Staff Paper

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Abstract

Certified labeling for credence attributes is examined using the concepts of pooled and separating equilibria. The analysis addresses a latent credence good demand that differs from a conventional good demand by willingness to pay for the credence characteristic. Third-party certified labeling vertically differentiates the two products and a two separate markets replace a single pooled market. Market outcomes are examined theoretically and with empirical simulations. Costless labeling is net welfare improving, but impacts are highly asymmetric. Credence producers gain largely at the expense of conventional producers. Costly labeling may reduce welfare even with rather modest labeling costs.

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The Welfare Consequences of Certified Labeling for Credence Attributes

Public agencies are under pressure to certify food labels for non-nutritional, credence attributes (Golan et al. 2001). Credence attributes are product features that cannot be directly experienced by consumers (Darby and Karni 1973). Notable examples of credence attributes include dolphin-safe tuna (Teisl, Roe, and Hicks 2002) and the National Organic Program (Agricultural Marketing Service 2003b). Additional examples include origin labeling (Agricultural Marketing Service 2003a), absence of pesticide residues (Ott, Huang, and Misra 1991), genetically modified content (Caswell 1998; Zedalis 2001), and hormone-free labeling (Kleiner).

Without credence labeling, consumers are unable to identify whether a product has a desired credence attribute. A conventional product without the credence attribute appears to be a perfect substitute for the credence good. In terms of consumers' direct experience, the credence and conventional goods are indistinguishable without labeling. Third-party monitoring and certification are necessary to improve the label uniformity (Golan et al. 2001) and avoid fraud (McCluskey 2000). Certified labeling removes the informational asymmetry and distinguishes products so that separate markets and prices emerge for the credence and conventional products.

Whether labeling improves consumer and producer welfare in a given case remains unclear. Full information may seem to be a welfare improving, but costly disclosure reduces welfare to the extent that it merely redistributes surpluses (Spence 1973). In an agricultural setting, Giannakas (Giannakas 2002)and Giannakas and Fulton (Giannakas and Fulton 2002) show that the welfare gains from certified labeling are *a priori* ambiguous for consumers. Crespi and Marette (Crespi and Marette 2001) develop a model where a high cost credence subsector is unable to compete with a lower cost, conventional subsector. A stark market failure occurs where high credence firms are driven out of the market by their persistent marginal cost disadvantage (Crespi and Marette 2001).

The market failure with zero high credence producers appears to be too restrictive for guiding actual food labeling policies. Empirically, labeling is not a necessary condition for high credence firms to survive in competition with conventional firms (Sedjo and Swallow 2002). For instance, a third of retail fruits and vegetables are pesticide-free (Agricultural Marketing Service 2001), two-thirds of corn production in the United States uses seeds that are not genetically engineered (National Agricultural Statistics Service 2002), and sixty-five percent of dairy cows produce milk without the use growth hormones (Barham and Foltz 2002). These data suggest that the market failure of zero high credence goods is the wrong baseline for assessing efficiency gains.

Our analysis develops a theoretically sound, empirically operational framework for evaluating the welfare consequences of product labeling in large agricultural markets. The markets are composed of a large number of consumers and producers who behave competitively. Producer and consumer behavior are summarized by aggregate supplies and demands that are inelastic. Latent credence good demand differs from a conventional good demand by willingness to pay for the credence characteristic. Third-party certified labeling vertically differentiates the two products and a two separate markets replace a single pooled market.

Without labeling, the credence and conventional goods are perfect substitutes. Credence and conventional firms coexist in the unlabeled market with a single market price, since inelastic supplies allow subsector marginal costs to rise and fall with subsector production levels. Consumers view the pooled product as a mixed good, and have a conjecture about the proportion of the high-credence attribute provided by the mixed good. Credence and conventional goods separate into two distinct markets for credence and conventional goods once certified labeling is introduced.

The analysis examines the price, quantity, and welfare consequences of labeling by comparing Nash equilibria for the pooled and separated markets. In contrast to previous results involving on consumers (Giannakas 2002; Giannakas and Fulton 2002), the numerical simulations shows that costless labeling unambiguously improves aggregate welfare when both demand and supply adjustments are considered. Gains and losses are highly asymmetric. Credence producers are certain to gain and conventional producers are certain to lose when a credence price premium emerges. The net gain from labeling is small, relative to the size of the gains to the credence subsector and the losses to conventional producers. Costly labeling may be inefficient in aggregate, while promising large gains for credence producers. Hence, myopic policy analysis that focuses only on the gains of the credence subsector may lead to policy choices that reduce economic well-being.

