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The Impacts of Labeling on Trade in Goods that may be Vertically Differentiated According to Quality*

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Abstract:

A model of vertical differentiation is used to analyze the introduction of continuous and binary labeling in a market for credence goods under autarky and free trade. The results indicate that continuous labeling increases welfare under autarky and free trade. In the case of binary labeling, welfare is increased if the standard is set above the level that would be chosen under continuous labeling under autarky. In the case of free trade, the effects depend on whether binary labeling is harmonized or whether there is mutual recognition of different standards.

Keywords: Labeling, trade, vertical differentiation

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1. Introduction

Following Nelson (1970) and Darby and Karni (1973), analysis of asymmetric information and product quality has focused on the distinction between *search*, *experience*, and *credence* goods. In the case of search goods, information to aid consumers in their purchasing decisions is often plentiful, so that market failure is not a significant problem, and government regulatory activity is relatively minor (Caswell and Mojduszka, 1996). Most analysis has focused on experience goods (Stiglitz, 1989), significant contributions being made by Klein and Leffler (1981), Shapiro (1983), Allen (1984), and Riordan (1986). Results in this literature rely on quality being signaled to consumers via reputation effects. For example, Klein and Leffler show that if firms incur sunk costs by investing in firm-specific assets that are observable by consumers, high-quality goods will be supplied in equilibrium.

Typically, experience good models rely on a repeat-purchase mechanism as a credible threat to potential cheating firms. It is assumed that, *ex post*, consumers will learn if they purchased a low-quality good at a high-quality price. This is then communicated to remaining consumers so that the cheating firm will be subject to a consumer boycott in future periods. There are two problems with this argument: first it does not allow for uncertain product performance, where a firm may be permanently marked as a cheat, even though there was no deliberate malfeasance on their part (Liebeskind and Rumelt, 1989). Second, it assumes that consumers are actually able to assess quality even after consumption. Many goods are credence rather than experience goods, where quality is difficult to signal via private, reputation-type mechanisms (Caswell and Mojduszka, *op. cit.*). In the case of credence goods, labeling, in its private or public forms, has the ability to transform a market for credence goods from one plagued with a lemons-type informational problem into a fully functioning market if testing and detection of cheating are possible. Specifically, under certain circumstances, labeling can work where a reputable, private or public certification agent is hired by firms to aid in the signaling of quality.

Interestingly, much of the literature on product differentiation has ignored the issue of imperfect information and product quality. Recently though, Bester (1998) introduces the notion of unobservable quality into a horizontal differentiation model of the type developed by d'Aspremont, Gabszewicz, and Thisse (1979), and shows that unobservable quality reduces firms' incentives for differentiation by relaxing price competition among firms in the sense that prices are a signal and include a quality premium. Bester suggests that such a result might also be generated in a vertical differentiation setting as developed by Shaked and Sutton (1982, 1983), but he does not develop the result. Boom (1995) and Lutz (2000) both introduce minimum quality standards into a vertical differentiation model, but neither addresses the issue of imperfect information and product quality in the presence of credence goods.

In this paper, we introduce continuous and binary labeling into a vertical differentiation model under both autarky and free trade, where the quality of the good has credence attributes. Continuous labeling of credence and experience attributes is common for many consumer durable goods, e.g., consumer reports ratings of durability; for complex service goods, e.g., report cards on Health Maintenance Organizations; in nutrition contexts, e.g., FDA's Nutrition Facts panel reports sodium content as a percent of a recommended daily value; for energy conservation, e.g., EPA's energy efficiency ratings; and in environmental settings, e.g., ISO 14000 cradle-to-grave environmental labels and the New England Power Pool's environmental ratings of residential electricity services. In each setting a vertical quality attribute that is difficult or impossible for a consumer to assess, even after extensive experience with the good, is revealed via a graduated scale as enforced by a governmental agency, e.g., FDA or EPA, or a private firm, e.g., Consumer Reports. Examples of binary labeling include dolphin-safe tuna, the Green-e electricity certification and Germany's Blue Angel seal. In this case a specific quality that can be labeled is certified and enforced by either a governmental agency or private firm.

The basic model used in the paper is outlined in Section 2. In Sections 3 and 4, the welfare effects of continuous versus binary versus no labeling under autarky are analyzed, while in section 5, the welfare effects of labeling under free trade are examined. Finally, in Section 6, the paper is summarized and conclusions drawn.

2. The Basic Model

Consumers, Firms and Quality

Suppose in a specific country that consumers have a unit demand for a quality differentiated product and utility is:

$$U = u(y - p), \tag{1}$$

where $u \in [\underline{u}, \infty)$ is the quality level of the differentiated good, $\underline{u} > 0$ is the minimum possible quality of the good, y is income, and p is the price of the differentiated good. If the consumer decides not to buy the differentiated good, u=0; hence, the good is always purchased unless price exceeds income. Income is uniformly distributed on the interval [a, b] with the simplifying assumption that $sN = b - a$ equals the population of the country under consideration; we shall normalize $s = 1$ when considering a single country's population.[1]

Firms produce only the differentiated product and all firms share the same production technology characterized by zero production costs and a fixed, quality-dependent cost, $F(u)$, which is sunk by the firm after entry. We assume:

[1] See Shaked and Sutton for a discussion (1987) concerning relaxation of the assumption on the shape of the income distribution.

$$F(u) = \varepsilon + \alpha(u - \underline{u})^2 \text{ ,}$$

where ε and α are strictly positive constants. Sunk costs are convex and strictly increasing in the quality level. Also note that a sunk cost of $\varepsilon > 0$ must be expended to achieve even the lowest quality product.

Note that the type of quality analyzed here occurs in a market characterized by vertical differentiation. Vertically differentiated goods have the following feature: if all products were priced at marginal cost, all consumers would choose the same quality. This clearly holds for the present utility and marginal cost of quality functions and will hold as long as consumer willingness to pay for quality increases more rapidly with quality than does the marginal cost of quality.

Game Structure

Firms maximize profit in the following one-shot, three-stage game described in Figure 1:

1. At the first stage, each firm decides to enter or not enter the market, incurring sunk costs ε if they choose to enter.
2. At the second stage, firms that have entered simultaneously choose the quality level of their differentiated product, incurring the additional sunk costs for producing the chosen quality and also the costs of communicating that quality.
3. At the third stage, firms simultaneously set product prices.

It is assumed firms are perfectly informed about consumer preferences, the income distribution, and all firms' technologies. We invoke the concepts of sub-game perfect equilibrium and Bertrand-Nash competition for both the price- and quality-setting stages of the game.

