2001 American Agricultural Economics Association Annual Meetings
August 5 – 8, 2001
Chicago, IL

The Impacts of Labeling on the Production and Trade of Vertically Differentiated Goods with Process Attributes

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Abstract:

A model of vertical quality differentiation is used to analyze the introduction of continuous and binary labeling in a market for credence goods with process attributes under autarky and free trade. The results indicate that continuous labeling increases welfare under autarky and free trade so long as labeling is not too expensive. With binary labeling, consumer 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, vertical differentiation, credence goods, trade

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1. Introduction

Increasingly, consumer goods are differentiated by process-attributes, e.g., organically produced food, dolphin-safe tuna, free-range livestock and poultry, low-emissions electricity, irradiated food, pasteurized fruit juices, etc., as well as by use-attributes, e.g., taste, texture, performance. Important implications may arise for various sectors of agriculture, for the environment, and for international trade as consumers shift purchases among goods produced by different methods. However, many of these newly demanded process-attributes are not correlated with end-use attributes and, hence, an asymmetric information problem ensues: consumers cannot verify the veracity of the process-attribute claims, even after lengthy inspection or consumption of the good. Darby and Karni coined the term *credence goods* to describe products with such characteristics and, for the most part, such goods have not been analyzed widely in the literature. Furthermore, the quality of these goods is often vertically aligned; i.e., if different goods were offered at marginal cost all consumers would prefer the same high-quality item. Typically, quality has been modeled in the product differentiation literature as horizontal or spatial differentiation where not all consumers agree upon the ranking of differentiated goods offered at marginal cost, e.g., Dixit and Stiglitz. In this paper, we analyze how several popular labeling institutions may affect market structure and international trade in this important, emerging class of vertically differentiated credence goods with process attributes.

Following Nelson, and Darby and Karni, 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 consumer purchase decisions is often plentiful, so that market failure is not a problem, and government regulatory activity is relatively minor (Caswell and Mojduszka). Most analysis has focused on experience goods (Stiglitz), with significant contributions being made by Klein and Leffler, Shapiro, Allen, Riordan, and Milgrom and Roberts. 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 a 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 (Liebeskind and Rumelt). Second, it assumes that consumers are actually able to assess quality even after consumption. In this paper the latter assumption is relaxed by modeling goods with credence attributes.

In the case of credence goods, we show that labeling, in its private or public forms, often has the ability to transform the market from one plagued with a lemons-type informational problem into a fully functioning market if testing and detection of cheating are possible at a reasonable cost. Specifically, labeling works where a reputable, private or public certification agent is hired by firms to aid in the communication of quality.

Interestingly, much of the literature on product differentiation has ignored the issue of imperfect information and product quality. Recently though, Bester introduces the notion of unobservable quality into a horizontal differentiation model of the type developed by d'Aspremont, Gabszewicz, and Thisse, and shows that unobservable vertical quality reduces firms' incentives for horizontal 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, and Lutz both introduce minimum quality standards[1] into a vertical differentiation model, but neither considers the possibility of imperfect information and product quality in the presence of credence goods. Recent papers in the agricultural economics literature, however, do address the issue of labeling and credence goods. Marette, Crespi, and Schiavina show that a cartel providing information through a common certified labeling scheme increases welfare if labeling costs are high, even if producers collude to reduce competition. While Marette, Bureau, and Gozlan show in a simple monopoly setting that unless the fixed costs of safety effort are high, both minimum standards and certified labeling can resolve the credence good problem in the case of food safety.

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., the U.S. Food and Drug Administration's (FDA) Nutrition Facts panel reports sodium and fat content as a percent of a recommended daily value; for energy conservation, e.g., the U.S. Environmental Protection Agency's (EPA) energy efficiency ratings; and in environmental settings, e.g., the International Standards Organization's 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 continuously monitored by a governmental agency, e.g., FDA or EPA, or a private firm, e.g., *Consumer Reports*. Examples of binary labeling include organic food certification,[2] dolphin-safe tuna labeling, the American Humane Association's Free-Farmed animal welfare label, the Center for Resource Solution's Green-E renewable electricity certification, the European Union's eco-label program, Underwriters' Laboratory safety and performance certification, and Germany's Blue Angel eco-label. In these cases, specific quality-levels are defined, labeled and verified by either a governmental agency or private firm.