The analysis is developed in the following manner. The second section describes the demand and supply conditions underlying the pooled and separating equilibria. The third section derives the price and quantity characteristics of the two equilibrium as well as equations for measuring the welfare effects of certified labeling. The fourth section presents market and welfare simulations for a range of initial demand and supply conditions. The final section suggests further research.

Demand, Supply, and Market Equilibria

Certified labeling is examined using the concepts of pooled and separating equilibria. Without labeling, credence and conventional goods are indistinguishable, so prices and quantities are determined by a pooled market equilibrium. Certified labeling distinguish the conventional from the credence good, and the single pooled market separates into two subsector markets, each with the potential for determining distinct prices and quantities. The markets described are composed of many suppliers and demanders. The intent is to reflect the market conditions of major agricultural food products such as fruits, vegetables, and grains.

This section describes supplies and demands and derives both the pooled and separating equilibria. The markets are composed of firms producing the conventional good, firms producing the credence good, and consumers. The credence and conventional sectors have different cost structures, but each is an increasing cost industry. Increasing costs may arise from an input supplied inelastically, such as land, dairy herd size, or climate. Credence firms have a cost advantage in using the fixed input under certain conditions, while low-credence firms may be cost advantaged by different conditions. For example, fruit producers in arid climates may have an advantage in producing fungicide-free fruits, while fungicide-using firms may be more cost advantaged by humid climates. Consumers are represented by aggregate demands for conventional, credence, and mixed goods. As in empirical studies, unconditional credence and conventional demands differ by a constant that represents the willingness to pay premium for the credence good (Blend and van Ravenswaay 1999; Ott, Huang, and Misra 1991).

In the analysis, there is a high credence good called the credence product and a low credence good called the conventional product. The latent demands for these products differ only by a constant representing willingness to pay for the credence characteristic. The latent demands are basic building blocks for the demands realized in the pooling and separating market equilibrium. In the pooled market, the realized demand is a mixture of the latent credence and conventional demands. In the separated markets with labeling, the realized conventional product demand is reduced by the quantity demanded of the credence product.

The latent aggregate demand for the conventional product is the quantity demanded at a given price when the credence good is not available,

(1)
$$\begin{aligned} q_c &= \beta_0 - \beta_2 r_c \\ &= q_c(r_c) \end{aligned}$$

where q_c is the quantity of the conventional good, β_0 is a demand intercept, $\beta_2 > 0$ is the absolute value of the demand slope, r_c is the price of the conventional good, and $q_c(r_c)$ indicates that the conventional quantity demanded is a function of conventional price. Equation (1) is an latent, unconditional demand since it does not allow for the market availability of the credence product. The conditional, realized demands are derived in the sections on the pooled and separating market equilibria.

The reservation price schedule describes the maximum price that demanders are willing to pay for a marginal unit of the conventional good. Reservation prices provide a money metric of the utility gained from consuming the marginal unit of conventional good. Mathematically, latent reservation price schedule for the conventional good is the mathematical inverse of equation (1),

$$r_c = \gamma_0 - \gamma_2 q_c \\ = r_c(q_c) \tag{2}$$

where $\gamma_0 = \beta_0/\beta_1$, $\gamma_2 = 1/\beta_1$, and $r_c(q_c)$ represents reservation price as a function of quantity.

The latent aggregate demand for the credence product is

$$q_g = \beta_0 + \beta_1 - \beta_2 r_g \\ = q_g(r_g) \tag{3}$$

where the term $\beta_1 \geq 0$ is a consumers' willingness to pay for the credence characteristic per unit of the credence product. Consumer studies show that willingness to pay for credence characteristics varies across consumers, with some consumer having zero willingness to pay (Blend and van Ravenswaay 1999; Rousu et al. in press). For simplicity, we let β_1 be a singleton rather than a distribution with a positive variance. Without loss of generality, β_1 may be thought of as the level of willingness to pay for the marginal consumer whose reservation price is just equal to credence producers marginal cost in the separated market equilibrium.

