H), where P' may equal (P(c(L),0) or not. For $P' \in [\underline{P},\overline{P})$, the best deviation is (P(c(H),0),H). But this is not improving since:

$$\begin{aligned}\tilde{\Pi}(H,x) - \tilde{\Pi}(L,x) &\leq \tilde{\Pi}(H,\hat{x}) - \tilde{\Pi}(L,\hat{x}) \\ &= \Pi(P(c(L),0),c(L),0) - \Pi(\overline{P},c(H),1) \\ &< \Pi(P(c(L),0),c(L),0) - \Pi(P(c(H),0),c(H),0)\end{aligned}$$

which uses (A2). Last, for $P' \notin [\underline{P},\overline{P})$, the best deviation by (A1) is $(\overline{P},H)$. But the inequality above indicates that this is also nonimproving.

Consider next $x > \hat{x}$. By (A1) and (A2), no deviation in price alone improves profit. Consider then a deviation (P',L), with $P' = \overline{P}$ allowed. For $P' \notin [\underline{P},\overline{P})$, the best deviation is $(\overline{P},L)$. But this is nonimproving:

$$\begin{aligned}\tilde{\Pi}(H,x) - \tilde{\Pi}(L,x) &> \tilde{\Pi}(H,\hat{x}) - \tilde{\Pi}(L,\hat{x}) \\ &= \Pi(P(c(L),0),c(L),0) - \Pi(\overline{P},c(H),1) \\ &= \Pi(\overline{P},c(L),1) - \Pi(\overline{P},c(H),1)\end{aligned}$$

Similarly, for $P' \in [\underline{P},\overline{P})$, the best deviation is (P(c(L),0),L), but the inequality above indicates that this too is not improving. Q.E.D.

Proof of Theorem 6: Suppose to the contrary that $\hat{P}(x_1) = \hat{P}(x_2) = P^P$ with $\hat{t}(x_1) = L$ and $\hat{t}(x_2) = H$. Then, by Lemma 1 and (E2)', there exists some $\hat{x} \in (\tilde{x},\bar{x})$ such that $\hat{b}(P^P) = 1 - F(\hat{x}) \in (0,1)$.. Further, for any x, $\Pi(P^P,c(\hat{t}(x)), 1 - F(\hat{x})) > 0$ must be true; otherwise, a deviation would occur to $(P(c(\hat{t}(x)),0), \hat{t}(x))$ which ensures positive introductory-phase profit and maintains the mature-phase profit. (A3) may be thus used to find $P' > \max[P^P,P(c(L),1)]$ such that:

$$\Pi(P',c(H),1) - \Pi(P^P,c(H), 1 - F(\hat{x})) > 0$$

and

$$\Pi(P',c(L),1) - \Pi(P^P,c(L), 1 - F(\hat{x})) = 0.$$

Next, note that the strategy $(P' + \epsilon, H)$ is not equilibrium dominated for x_2. Observe, however, that the strategy $(P' + \epsilon, L)$ is equilibrium dominated for every x:

$$\begin{aligned} &\Pi(P^P,c(\hat{t}(x)), 1 - F(\hat{x})) + \tilde{\Pi}(\hat{t}(x),x) \\ &\geq \Pi(P^P,c(L), 1 - F(\hat{x})) + \tilde{\Pi}(L,x) \\ &> \Pi(P' + \epsilon,c(L), 1) + \tilde{\Pi}(L,x) \end{aligned}$$

Thus, (E3)' requires $\hat{b}(P' + \epsilon) = 1$. But this contradicts (E1)', since x_2, e.g., then deviates to $(P' + \epsilon, H)$. Q.E.D.