Labeling Policy

This model differs from other vertical differentiation models in that the quality inherent in the product is a pure credence attribute. Hence, we assume no firm-based communication strategy can circumvent this problem, and, that all communication of quality occurs through a label that is administered either by a separate, private firm, or a government agency. We assume the firm or agency monitors the quality of individual firms for a fee paid by the firms. The labeling firm (government agency) can provide two types of labeling. Under continuous labeling the labeling firm (government agency) assesses the production process and assigns a rating that perfectly corresponds with the quality; the labeling firm (government agency) then precisely communicates each paying firm's rating to the consuming public. Under binary labeling the labeling firm (government agency) sets a single quality threshold and, upon payment by the firm, monitors the firm's production. If quality is greater than or equal to the standard, the labeling firm/agency communicates to the consuming public that the firm has either met or exceeded the quality standard.[2]

Specifically, this labeling firm (government agency) charges a fee of:

$$I(u) \quad = I^{i} \text{ for } u > \underline{u},\ i = ct, bn$$

$$= 0 \text{ for } u = \underline{u},$$

where *ct* and *bn* stand for continuous and binary labeling respectively. The second line of the definition reflects the following fact: if a firm has no label, consumers assume it is of the lowest quality. Hence a firm producing $\underline{u}$ will never purchase a labeling service. If more than one firm produced at a level above $\underline{u}$ we assume each firm is charged I^{i}, i.e., the cost of labeling involves

[2] Note that our use of the term quality standard differs from the term minimum quality standard as used in other vertical differentiation papers, e.g., Boom (1995), in that not all firms are required to produce at or above the standard; rather firms must do so to receive the binary label.

no fixed costs and there exist no economies of scale in providing this service. We consider two forms of labeling: continuous and binary.

Entry and Number of Firms

Though solutions to multi-stage games typically begin with analysis of the third stage, and then proceed by backwards induction, we draw upon previous results in the literature of vertical differentiation to make some initial remarks about the number of firms that will enter this market in the first stage of this game (see, for example, Shaked and Sutton, 1982, 1983; Motta, 1993; Boom, *op. cit.*; and Aoki and Prusa, 1996). First, we assume the following:

$$4a > b > 2a. \qquad (2)$$

This assumption limits the dispersion of income across the population. When more than one quality level is communicable via labeling, this assumption ensures that exactly two firms will enter this market, so long as fixed costs plus labeling costs are not prohibitively high, and that each entrant experiences a positive market share in equilibrium, i.e., a natural duopoly. Also, this restriction on income dispersion ensures that all consumers will be at least indifferent between not purchasing the differentiated product and purchasing the lowest quality product (i.e., the market is covered). The proof follows from lemmas 1 and 2 in Shaked and Sutton (1982) and is sketched in the Appendix. We also note that widening the income distribution will increase the number of firms that will enter the market so long as additional quality levels can be communicated by the labeling firm.

Price Equilibrium

We begin by solving the third stage of the game under the assumption that two firms have entered and chosen distinct, communicable quality levels ($0 < \underline{u} \leq u_1 < u_2$). Higher income consumers will choose the higher-quality good. Define y_1 as the income at which the consumer is indifferent to buying either the high or low quality good:

$$y_1 = (1 - r)p_1 + rp_2 \quad \text{with } r = u_2 / (u_2 - u_1), \tag{3}$$

where p_j is the price of the product with quality level j, and expression (3) is derived from (1). Also note that, given these prices, a consumer is indifferent between a product of quality u_1 and no product when $p_1 = y$. Given (3) profits of the two firms are:

$$\pi_1 = p_1(y_1 - \max[p_1, a]) - F(u_1) - I^{i}(u_1) \text{ and} \tag{4}$$

$$\pi_2 = p_2(b - y_1) - F(u_2) - I^{i}(u_2), \tag{5}$$

where $I^{i}(u_j)$ is the cost of communicating quality level u_j to consumers, and will depend upon the type of labeling policy in place, $i = ct, bn$.

By taking first-order conditions of these profit functions we can derive the Bertrand-Nash equilibrium. Three different equilibria could occur: the first is a *covered market* with equilibrium prices:

$$p_1^{cm} = \frac{b - 2a}{3(r - 1)} \tag{6}$$

$$p_2^{cm} = \frac{2b - a}{3r}. \tag{7}$$

These hold if $p_1^{cm} < a$. This is equivalent to:

$$u_1 > \frac{u_2(b - 2a)}{b + a}. \tag{8}$$

The second is a *corner solution* in which equilibrium prices are represented by:

$$p_1^{cs} = a \tag{9}$$

$$p_2^{cs} = \frac{a(r - 1) + b}{2r}, \tag{10}$$

which holds if $p_1^{cm} \geq a \geq p_1^{uc}$; this condition is equivalent to:

$$\frac{u_2(b-2a)}{b+a} \geq u_1 \geq \frac{u_2(b-4a)}{b-a}. \qquad (11)$$

The third is an *uncovered market* with equilibrium prices of:

$$p_1^{uc} = \frac{b}{3r+1} \qquad (12)$$

$$p_2^{uc} = \frac{2b}{3r+1}, \qquad (13)$$

if $p_1^{uc} > a$; which holds if:

$$u_1 < \frac{u_2(b-4a)}{b-a}. \qquad (14)$$

Condition (14) can never hold because of assumption (2), and because $\underline{u} > 0$ by assumption. Hence, all consumers will have a choice among two distinct qualities offered by the two firms and will either always choose a differentiated product or be indifferent between the lowest quality and not purchasing a differentiated product.

Finally we note that the results concerning equilibrium prices will hold as long as $\underline{u} < u_1 < u_2$. These qualities levels are assumed fixed during this third stage, hence, the quality levels need not have emerged from a second-stage optimal choice by firms over all possible qualities but could have also emerged from firms' discrete choice over several communicable qualities.

Quality Equilibrium

If two firms enter and can communicate a continuum of quality, they will choose quality levels to maximize their profits. We now express the two profit functions as a function of qualities by utilizing (2) and by using equilibrium price expressions from (6) and (7) or (9) and (10):

$$\pi_1(u_1;u_2)=\begin{cases}\pi_1^{cm}\equiv\dfrac{(b-2a)^2(u_2-u_1)}{9u_1}-F(u_1)-I^i(u_1)\text{ for }u_1>\hat{u}_1(u_2)\\ \pi_1^{cm}\equiv\dfrac{1}{2}a(b-a-\dfrac{au_2}{u_2-u_1})-F(u_1)-I^i(u_1)\text{ for }u_1<\hat{u}_1(u_2)\end{cases}\tag{15}$$

$$\pi_2(u_1;u_2)=\begin{cases}\pi_2^{cm}\equiv\dfrac{(2b-a)^2(u_2-u_1)}{9u_2}-F(u_2)-I^i(u_2)\text{ for }u_2<\hat{u}_2(u_1)\\ \pi_2^{cs}\equiv\dfrac{1}{4}\dfrac{((a-b)u_1+bu_2)^2}{u_2(u_2-u_1)}-F(u_2)-I^i(u_2)\text{ for }u_2>\hat{u}_2(u_1)\end{cases}.\tag{16}$$

The profit function changes at the same critical quality level as where the equilibrium price regime changes from a covered market to a market with a corner solution ($p_1 = a$). These quality thresholds are based upon the inequalities in (11) and are defined:

$$\hat{u}_1(u_2)=\frac{u_2(b-2a)}{b+a},\ \hat{u}_2(u_1)=\frac{u_1(b+a)}{b-2a}.\tag{17}$$

By (17) we can see that the qualities chosen in stage two will determine if the price equilibrium established in stage three is that of a covered or corner market.