Unless otherwise stated, β_1 is assumed to be greater than zero in the main analysis. Of course, willingness to pay studies show that a proportion of consumers have zero willingness to pay (Blend and van Ravenswaay 1999; Rousu et al. in press). There may be cases where there the proportion and number of consumers with positive willingness to pay is small relative to the quantity supplied of the credence good. When this type of market saturation occurs, price differential is in doubt (Sedjo and Swallow 2002). We consider this special case of market saturation in a separate section where willingness to pay be equal is zero,

$\beta_1 = 0$, at the point of price determination for the credence good. That is, when quantity supplied is greater than some threshold amount, q_g^*, $\beta_1 = 0$ for $q_g > q_g^*$.

Analogous to equation (2), the latent aggregate reservation price schedule for the credence product is

$$
\begin{aligned}
r_g &= \gamma_0 + \gamma_1 - \gamma_2 q_g \\
&= r_g(q_g)
\end{aligned}
\tag{4}
$$

where $\gamma_1 = \beta_1/\beta_2 > 0$ for $q_g \leq q_g^*$ and $\gamma_1 = 0$ for $q_g > q_g^*$. As shown in equations (2) and (4), conventional and high value reservation price loci differ only by a fixed intercept shifter, γ_1. The latter shifter is the willingness to pay premium for the credence product.

Within each sector, production functions at the firm-level are constant returns to scale. However, as output rises, input prices increase, so that subsector supplies are inelastic for both the credence and conventional products.[1] The relationship between firm-level marginal costs and the quantity supplied by the conventional sector is,

$$mc_c = \mu_0 + \mu_1 q_c \tag{5}$$

where $\mu_0 > 0$ is an intercept term and $\mu_1 > 0$ is the slope of marginal costs within the conventional sector with respect to sector output. Equation (5) is the conventional product supply function.

The relationship between marginal cost and the quantity supplied by the credence sector is

$$mc_g = \delta_0 + \delta_1 q_g + \tau \tag{6}$$

where $\delta_0 > 0$ is an intercept, $\delta_1 > 0$ is the slope of marginal cost in market share, and τ is a fixed per unit cost of labeling in the separating equilibrium. Labeling costs are zero in the pooled equilibrium, so $\tau = 0$ in this cases. In a separating equilibrium with costly labeling, the credence industry may incur a certification cost, so $\tau \geq 0$.

A Pooled Market

Demanders in a pooled market are unable to match their willingness to pay to a pure conventional or pure credence product. Rather, they purchase a mixed product. The mix exists because credence and conventional producers are competitive even prior to labels. The relative mix of credence and conventional product depends on the market equilibrium conditions.

In the pooled equilibrium demanders are not able to identify products by the presence or absence of a credence attribute. However, because a mix of credence and conventional products exists, consumers formulate a conjecture about the proportions of credence and conventional products contained in the mix. The conjectured proportion of credence product in the market mix is α, $0 < \alpha < 1$. In the pooled market, market demand is conditioned on the conjecture. Realized aggregate demand is a α-weighted sum of the latent credence and conventional demands,

$$
\textbf{(7)} \qquad
\begin{aligned}
Q_\alpha &= (1-\alpha)q_c + \alpha q_g \\
&= \beta_0 + \alpha\beta_1 - \beta_2 r_\alpha \\
&= Q_\alpha(r_\alpha)
\end{aligned}
$$

Demanders conjecture that the market mix contains 100α percent of the credence product. The reservation price schedule for the conjectured market mixture is the inverse of line (2) of equation (8),

$$r_\alpha = \gamma_0 + \alpha\gamma_1 - \gamma_2(Q_\alpha) \quad (8)$$
$$= r_\alpha(Q_\alpha)$$

The actual mix in the market is not restricted by the α-weighting.

Aggregate supply in the pooled market is the sum of the amounts produced by the credence and conventional subsectors. In a pooled market, the quantity of the credence good is positive as long as market price is above the vertical intercept of the credence supply curve, δ_0. Aggregate supply is the horizontal summation of each sector's marginal costs,

$$mc = \phi_0 + \phi_1 Q \quad (9)$$
$$= mc(Q)$$

where $Q = q_c + q_g$, $\phi_0 = \dfrac{\delta_1\mu_0 + \mu_1\delta_0 + \mu_1\tau}{\delta_1 + \mu_1}$, $\phi_1 = \dfrac{\mu_1\delta_1}{\delta_1 + \mu_1}$, and $mc(Q) = mc_j(q_j)$, $j = \{c,g\}$. Note that per unit labeling costs shift the intercept of the aggregate marginal cost curve.