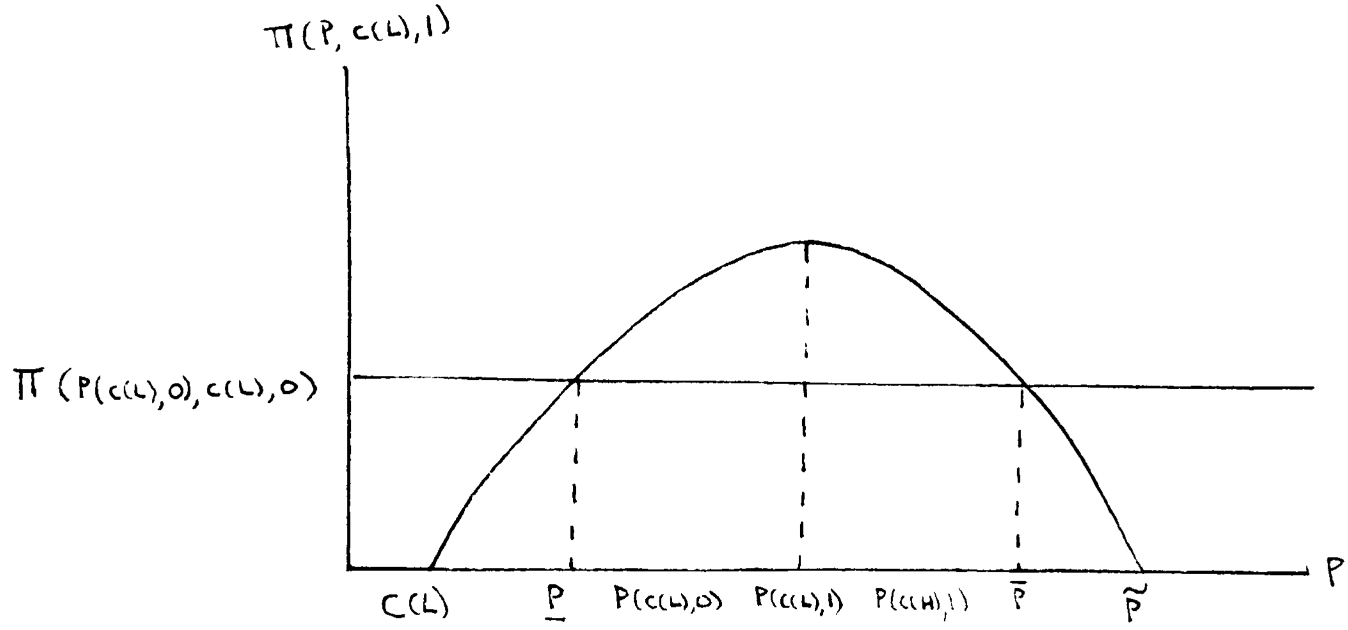

Figure 1

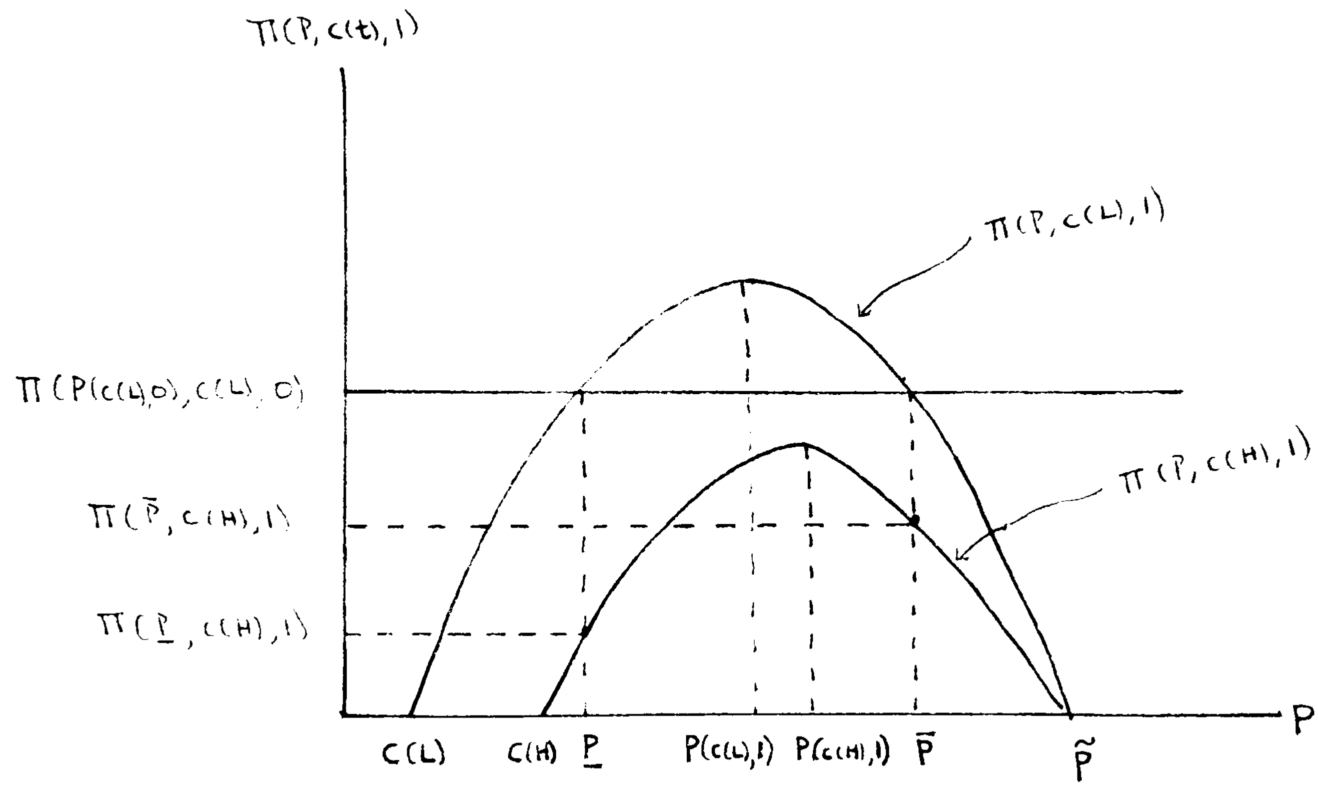