First consider the quality choice of the low-quality firm. First-order conditions yield:

$$\frac{\partial\pi_1}{\partial u_1}(u_1;u_2)=\begin{cases}\dfrac{\partial\pi_1^{cm}}{\partial u_1}=-\dfrac{2(b-2a)^2}{9}\dfrac{u_2}{u_1^2}-F'(u_1)<0\text{ for }u_1>\hat{u}_1(u_2)\\ \dfrac{\partial\pi_1^{cs}}{\partial u_1}=-\dfrac{a^2u_2}{(u_2-u_1)^2}-F'(u_1)<0\text{ for }u_1<\hat{u}_1(u_2)\end{cases}\tag{18}$$

Whether the market is a covered or corner equilibrium, the profits of the low-quality firm decrease as it raises its quality level. Increasing quality increases sunk costs, increases price competition with the higher quality firm and requires a fixed expenditure to communicate quality via labeling. Further, we have already shown that all consumers will buy the differentiated good; hence raising quality never pulls more customers into the market. Hence, the low-quality firm always chooses:

$$u_1^{cm}=u_1^{cs}=\underline{u}\,.\tag{19}$$

If the income distribution were broader such that the market is uncovered, increasing quality could draw more consumers into the market and may cause firm one's optimal quality to be interior.

The high-quality firm's optimal quality decision follows from differentiation of its profit function:

$$\frac{\partial \pi_2}{\partial u_2}(u_1;u_2)=\begin{cases}\dfrac{\partial \pi_2^{cm}}{\partial u_2}=\dfrac{(2b-a)^2}{9}\dfrac{u_1}{u_2^2}-F'(u_2)\ \text{for}\ u_2<\hat{u}_2(u_1)\\ \dfrac{\partial \pi_2^{cs}}{\partial u_2}=\dfrac{u_1}{2(u_2-u_1)^2}\left[\dfrac{(b-a)^2(u_2-u_1)^2}{2u_2^2}-\dfrac{a^2}{2}\right]-F'(u_2)\ \text{for}\ u_2>\hat{u}_2(u_1)\end{cases}, \quad (20)$$

where the second derivative of π_2^{cm} is:

$$\frac{\partial^2 \pi_2^{cm}}{\partial u_2^2}=-\frac{2}{9}\left[\frac{2b-a}{u_2}\right]^2\frac{u_1}{u_2}<0, \quad (21)$$

and, the second derivative of π_2^{cs} is:

$$\frac{\partial^2 \pi_2^{cs}}{\partial u_2^2}=\frac{u_1}{2u_2^3(u_2-u_1)^3}[a^2u_2^3-(b-a)^2(u_2-u_1)^3]-F''(u_2). \quad (22)$$

One can establish the negativity of (22) in the following manner. First define $k = (b - a)/a$ and, by (2), we easily establish that $1 < k < 3$. Also note that π_2^{cs} is only of interest for $u_2>\hat{u}_2(u_1)=\dfrac{u_1(k+2)}{k-1}$. A sufficient condition for (22) to be negative is: $\dfrac{k^{2/3}}{k^{2/3}-1}<\dfrac{u_2}{u_1}$. If this holds for the smallest allowable u_2, and for $1 < k < 3$, then it will hold for all larger u_2. This reduces to verifying that $g(k) = 3k^{2/3} - k - 2 > 0$ for $1 < k < 3$ which, by visual inspection of Figure 2, holds. Hence, firm 2's profit is a concave function of its own quality choice in the second stage. It can also be verified that firm 2's profit function is continuous as π_2^{cs} and π_2^{cm} are equal at $u_2=\hat{u}_2(u_1)$.

Given the low-quality firm always chooses $u_1 = \underline{u}$, firm 2's optimal choice of quality is such that u_2 induces either a covered-market price equilibrium:

$$\frac{\partial \pi_2}{\partial u_2}(u_2;\underline{u}) = 0 \text{ for } u_2 < \hat{u}_2(\underline{u})\text{)},$$

a corner solution in prices:

$$\frac{\partial \pi_2}{\partial u_2}(u_2;\underline{u}) > 0 \text{ for } u_2 < \hat{u}_2(\underline{u}), \text{ and } \frac{\partial \pi_2}{\partial u_2}(u_2;\underline{u}) < 0 \text{ for } u_2 > \hat{u}_2(\underline{u}),$$

or an uncovered market:

$$\frac{\partial \pi_2}{\partial u_2}(u_2;\underline{u}) = 0 \text{ for } u_2 > \hat{u}_2(\underline{u}).$$

The equilibrium quality in a covered market is implicitly defined by:

$$u_2^{cm} = \left\{ u_2 \left| \frac{(2b-a)^2}{9} \frac{u_1}{u_2^2} - F'(u_2) = 0 \right. \right\}. \tag{23}$$

In a corner solution, equilibrium is defined by:

$$u_2^{cs} = \hat{u}_2(\underline{u}) = \frac{\underline{u}(b+a)}{2b-a}, \tag{24}$$

and, for an uncovered market equilibrium is implicitly defined by:

$$u_2^{uc} = \left\{ u_2 \left| \frac{u_1}{2(u_2-u_1)^2} \left[\frac{(b-a)^2 (u_2-u_1)^2}{2u_2^2} - \frac{a^2}{2} \right] - F'(u_2) = 0 \right. \right\}. \tag{25}$$

The quality pairs of (19) and (23), (19) and (24), or (19) and (25) represent a Nash equilibrium only if the low-quality firm has no incentive to leapfrog the high-quality firm, and, hence become the high-quality provider given that the high-quality firm has already chosen (23), (24) or (25). Boom (*op.cit.*) shows such an incentive never exists if (23) holds; hence a unique Nash equilibrium exists in such a case. Otherwise, a unique equilibrium may consist of (19) and (24) or (19) and (25) or a unique Nash equilibrium may not exist. The exact outcome depends on the severity of sunk costs, the lower threshold of quality and the income distribution.

An Example: Continuous Labeling Under Autarky

At this point an explicit numerical example, assuming continuous labeling, helps to solidify the model. Recall that $F(u_j) = \varepsilon + \alpha(u_j - \underline{u})^2$ represents the structure of sunk quality costs and assume that $\underline{u} = 1$, $a = 4$, $b = 10$, $\alpha = 0.5$ and $\varepsilon = 0.001$. The results from this example are given in the second column of Table 1. The equilibrium in qualities is:

$$u_1^{cm} = 1,\ u_2^{cm} = 3.42 < \hat{u}_2(1) = 7\,.$$

We verify that $u_1 = 1 > \frac{u_2(b-2a)}{b+a} = 0.60$ to assure a covered equilibrium in prices. The price equilibrium is:

$$p_1^{cm} = 0.62,\ p_2^{cm} = 3.77\,.$$

Finally we note that profits for the two firms are:

$$\pi_1^{cm} = 1.08, \pi_2^{cm} = 17.20 - I^{ct}\,.$$

Firm 1 and firm 2's profits are also plotted in Figures 3 and 4 respectively as a function of their own quality choices in the second stage of the game for this example.