In this paper we show that labeling can improve consumer welfare in markets with credence goods with process attributes so long as the administrative costs are not too high; this is easy to show and quite intuitive. We also address several other substantive questions: how is total social welfare impacted by the type of labeling employed and how does the type of labeling scheme impact social welfare in a simple trade scenario? The basic model used to answer these questions 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.[3] 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, and $s = 2$ for trade between two countries.[4]

Firms produce only the differentiated product and all firms share the same production technology characterized by zero production costs[5] and a fixed, quality-dependent cost, $F(u)$, which is sunk by the firm after entry.[6] We assume:

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

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.

Game Structure

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

1. Each firm decides to enter or not enter the market, incurring sunk costs ε upon entry.
2. 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. 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.

Labeling Policy

This model differs from other vertical differentiation models in that product quality 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, hereafter labeling agency. We assume this labeling agency monitors the quality of individual firms for a fee paid by the firms.[7] The labeling agency can provide two types of labeling. Under continuous labeling the firm assesses the production process and assigns a rating that perfectly corresponds with the quality; the labeling agency then precisely communicates each paying firm's rating to the consuming public. Under binary labeling the labeling 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 agency communicates to the consuming public that the firm has either met or exceeded the quality standard.

Specifically, the labeling agency charges a fee of:

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

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

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., labeling involves no fixed costs and no economies of size.

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 game's first stage (see, for example, Shaked and Sutton, 1982, 1983; Motta; Boom; and Aoki and Prusa). First, we assume the following:

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

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 Appendix A. Widening the income distribution will increase the number of firms that will enter the market so long as additional quality levels can be communicated.

Price Equilibrium

We now solve 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:

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

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:

(4) $$\pi_1 = sp_1(y_1 - \max[p_1, a]) - F(u_1) - I^{i}(u_1) \text{ and}$$

(5) $$\pi_2 = sp_2(b - y_1) - F(u_2) - I^{i}(u_2),$$

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 equilibria are possible: a *covered market*, a *corner solution*, or an *uncovered market*. In common with the previous literature on vertical product differentiation, we focus on a covered market with equilibrium prices:

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

(7) $$p_2 = \frac{2b-a}{3r}.$$

These hold if $p_1 < a$. This is equivalent to:

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

Hence, all consumers will have a choice amongst two distinct qualities offered by the two firms and will always choose 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. Express the two profit functions as a function of qualities by utilizing (2) and by using equilibrium price expressions from (6) and (7):

(9) $$\pi_1(u_1;u_2) = \frac{s(b-2a)^2(u_2-u_1)}{9u_1} - F(u_1) - I^i(u_1) \text{ for } u_1 > \hat{u}_1(u_2)$$

(10) $$\pi_2(u_1;u_2) = \frac{s(2b-a)^2(u_2-u_1)}{9u_2} - F(u_2) - I^i(u_2) \text{ for } u_2 < \hat{u}_2(u_1).$$

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

(11) $$\frac{\partial \pi_1}{\partial u_1}(u_1;u_2) = -\frac{2s(b-2a)^2}{9}\frac{u_2}{u_1^2} - F'(u_1) < 0 \text{ for } u_1 > \hat{u}_1(u_2)\,.$$

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.[8] Hence, the low-quality firm chooses:

(12) $$u_1 = \underline{u}\,.$$

The high-quality firm's optimal quality decision follows from differentiating (10):

(13) $$\frac{\partial \pi_2}{\partial u_2}(u_1;u_2) = \frac{s(2b-a)^2}{9}\frac{u_1}{u_2^2} - F'(u_2) \text{ for } u_2 < \hat{u}_2(u_1)\,,$$

where the second derivative of π_2 is:

(14) $$\frac{\partial^2 \pi_2}{\partial u_2^2} = -\frac{2s}{9}\left[\frac{2b-a}{u_2}\right]^2 \frac{u_1}{u_2} < 0.$$

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

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

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

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

The quality pairs of (12) and (15) 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 (15). Boom shows such an incentive never exists if (15) holds; hence, a unique Nash equilibrium exists.

An Example: Continuous Labeling Under Autarky

At this point an explicit 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:

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

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:

$$p_1 = 0.62,\ p_2 = 3.77\ .$$

Finally we note that profits for the two firms are:

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

3. Labeling Cost, Entry and Welfare Measurement

Note in the above example that profits net of the labeling fee, Π_i, 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), 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 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.[9] 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:

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

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.