Figure 2

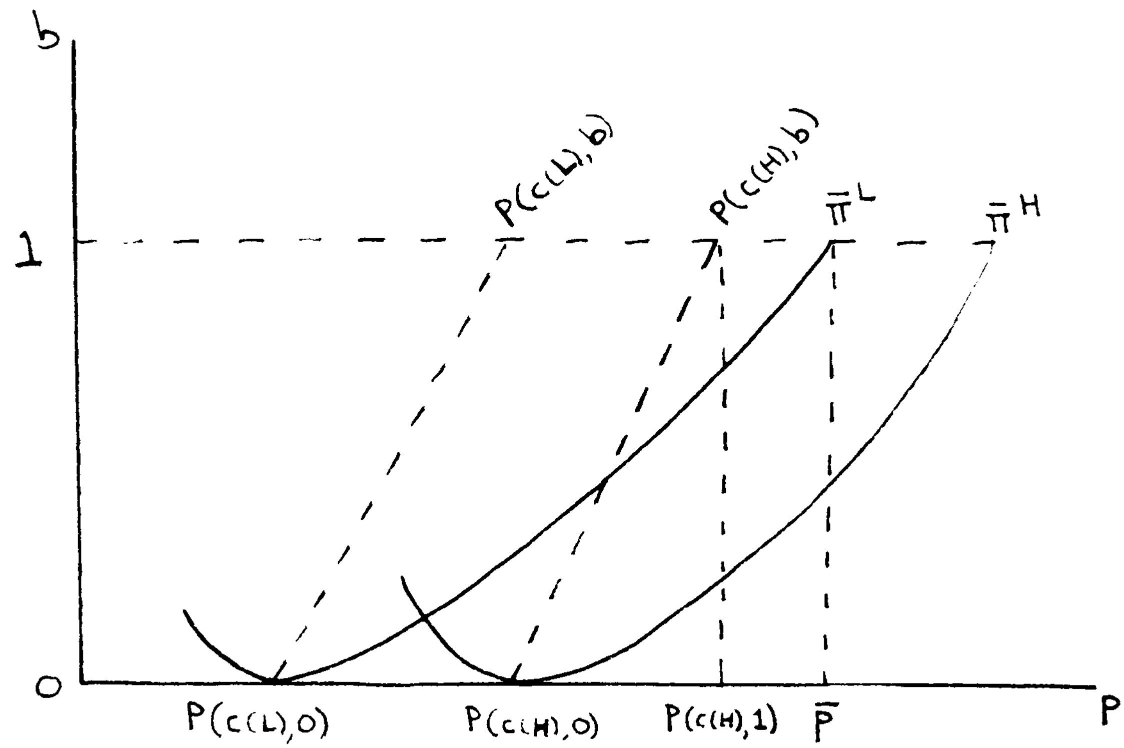

Figure 3