3. Labeling Cost, Entry and Welfare Measurement

Note in the above example that profits are positive for each firm; hence, the cost of the labeling program could approach π_2 and the entrance of both firms is still guaranteed. This stems from the assumption made about the labeling program; i.e., a firm that produces the lowest possible level of quality does not need a labeling program to effectively communicate its quality level and any quality level above this must pay the full cost of the labeling program. Hence, a firm producing $\underline{u}$ will not pay for a voluntary program. A general result from the literature on vertically differentiated goods is that, when both firms enter the market, the high-quality firm will enjoy higher profits. Our example can differ from this result; if the cost of the labeling program approaches π_2 the lower quality firm enjoys higher profits.

Consumers' willingness to pay for the labeling program can be measured by calculating the compensating variation associated with the production of the quality-differentiated goods less the cost of the labeling program. To do this we must establish the level of welfare obtained without labeling. Using standard arguments about market structure and price competition in the presence of exogenous sunk costs (Sutton, 1991), we deduce that, in the absence of labeling, one firm enters the market, incurs a sunk cost ε, and then sells a product of quality $\underline{u}$ and charges a monopoly price, i.e., the second stage of the game in Figure 1 disappears. This follows from the fact that if a second firm were to enter at quality $\underline{u}$, Bertrand-Nash competition drives the price to zero, and firms would not cover their sunk costs.

The effects of the no labeling case using the previous numerical example are reported in the first column of Table 1. Given the assumption of a uniform income distribution, there exists a simple linear inverse demand function. Therefore, with zero marginal production costs, the monopoly price is p^*_{nl} = ½b = 5, where the subscript *nl* refers to no labeling.[3] Also, as we have assumed that ½b > a, this means that the monopoly price with no labeling drives some portion of the income distribution out of the market because price exceeds this segment's incomes. The firm's profits are:

$$\pi^*_{nl} = s\frac{b^2}{4} - \varepsilon = 25.$$

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[3] Following Baumol, Panzar and Willig (1982), if sunk costs were zero, the problem would reduce to that of a contestable market where the incumbent firm would price at zero given zero marginal production costs

Not surprisingly, the firm making monopoly profits in the case of no labeling is better off than producing either low or high quality in the presence of continuous labeling. Total consumer welfare without labeling is considerably lower, however, than in the case with continuous labeling:

$$CW_{nl} = \int_{1/2b}^{b} \underline{u}(y - \frac{1}{2}b)dy = \frac{1}{8}\underline{u}b^2 = 12.5$$

Consumer's compensating variation for the labeling program will depend upon consumer income, the quality received under labeling, i.e., high or low since the market will be covered, and the quality received without labeling, i.e., is the consumer in or out of the market without labeling? This leads to three possible definitions of consumer compensating variation; the one that is correct depends on the relative magnitudes of y_1 and ½ b.

$$CV = \begin{cases} \int_a^{y_1}[y - p_1^*]dy + \int_{y_1}^{1/2b}[y - p_2^*]dy + \int_{1/2b}^{b}[y(1-\tilde{u}_2) + \tilde{u}_2 p_N^* - p_2^*]dy, y_1 < \frac{1}{2}b \\ \int_a^{y_1(u_1^*,u_2^*)}[y - p_1^*]dy + \int_{y_1(u_1^*,u_2^*)}^{b}[y(1-\tilde{u}_2) + \tilde{u}_2 p_N^* - p_2^*]dy, y_1 = \frac{1}{2}b \\ \int_a^{1/2b}[y - p_1^*]dy + \int_{1/2b_1}^{y_1}[y(1-\tilde{u}_1) + \tilde{u}_1 p_N^* - p_1^*]dy + \int_{y_1}^{b}[y(1-\tilde{u}_2) + \tilde{u}_2 p_N^* - p_2^*]dy, y_1 > \frac{1}{2}b \end{cases} \quad ,(26)$$

where $\tilde{u}_j = \underline{u}/u_j^*$, u_j^* refers to the optimal quality level for the *j*th firm and p_j^* refers to the equilibrium price for the *j*th firm. For the example used above, *CV* equals 19.10. Compensating variation is independent of quality for those consumers with incomes less than ½ *b* because they are moving from a baseline in which utility equals zero because no differentiated good was purchased. Hence, lower prices are most critical to this group's willingness to pay for labeling. For consumers in the other portion of the income distribution, both higher quality and lower prices increase willingness to pay.

Consumer welfare under continuous labeling is defined as:

$$CW_{ct} = \int_a^{y_1} u_1^*(y - p_1^*)dy + \int_{y_1}^b u_2^*(y - p_2^*)dy\,, \qquad (27)$$

which equals 67.61 for the data used in the example from the previous section. In contrast to compensating variation, all consumers benefit from higher quality. In the later examples we will find that rankings of various labeling policies by simple summation of *CV* across consumers will often be different from rankings that emerge from a utilitarian summation of consumers' welfare.

4. Binary Labeling

Now consider the case of binary labeling in which the only available labeling is a binary program offered by a private firm (government agency) that charges $I^{bn} < I^{ct}$ for the labeling service. We make this assumption based on the stylized observation that a binary labeling scheme should be less costly to provide. The labeling firm (government agency) sets a quality standard at u_L such that firms with quality $u \geq u_L$ are allowed to pay I^{bn} and, hence, communicate to the consumer that it has quality of u_L or higher. Consumers know that quality is costly and always assume that no additional effort is taken beyond that of u_L if such a label is observed.

Firms no longer have the ability to marginally alter quality; hence they play a two-stage game involving the two communicable qualities: $\underline{u}$ and u_L. We assume a large number of firms consider entering at each quality. First they simultaneously decide whether to enter. Given our assumptions of Bertrand-Nash competition and the presence of strictly positive sunk costs at all quality levels, we determine that no more than one firm will enter at each communicable quality level, else sunk costs will not be recovered. Essentially, sunk costs are exogenous, the level of quality being fixed by the labeling program. After entry, those firms who have entered must simultaneously decide prices.

The price-setting stage of the game under binary labeling perfectly mimics the price-setting stage under continuous labeling with the exception that the quality levels are fixed by decree of the labeling firm (government agency) rather than from a strategic choice by the two firms in a previous stage. Which of the three price equilibria that hold, covered, corner or uncovered, is uniquely determined by the relative qualities $\underline{u}$ and u_L. In the case of a single labeling standard we can quickly determine the type of price equilibrium that will occur by recalling the criteria from stage two of the continuous labeling game:

- if $\underline{u} > \frac{u_L(b-2a)}{b+a}$, a covered price equilibrium occurs;

- if $\frac{u_L(b-2a)}{b+a} \geq \underline{u} \geq \frac{u_L(b-4a)}{b-a}$, a corner solution price equilibrium occurs.