(16)

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

where $\tilde{u}_j = \underline{u}/u_j^*$, u_j^* refers to the optimal quality level for the jth firm and p_j^* refers to the equilibrium price for the jth firm. For the example of continuous labeling under autarky, 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:

$$CW_{ct} = \int_a^{y_1} u_1^*(y - p_1^*)dy + \int_{y_1}^{b} u_2^*(y - p_2^*)dy \,, \tag{17}$$

which equals 67.61 for the data used in the previous example. 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. Hence, we summarize consumer welfare effects in terms of changes in *CW* while we summarize total welfare effects using the sum of *CV* and changes in firm profits.

4. Binary Labeling

Now consider the case of binary labeling in which the only available labeling is a binary program offered by the labeling 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 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, ε, 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 agency rather than from a strategic choice by the two firms in a previous stage. In the case of a single labeling standard we can determine that, a covered price equilibrium will occur, by recalling condition (8) from stage two of the continuous labeling game. 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. We now consider how welfare is affected if the labeling agency does not choose the standard to be identical to endogenous quality 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.

The welfare effects of binary labeling versus continuous labeling are straightforward for firms. If the binary quality standard equals the higher quality level that emerges from continuous labeling, firm 1 earns the same profit while firm 2 is unambiguously better off because of binary labeling's lower costs. Hence, if the labeling agency chooses a binary standard to replicate the quality levels achieved under continuous labeling, firms fare better while consumers experience no change.

As the binary quality standard deviates from the level endogenously obtained under continuous labeling (u_2^*), the profits of firm 2, net of labeling costs, decreases; this arises from the concavity of (10) in u_2. Hence, for a small neighborhood around u_2^*, firm 2 is better off with binary labeling because the decrease in profit net of labeling costs is smaller than the increased profits gained from the cheaper labeling cost. The profits for firm 1 are higher (lower) if the standard is set higher (lower) than u_2^*; this is easily verified by noting that (9) is strictly increasing in u_2. As the standard increases, firm 1's price competition with firm 2 is lessened but firm 1 absorbs no additional cost of quality or labeling. As the binary standard moves lower than continuous quality, however, firm 1 suffers stronger price competition from firm 2. Hence, the firm producing the lowest quality hopes for the standard to be set higher than u_2^* while the firm producing high quality hopes for a binary standard very close to u_2^*. The third and fourth columns of Table 1 verify these results for the example used earlier.

Under binary labeling, consumer welfare is strictly increasing in the binary quality standard up to the point where no firm will enter at the labeled quality level due to the prohibitive sunk cost of producing such a quality (See Appendix B for the derivation). For the example data, *CW* increases from 67.61 in the continuous labeling case to 84.65 as the standard is raised to $u_2 = 5$. 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 (EU), 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.

Continuous Labeling

Under continuous labeling, the 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 we now allow $s = 2$ in the numerical example.

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 Shaked and Sutton, 1984; Beath and Katsoulacos).[10]

As in the case under autarky, the profit of firm 1 is monotonically decreasing in its own quality for all $u_1 > 0$; hence $u_1^* = \underline{u}$. Firm 2's profits are still concave in own quality over the interval $[\underline{u}, \infty)$ and, as s increases, so does u_2^*.

The effects of free trade in the presence of continuous labeling are shown for the numeric example 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 (9) and (10), 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. Hence, more people consume the lower quality good at a higher price. The net effect is that under a utilitarian social welfare function consumers are better off with trade as the improvement in quality effect dominates the increase in prices; for example *CW* increases from 67.61 under autarky to 76.12 under free trade in the numeric example. 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 and both countries utilize binary labeling schemes, a key issue is whether to harmonize labeling standards to a common quality level. As in the case under autarky (see Appendix B), consumer welfare hinges upon the net effect of trade on the quality standard. If trade increases the quality standard, consumer welfare increases. Comparing the results in columns three and four of Table 2 to columns three and four in Table 1 verifies these results for the example. The two 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; this holds even if the firm is forced to produce at a lower 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 EU went through in completing integration of its internal market (Sheldon and von Witzke). 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. 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 $\underline{u}$.[11] Hence, the firm 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 $\underline{u}$ may 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:

$$(20) \qquad \frac{\partial CW}{\partial u_1} = \frac{\partial y_1}{\partial u_1}\left[u_1(y_1-p_1)-u_2(y_1-p_2)\right]+\int_a^{y_1}(y-p_1)dy+\int_{y_1}^{b}\left[\frac{\partial u_2}{\partial u_1}(y-p_2)-u_2\frac{\partial p_2}{\partial u_1}\right]dy.$$