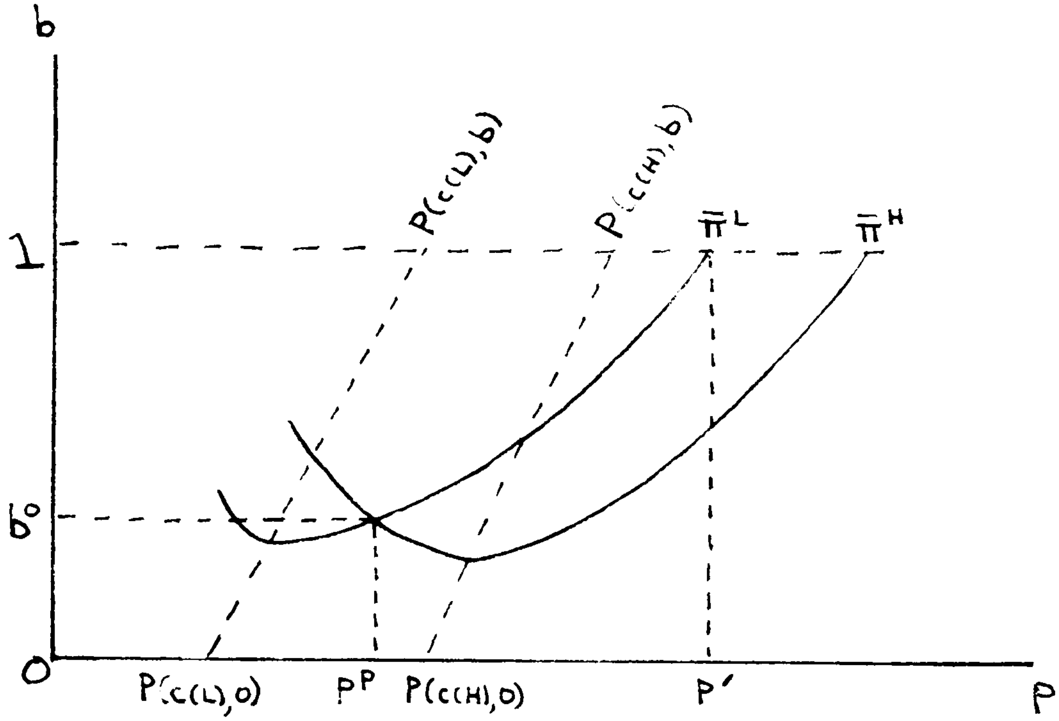

Figure 4

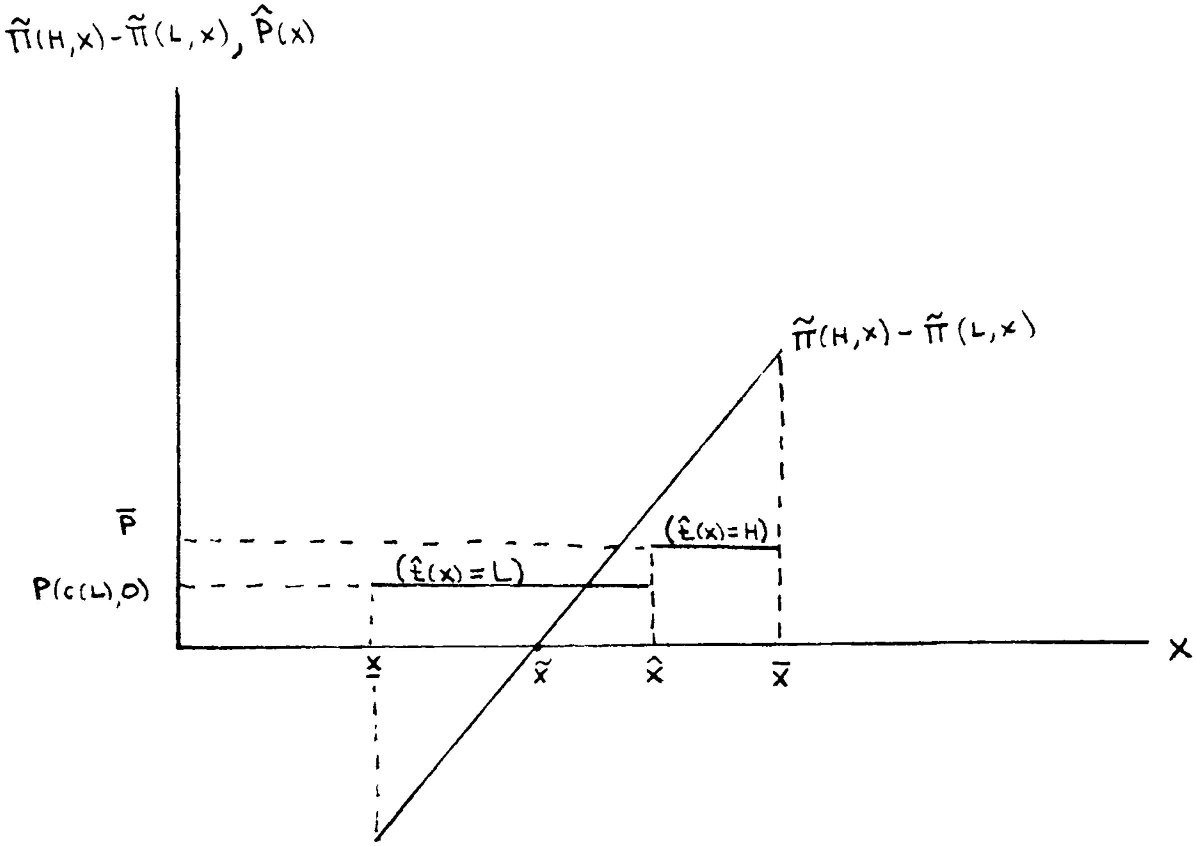