Recall an uncovered solution cannot obtain due to the assumptions made concerning the income dispersion. Also note that the results of continuous labeling can be perfectly replicated if the binary labeling standard is chosen to be identical to the quality that would be chosen under continuous labeling; consumer welfare and compensating variation would be unchanged while firms would prefer binary labeling as it is less costly by assumption. Given that the labeling firm (government agency) may not choose the standard to be identical to endogenous quality from continuous labeling, we explore how welfare is affected if the standard is moved to either a higher or lower level relative to that from continuous labeling.

Entry of a firm at the standardized labeling quality level cannot be guaranteed if the standardized level is too high or too low. First, if the standard is very high, the fixed cost of producing this quality may be prohibitive and produce negative profits after price setting occurs in the final stage. Note that this did not occur in the continuous labeling situation because firms could marginally adjust quality. Also, firms might be guaranteed negative profits and not enter at the standard quality if the cost of labeling is too high. Labeling costs may also deter entry at the standard, if the standard is very close to $\underline{u}$ because strong price competition will emerge and drive firm 2's profits toward zero, and, hence, above labeling and fixed costs.

As reported in the third and fourth columns of Table 1, the welfare effects of binary labeling versus continuous labeling are straightforward for the firm. If the binary quality standard equals the higher quality level that emerges from continuous labeling, the firm is unambiguously better off because of the lower costs associated with binary labeling. As the binary quality standard is set higher relative to the continuous quality level, profits of firm 2 decrease from (17.20 - I^{ct}) to (14.76 – I^{bn}) due to rising sunk costs associated with quality, but profits of firm 1 increase from 1.08 to 1.78 because price competition is lessened. As the binary standard moves lower than continuous quality, both firms suffer stronger price competition but firm 2's sunk costs decrease. Hence, the firm producing the lowest quality hopes for the standard to be set higher than the endogenous continuous level while the firm producing high quality loses profits in both directions.

Under binary labeling, consumer welfare can be shown to be strictly increasing in the binary quality standard up to the point where no firm will enter due to the prohibitive sunk cost of producing such a quality. Taking the derivative of consumer welfare with respect to u_2^* yields:

$$\frac{\partial CW}{\partial u_2} = \frac{\partial y_1}{\partial u_2}\left[u_1(y_1 - p_1) - u_2(y_1 - p_2)\right] - \int_a^{y_1} u_1 \frac{\partial p_1}{\partial u_2} dy + \int_{y_1}^{b} [y - p_2 - u_2 \frac{\partial p_2}{\partial u_2}] dy\ . \qquad (28)$$

The first term in square brackets is the term that implicitly defines y_1 and is zero. The second term is negative because the price of the low-quality good will increase as price competition between the two goods relaxes; hence consumers with incomes less than y_1 are unambiguously worse off. The third term contains both positive and negative terms. To sign the entire expression we expanding the other two terms and use the substitution of $b = a(k + 1)$. This yields the expression:

$$\frac{\partial CW}{\partial u_2} = \left[\frac{a^2}{18(2u_2 + u_1)^3}\right] * [12u_1 k\left(17u_1u_2 + 4u_2^2 - 7u_1u_2k\right) + 2k\left(16u_2^3 - 7u_1^3\right) + 2u_2\left(24u_1u_2 + 4u_2^2k^2 + 6u_1u_2k^2 - 33u_1^3\right) + 13u_1^3 + 10u_1^3 + 32u_2^3]. \qquad (28')$$

The first term in square brackets is clearly positive. The second set of square brackets contains three negative terms. Recalling that $1 < k < 3$ and that $u_1 < u_2$, however, one can quickly verify that, in each set of round brackets, the positive terms dominate the negative term. Hence, we conclude that increasing the standard is welfare improving for consumers unless such an increase will not allow the entrant to recover sunk and labeling costs, thus thwarting entry. For the example data, *CW* increases from 67.61 in the continuous labeling case to 84.65 as the standard is raised to $u_1 = 5$. This net positive effect is driven by increases in welfare experienced by higher-income consumers while lower-income consumers are unambiguously worse off.

5. International Trade and Labeling

We now consider a north-north trade scenario, such as in the European Union, in which two identical countries open up their markets for the credence good under each of the aforementioned labeling schemes. By identical, we mean that they have the same income distributions, and firms face the same technology, resulting in the same market structure in each country. Specifically, there are no orthodox reasons for trade to occur between the two countries.

Continuous Labeling

Under continuous labeling, the firms or agencies communicating quality in each country choose a common ratings scale or other means of continuous quality communication that is credible and comprehensible to consumers in both countries. To analyze such a case, we replicate the steps from the single-country, autarky case from above but modify the profit functions to accommodate that $b - a = sN$ where s will take on the value of two in the numerical example. This thickening of the population of possible buyers has no effect on the possible price equilibria and conditions listed in (6) – (14).

The first thing to note is that exactly two firms will enter the unified market as the income dispersion is unchanged; hence, two firms that would have serviced each market under autarky will have to exit the integrated market when there is trade. Which firms exit, and the location of the remaining firms, is completely arbitrary in the case considered here. Essentially, there is no underlying reason in terms of either technology or income distribution that would generate an incentive for firms to locate in one country as opposed to the other. Therefore, the direction of trade in the model is indeterminate, although the structure of trade may be intra-industry in nature if a firm in one country produces the low-quality good and exports it in exchange for the high-quality good produced by the other country (see Gabszewicz *et al.*, 1981; Shaked and Sutton, 1984; Beath and Katsoulacos, 1991).[4]

The profit functions change slightly in the case of trade to reflect the larger market:

$$\pi_1(u_1;u_2) = \begin{cases} \pi_1^{cm} \equiv \dfrac{s(b-2a)^2(u_2-u_1)}{9u_1} - F(u_1) - I(u_1) \text{ for } u_1 > \hat{u}_1(u_2) \\ \pi_1^{cs} \equiv \dfrac{sa}{2}(b-a-\dfrac{au_2}{u_2-u_1}) - F(u_1) - I(u_1) \text{ for } u_1 < \hat{u}_1(u_2) \end{cases} \tag{29}$$

$$\pi_2(u_1;u_2) = \begin{cases} \pi_2^{cm} \equiv \dfrac{s(2b-a)^2(u_2-u_1)}{9u_2} - F(u_2) - I(u_2) \text{ for } u_2 < \hat{u}_2(u_1) \\ \pi_2^{cs} \equiv \dfrac{s}{4}\dfrac{((a-b)u_1+bu_2)^2}{u_2(u_2-u_1)} - F(u_2) - I(u_2) \text{ for } u_2 > \hat{u}_2(u_1) \end{cases}. \tag{30}$$

[4] To guarantee intra-industry trade, there would have to be overlapping income distributions where one country has a higher mean income than the other country, the former producing the high-quality good , the latter the low-quality good.