A pooled equilibrium equates quantity supplied with quantity demanded at a single market price. Consumers perceive the α-mixture, the total market quantity, Q, is the sum of the credence and conventional quantities, $Q = q_c + q_g$. The conjecture may be wrong so that the market mix is over- or under-valued. The only restriction at the market level is that the market clears, so that aggregate quantity demanded, Q_α, equals aggregate quantity supplied, $Q = q_c + q_g$. Thus, the mixed, unlabeled competitive market equilibrium is a single pooled market price, p_α^p, that clears the market given the α-conjecture and firms earn zero profits, where, for simplicity of notation, the conditionality of the equilibrium quantities is left implicit. Equation (10) implies that production of credence and conventional goods is positive as long as pooled price is greater

(10)
$$q_c^p + q_g^p = Q(p_\alpha^p)$$
$$p_\alpha^p = mc_c(q_c^p)$$
$$p_\alpha^p = mc_g(q_g^p)$$

than the vertical intercepts for the credence and conventional supply schedules. In terms of aggregate supply, the pooled equilibrium conditions are

(11)
$$Q^p = Q(p_\alpha^p)$$
$$p_\alpha^p = mc(Q_\alpha^p)$$

Equations (10) and (11) define a pooled market equilibrium using, respectively, subsector supply conditions and aggregate supply conditions. The pooled equilibrium conditions provide the baseline conditions for evaluating the economic and welfare consequences of certified labeling.

Figure 1 illustrates the supply and demand structures underlying the pooled equilibrium. Panel A describes the latent elements underlying aggregate demand and supply in Panel B. Aggregate market demand in Panel B is the alpha-weighted sum of the credence and conventional demands in Panel B. Aggregate supply in Panel B is the horizontal sum of credence and conventional supplies in Panel A. The equilibrium aggregate quantity and pooled priced are determined by demand and supply in Panel B. The pooled market price is consistent with the non-zero subsector quantities supplied shown in Panel A.

A Separating Equilibrium with Certified Labeling

Once certified labeling is introduced, buyers can identify the credence product from the conventional product. The single mixed market is replaced with separate markets for the credence and conventional good.

Consumers buy either the credence or conventional product. Conventional market demand is conditional on the availability of the credence good, in the sense that once a buyer purchases a unit of the credence product, demand for that unit is lost to conventional market. Demand for the conventional product in a labeled market is a conditional, residual demand.[2]

With the credence good available in a separate market, residual demand for the conventional good is the latent demand for the conventional product, equation (3), minus the demands of consumer who shift to the credence market,

(12)
$$\begin{aligned} \tilde{q}_c &= q_c(r_c) - \gamma_2 q_g^s \\ &= \beta_2 p_g - \beta_2 r_c \\ &= \tilde{q}_c(r_c | p_g^s) \end{aligned}$$

where p_g^s is the credence product price prevailing in an labeled, separating market equilibrium. Analogously, th market residual reservation price schedule for the conventional good is the latent reservation price reduced by the value of the conventional good for consumers who shift to the credence market. This reduction in value is q_g^s, so the residual conventional demand is,

(13)
$$\begin{aligned} \tilde{r}_c &= \gamma_0 - \gamma_2 q_g^s - \gamma_2 q_c \\ &= r(q_g^s) - \gamma_1 - \gamma_2 q_c \\ &= \tilde{r}_c(q_c | q_g^s) \end{aligned}$$

where p_g^s is the credence product price prevailing in an labeled market. The second line in equation line in equation (13) follows by adding and subtracting γ_1 to the first line and then substituting the reservation price for the marginal consumer of the credence. Thus, the intercept for the conventional aggregate reservation price is the marginal reservation price for the credence product adjusted downward by the incremental willingness to pay for the credence product, γ_1.

While some previous research divides consumers into two fixed and distinct consumption groups (Sedjo and Swallow 2002), we suppose consumer choose products on the basis of their aggregate reservation prices, equations (4) and (13) and market prices. Following (Giannakas and Fulton 2002) and (Giannakas 2002), an individual consumer chooses a product that yields the largest relative gain in individual welfare, given market prices for both the credence and conventional products. In the analysis below, the analytical money metric of welfare is consumer surplus per unit of product. Consumer surplus is for a particular product is reservation price less market price.