Figure 5

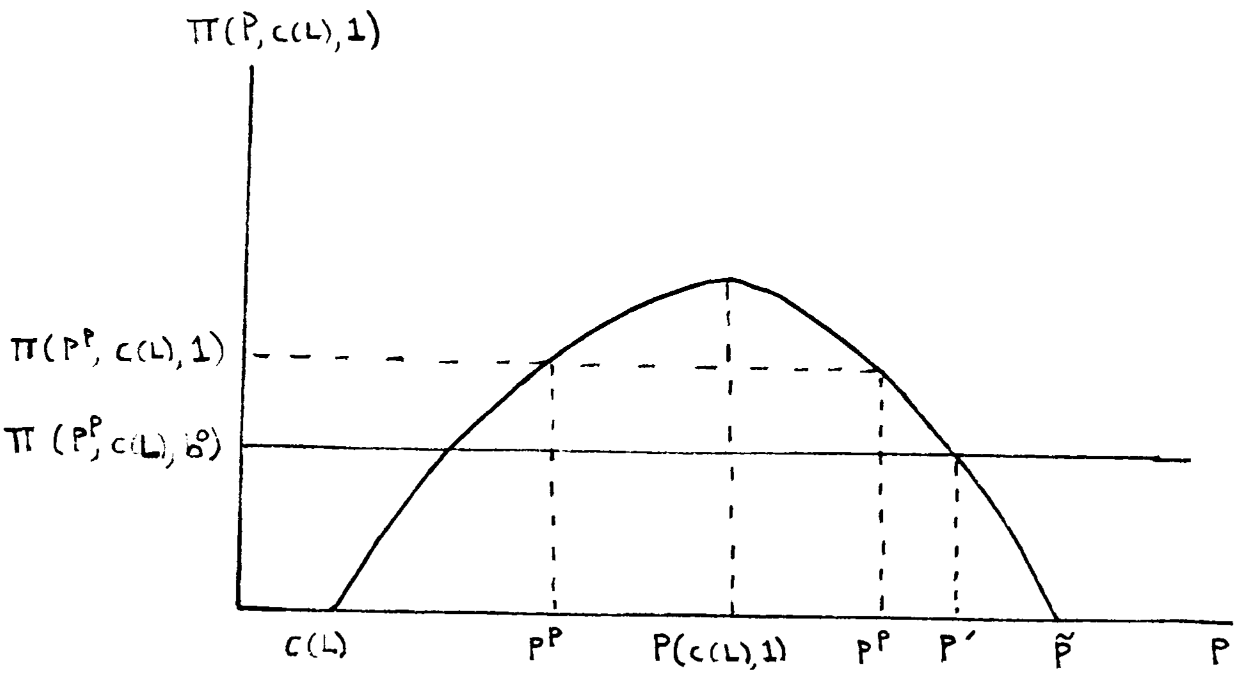

Figure 6