As in the case under autarky, the profit of firm 1 is monotonically decreasing in its own quality for all $u_1 > 0$; hence $u_1^* = \underline{u}$. An example is given in Figure 5 under various sizes of the population.

Firm 2's profits are concave in its own quality over the interval $[\underline{u}\ , \infty]$. This can be verified in a manner similar to that conducted in the case of autarky. Again, we concentrate on the covered market equilibrium, which is defined by:

$$u_{2cm} = \left\{ u_2 \left| \frac{s(2b-a)^2}{9} \frac{u_1}{u_2^2} - F'(u_2) = 0 \right. \right\}.$$

Figure 6 offers a plot of profits and the different resulting quality levels under autarky and trade for the example used in this paper.

The effects of free trade in the presence of continuous labeling are shown in the second column of Table 2. Clearly firms are better off under trade as the variable *s* has a purely multiplicative effect on the profit functions listed in (30) and (31), the profits of firm 1 increasing to 2.85, and those of firm 2 increasing to (38.22 - I^{ct}). With respect to consumer welfare there are competing effects. Higher quality is experienced for the segment of the population that purchases the labeled good. However, fewer individuals fall into this segment and the prices of both goods increase. The net effect is that consumers are better off with trade as the improvement in quality effect dominates the increase in prices, *CW* increasing from 67.61 under autarky to 76.12 under free trade. It is interesting to note that consumers' compensating variation for labeling is slightly higher under autarky than under trade.

Binary Labeling and Harmonization

When the two countries open up to trade, a key issue is whether to harmonize their quality standards for issuing binary labels to a common standard. The results in the third and fourth columns of Table 2 indicate that the change in consumer welfare *CW* is dependent on whether the standard is harmonized at a higher or lower level relative to the autarky case. If countries harmonize at a lower (higher) standard, consumer welfare in a country that lowers (increases) its standard has lower (higher) consumer welfare relative to binary labeling under autarky. However, both firms that remain in the market generally improve profits as they spread the fixed cost of quality over more consumers and sell to more consumers, even if the firm experiences a decrease in quality level because the standard is harmonized at the lower level. As with the continuous labeling case, the direction of trade is indeterminate.

Binary Labeling and Mutual Recognition

An alternative approach to harmonizing standards when markets are liberalized is the concept of mutual recognition, which was a key feature of the process the European Union went through in completing integration of its internal market (Lutz, *op. cit.*; Sheldon and von Witzke, 1991). Under mutual recognition, each country continues to administer its current labeling program and associated quality threshold. However, each country now recognizes the other country's labels and the associated quality standards are assumed to be fully understandable and comparable by the consuming public. Under the given assumptions, at most two firms will enter and have positive market shares but there will be three communicable quality levels: $0 < \underline{u} < u_L < u_H$, where u_L denotes the lower of the two mutually recognized standards.[5] The key issue, therefore, is which two of the three communicable levels will be produced in equilibrium.

If the mutually recognized standards are too close, typically, one firm will produce the highest quality u_H, and, the other firm will produce the lowest feasible quality $\underline{u}$.[6] Hence, the firm

[5] Both countries might have had chosen the same standard under autarky in which case mutual recognition yields the same results as harmonization.

[6] If u_H is high enough, such that a firm would just cover its fixed costs in equilibrium, it is possible that the lower quality u_L would be produced in equilibrium, along with $\underline{u}$.

in the country with the lower quality standard for labeling will produce at $\underline{u}$ for both domestic and export markets while the firm in the country with the higher labeling standard will produce at u_H for both domestic and export markets. If the firm in the country with the low labeling standard were to enter at that quality standard, it would face intense price competition from above and could not cover its sunk costs. The welfare effects of this case are essentially the same as the case where standards are harmonized at the high level as described in the fourth column of Table 2.

If the two standards are sufficiently different, the lowest quality $\underline{u}$ will be driven from the market, as firms supply at each of the two recognized standards. Such an outcome generally is optimal for consumers as average quality is inflated and price competition is partially maintained. The change in consumer welfare is:

$$\frac{\partial CW}{\partial u_1} = \frac{\partial y_1}{\partial u_1}\left[u_1(y_1 - p_1) - u_2(y_1 - p_2)\right] + \int_a^{y_1}(y - p_1)dy + \int_{y_1}^{b}\left[\frac{\partial u_2}{\partial u_1}(y - p_2) - u_2\frac{\partial p_2}{\partial u_1}\right]dy\ . \quad (31)$$

The first term in square brackets equals zero by the definition of $y_1$and the second term is positive because $p_1<a$. The third term is positive because an increase in u_1 will decrease p_2 all else equal due to greater price competition while an increase in u_1 will have no effect on u_2 because u_2 is exogenously set by the labeling agency.

Therefore, when the mutually recognized standards are such that neither of the two firms produces $\underline{u}$, consumers are unambiguously better off than if the highest standard and $\underline{u}$ were produced. This result is illustrated in the final column of Table 2. In such a situation, consumers experience greater average quality and price competition is increased, *CW* increasing to 114.04. In addition, the firm supplying the highest quality suffers the most relative to continuous labeling, its profits falling to (28.06-I^{bn}), as the standard is generally too high for its own selfinterest. In contrast, the lower quality firm fares better than if it were producing at $\underline{u}$, its profits increasing to (4.39- I^{bn}), unless labeling is very expensive.

6. Summary and Conclusions

In this paper we focus on analyzing a model of vertical differentiation in the presence of credence goods. In the absence of a certified labeling scheme, there is market failure in that only the lowest possible quality will be supplied in equilibrium by a single firm that extracts monopoly profits given sunk costs of entry. If a continuous labeling system is implemented, and given specific assumptions about the distribution of income, consumer welfare is increased, as a second firm enters the market and produces a higher-quality good. This essentially replicates the results derived in the vertical differentiation literature when there is no credence good problem. In the case of a binary labeling system, the welfare effects depend on whether the standard is set higher or lower than that which would emerge under a continuous labeling system.

We also extend our analysis of continuous versus binary labeling from autarky to the case of free trade. We establish that consumer welfare increases with trade and continuous labeling. We we are unable to predict the direction of trade, although its structure could be intra-industry in nature. In the case of binary labeling, the results are very sensitive to whether the standards are either harmonized or there is mutual recognition of labeling schemes. The welfare effects of harmonization depend on the direction of harmonization relative to the situation under autarky. Specifically, if harmonization occurs at the higher standard, total consumer welfare in the country that previously had a low standard increases though welfare of that country's lower-income consumers is unambiguously decreased.

In the case of mutual recognition, the welfare effects depend on distance between the two standards. If it is very close, only the high standard is produced in equilibrium, while if they are farther apart, the low quality good disappears and one good is produced at each standard. In the former case, the welfare effects are the same as harmonizing standards at the higher-level, while in the latter case there is an increase in consumer welfare.