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* increases to 114.04. In such a situation the firm supplying the highest quality suffers the most relative to continuous labeling; for example, firm two's profits fall to (28.06-I^{bn}) in the numeric example, as the standard is generally too high for its own self-interest. In contrast, the lower quality firm may improve its situation by increasing quality above $\underline{u}$; in the numeric example its profits increase to (4.39- I^{bn}) and will increase its profits unless labeling is very expensive.

6. Summary and Conclusions

In this paper we analyze 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. In the case of a binary labeling system, total consumer welfare increases (decreases) if the binary standard is set higher (lower) than that which would emerge under a continuous labeling system, u_2^*. High (low) income consumers benefit while low (high) income consumers suffer if the binary standard is set higher (lower) than u_2^*. The profits of the firm producing the lower quality increase (decrease) as the binary standard is higher (lower) than u_2^* while the profits of the firm producing the higher quality are higher so long as the binary standard does not deviate from u_2^* by too much.

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 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 consumer welfare increases.

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, either 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 A

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

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

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

From the definition of y_2 note that $p_3\, r'' = y_2 - (1\text{-}r'')p_2$; 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.

Appendix B

To show that consumer welfare is increasing in the binary labeling standard, take the derivative of consumer welfare with respect to u_2^*:

$$\text{(B1)}\qquad \frac{\partial CW}{\partial u_2} = \frac{\partial y_1}{\partial u_2}[u_1(y_1 - p_1) - u_2(y_1 - p_2)] - \int_a^{y_1} u_1 \frac{\partial p_1}{\partial u_2} dy + \int_{y_1}^{b} [y - p_2 - u_2 \frac{\partial p_2}{\partial u_2}] dy\ .$$

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:

$$\text{(B1}'\text{)}\quad \frac{\partial CW}{\partial u_2} = \left[\frac{a^2}{18(2u_2 + u_1)^3}\right] * [12u_1 k\left(17u_1u_2 + 4u_2^2 - 7u_1u_2k\right) + 2k\left(16u_2^3 - 7u_1^3\right) + 2u_2\left(24u_1u_2 + 4u_2^2k^2 + 6u_1u_2k^2 - 33u_1^3\right) + 13u_1^3 + 10u_1^3 + 32u_2^3]\ .$$

The first term in square brackets is clearly positive. The second set of square brackets contains three terms preceded by negative signs. 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 one firm's entry and inducing monopoly.

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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.

Endnotes

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

[2] USDA's organic certification actually identifies four distinct levels of organic production – 100 percent organic, organic (≥ 95 percent organic by weight), made with organic (≥ 70 percent organic by weight) and made with some organic ingredients – rather than two levels as in a true binary label. Many state certifications that preceded the national certification system were often truly binary, however. Perhaps the more important distinction is that between continuous quality labeling and discrete quality level labeling. For brevity, we continue with the term binary.

[3] Assumptions concerning the form of the utility function and the reservation utility level can be relaxed without substantially changing the main results; see Cremer and Thisse for an example of a more general utility function.

[4] See Shaked and Sutton for a discussion (1983) concerning relaxation of the assumption on the shape of the income distribution.

[5] The assumption of zero production costs can also be relaxed without altering the main results of the paper. The key assumption needed to retain the results is that production costs do not increase in quality more rapidly than consumer willingness to pay increases in quality; if this is not met the results resemble those of a model of horizontal quality differentiation (Beath and Katsoulacos).

[6] Many goods can be characterized by a vertical quality that is dominated by fixed costs: e.g., scrubbers for lowering emissions, production line changes to improve food safety, etc. Other products, such as organic food, dolphin-safe tuna or free-range poultry, may rely on higher production costs as well.

[7] See Crespi and Marette for a discussion of the financing of food safety certification.

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

[9] 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 (Baumol, Panzar and Willig).

[10] 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.

[11] 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 $\underline{u}$.