Given the specific assumptions made in this paper, there are clearly some directions in which this research could be taken. For example, the assumptions concerning the income distribution and technology could be relaxed which would likely allow one to make unambiguous predictions about the direction and structure of trade. This would be particularly relevant in examining North-South trade in the presence of credence goods. Furthermore, firms often use labeling in tandem with private communications to signal the quality of credence or experience attributes. Integrating non-labeling communications (advertising or public relations campaigns) into the current model, might improve our understanding of the interaction between firm-level and agency-level communications, in establishing market structure and altering consumer welfare.

Appendix

We establish that, when $2a < b < 4a$, only two firms at most will enter then market. We follow closely the proofs from Lemmas 1 and 2 in Shaked and Sutton (1982). Suppose three firms were to enter at each quality; the following profit functions would emerge:

(A1) $\pi_1 = p_1(y_1 - \max[p_1, a]) - \varepsilon$

(A2) $\pi_2 = p_2(y_2 - y_1) - F(u_2)$

(A3) $\pi_3 = p_3(b - y_3) - F(u_3)$,

where $y_1 = (1 - r')\, p_1 + r'p_2$ and $y_2 = (1 - r'')p_2 + r''\, p_3$, $r' = u_2/(u_2 - u_1)$, and $r'' = u_3/(u_3 - u_2)$,

First-order conditions are:

(A4) $$\frac{\partial \pi_1}{\partial p_1} = \begin{cases} y_1 - a - p_1(r' - 1) = 0 \text{ for } p_1 \leq a \\ y_1 - 2p_1 - p_1(r' - 1) = 0 \text{ for } p_1 \geq a \end{cases},$$

(A5) $$\frac{\partial \pi_2}{\partial p_2} = y_2 - y_1 - p_2(r'' - 1) - p_2 r' = 0, \text{ and}$$

(A6) $$\frac{\partial \pi_3}{\partial p_3} = b - y_2 - p_3 r'' = 0.$$

From the definition of y_2 note that $p_3\, r'' = y_2 - (1-r'')p_2$; substituting this into (A6) yields:

(A7) $b - 2y_2 - p_2(r'' - 1) = 0$,

which, by the fact that $r'' > 1$ implies that $b > 2y_2$. A similar substitution can be made into (A5) which yields:

(A8) $y_2 - 2y_1 - p_2(r'' - 1) - p_0(r' - 1) = 0$,

which implies $y_2 > 2y_1$. Taken together this implies $b > 4y_1$. Recalling our assumption that $4a > b$ implies that $4a > 4y_1$ or that $a > y_1$. This means that even the poorest consumer will not buy the lowest quality if all three firms were to enter and allowed to choose prices simultaneously.

Given the above, if three firms entered, at most two would obtain positive market share. Firms must at least cover their fixed costs if they are to enter at any given quality.

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Table 1: Welfare Effects of Labeling Under Autarky

	No Labeling	Continuous Labeling	Binary Labeling High	Binary Labeling Low
Low Quality (u_1)	$\underline{u} = 1$	$\underline{u} = 1$	$\underline{u} = 1$	$\underline{u} = 1$
High Quality (u_2)	none	3.42	5*	2*
Price of Low Quality (p_1)	5	0.62	0.73	0.40
Price of High Quality (p_2)	NA	3.77	4.27	2.27
Income at which quality preference switches (y_1)	$y < 5$ do not purchase	5.08	5.15	4.93
Low Quality Firm's Profits (π_1)	25	1.08	1.78	0.44
High Quality Firm's Profits (π_2)	NA	$17.20 – I^{ct}$	$14.76 – I^{bn}$	$13.72 - I^{bn}$
Total Consumer Welfare per Country (*CW*)	12.5	67.61	84.65	52.44
Compensating Variation to Implement Labeling Policy per Country (*CV*)	NA	19.10	17.97	21.87
Firms' Increase in Profits per Country	NA	$-6.73 – I^{ct}$	$- 8.46 – I^{bn}$	$- 10.83 – I^{bn}$
Firms' Increase in Profits + Total Consumer *CV* per Country	NA	$12.38 – I^{ct}$	$9.50 – I^{bn}$	$11.03 – I^{bn}$

*Quality level is an assigned standard and not the result of firm optimization.

Table 2: Welfare Effects of Trade vs. Autarky with Various Labeling Schemes

	Autarky, Continuous Labeling	**Trade, Continuous Labeling**	**Trade, Binary Labeling Harmonized Low**	**Trade, Binary Labeling Harmonized High**	**Trade, Binary Labeling Mutual Recognition**
Low Quality (u_1)	$\underline{u} = 1$	$\underline{u} = 1$	$\underline{u} = 1$	$\underline{u} = 1$	$u_L = 1.21$*
High Quality (u_2)	3.42	4.21	3.42*	5*	$u_H = 7.21$*
Price of Low Quality (p_1)	0.62	0.68	0.62	0.73	0.77
Price of High Quality (p_2)	3.77	4.07	3.77	4.27	4.44
Income at which quality preference switches (y_1)	5 .08	5.12	5.08	5.15	5.18
Low Quality Firm's Profits (π_1)	1.08	2.85	2.15	3.56	$4.39 - I^{bn}$
High Quality Firm's Profits (π_2)	$17.20 - I^{ct}$	$38.22 - I^{ct}$	$37.33 – I^{bn}$	$37.51 - I^{bn}$	$28.06 - I^{bn}$
Total Consumer Welfare per Country (*CW*)	67.61	76.12	67.61	84.65	114.04
Compensating Variation to Implement Labeling Policy per Country (*CV*)	19.10	18.42	19.10	17.97	17.95
Firms' Increase in Profits (per country)	$-6.72 – I^{ct}$	$-4.46 – I^{ct}$	$- 5.26 – I^{bn}$	$- 4.47 – I^{bn}$	$-8.78 – 2I^{bn}$
Firms' Increase in Profits + Total Consumer *CV* (per country)	$-12.38 – I^{ct}$	$13.96 – I^{ct}$	$13.84 – I^{bn}$	$13.50 – I^{bn}$	$9.17 – 2I^{bn}$

*Quality level is an assigned standard and not the result of firm optimization.

Figure 1: The Three-Stage Game

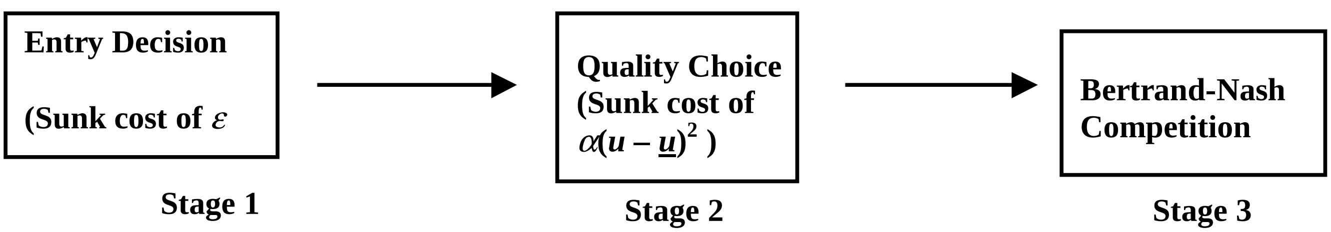

Figure 2: Verifying Concavity of Firm 2's Profits in Own Quality

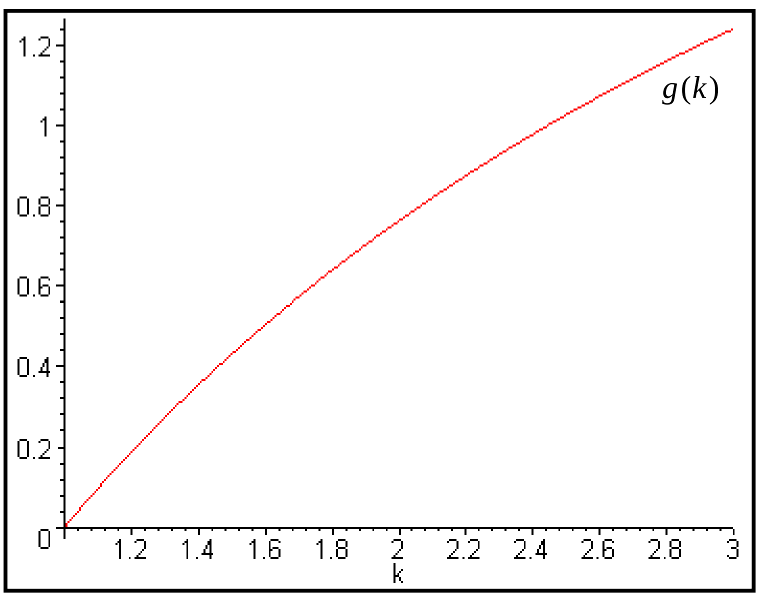

Figure 3: Firm 1's Profits as a Function of Own Quality

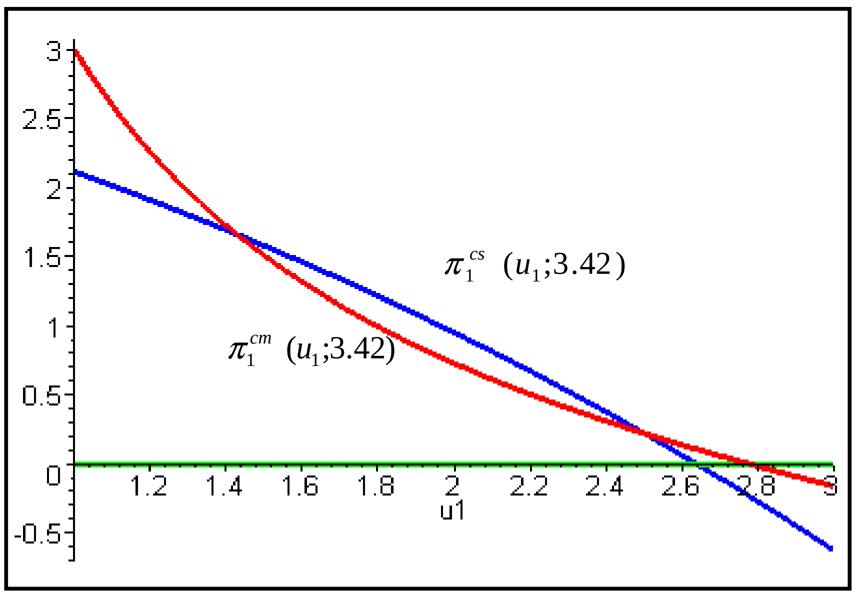

Figure 4: Firm 2's Profits as a Function of Own Quality

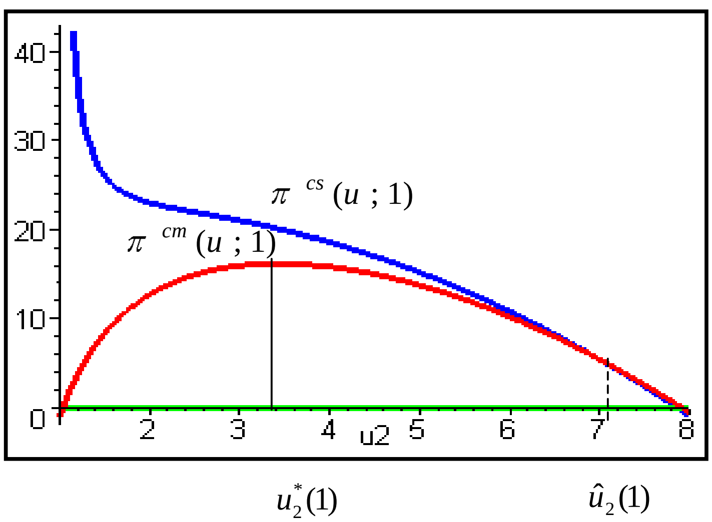

Figure 5: Firm 1's Profits as a Function of Own Quality with and without Trade

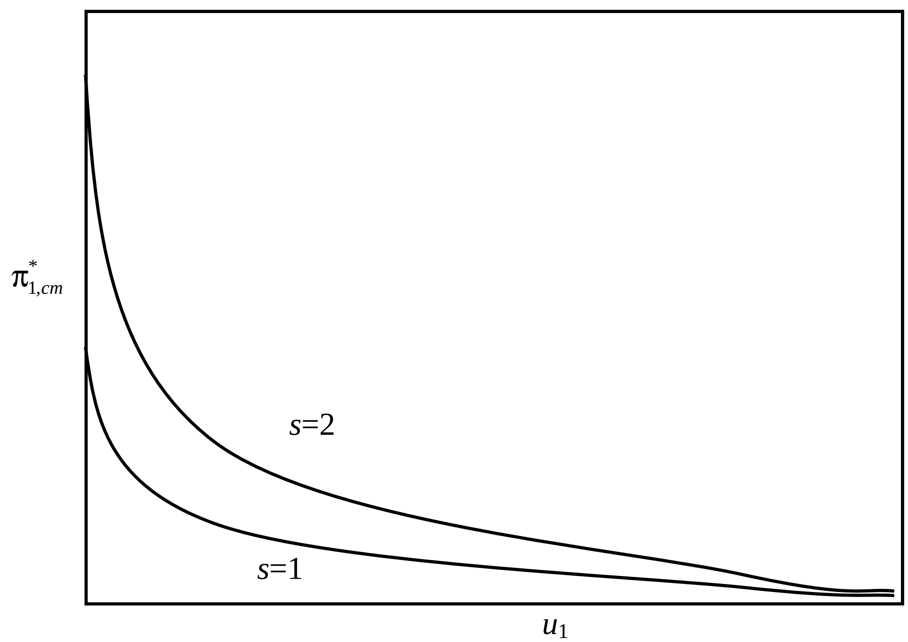

Figure 6: Firm 2's Profits as a Function of Own Quality with and without Trade