In choosing being credence and conventional products, a consumer compares the consumer surplus gain of purchasing the credence product with the consumer surplus opportunity cost of foregoing the conventional product. If the gain is greater than the opportunity cost, the consumer purchases the credence product. If it is not, the consumer purchase the conventional product. The marginal credence consumer is content to remain in the high value market only as the consumer surplus from consumption, reservation prices less market price, is greater or equal to the surplus forgone by purchasing the conventional product. The infra-marginal consumers who purchases the low value product obtains consumer surplus that is greater or equal to consumer a unit of product in the high value market.

An market equilibrium with labeling is a set of prices for the high and low valued products such that consumers are unable to improve their welfare and firms are unable to improve their profits by entering or leaving a subsection. Thus, this is a Nash equilibrium with competitive behavior. The conditions for a Nash equilibrium are

$$
\textbf{(14)} \qquad \begin{aligned} r_g(q_g^s) - p_g^s &= r_c(q_g^s) - p_c^s \\ p_g^s &= mc_g(q_g^s) + \tau \\ p_c^s &= mc_c(q_c^s) \\ p_c^s &= \tilde{r}_c(q_c^s | q_g^s) \end{aligned}
$$

where the first line of equations (15) is the net surplus condition that ensures consumers maximize the surplus obtained from their purchases. The second line of equation (15) requires the credence market to clear at a price where the marginal product earns zero rent. The third and fourth lines of equations (15) set prices and quantities so that the conventional markets clear where price equals marginal costs.

Figure 2 describes the separating market equilibrium for the credence and conventional markets. Panel A describes the credence market and Panel B shows the conventional market. Labeling allows the credence demand that was latent in the pooled equilibrium, to be the realized market demand in the separate credence market in Panel A. The conventional reservation price schedule in Panel B is a residual schedule that accounts for the loss of consumers to the credence market.

Price, Quantity, and Welfare Effects of Labeling

This section examines the price, quantity, and welfare effects of labeling. We first examine the special case to compare the basic properties of the two equilibria. A general comparison of prices and quantities is then derived mathematically. We consider cases with and without market saturation. The final segment describes the welfare effects of labeling.

Figure 2 shows that the price of the green product is higher than the price of the conventional product. Thus, labeling introduces a price premium for the credence product. Rearranging the first line of the equilibrium conditions, equation (14), shows that the price difference is exactly equal to willingness to pay per unit of product, γ_1. Figure 2 is less clear as the how the pooled market quantities and prices compare to the quantities and prices in the separated markets. The following two propositions and their mathematical proofs clarify how prices and quantities change with labeling.[3]

Proposition 1: The credence quantity supplied in the separating equilibrium with labeling is greater than credence quantity supplied in the pooled equilibrium. The conventional quantity supplied in the separating equilibrium is less to the conventional quantity supplied in the pooled equilibrium.

The proof of Proposition 1 is by contradiction, so suppose that the quantity of the conventional good is greater in the separating equilibrium than in the pooled equilibrium. A greater quantity implies that (a) the marginal cost of the conventional subsector is greater in the separating equilibrium than in the pooled equilibrium. The latter means that the price of the conventional product is greater in the separating equilibrium than the pooled product price, since prices equal marginal costs in both equilibria for the conventional subsector. However, if the pooled product price is less and the conventional product quantity is also less, the quantity of the credence product must be greater in the pooled than in the separating equilibrium since demand is negatively sloped. A larger quantity means that marginal cost in the credence subsector is greater than in the pooled equilibrium than in the separating equilibrium. Since pooled marginal costs are equal across the two subsectors, the latter also implies that (b) conventional marginal costs in the pooled equilibrium are greater than credence marginal costs in the separating equilibrium. Conclusions (a) and (b) along with the equality of pooled marginal costs imply that conventional marginal costs are greater than credence marginal costs in the separating equilibrium. Since marginal cost equals price, the latter conclusion contradicts the finding that the credence price is greater than the conventional price in the separating equilibrium as long as willingness to pay is positive.

The contradiction indicates that the separating conventional quantity cannot be greater than the pooled conventional quantity, so it must be less. Similar logic can be used to show that the separating quantity of the credence good is greater than the pooled credence quantity.

Proposition 2: The credence price in the separating equilibrium is greater than the pooled market price and the conventional price in the separating equilibrium is less than or equal to the pooled market price.

Potential certified producers may want to know the price increase that they may expect. Proposition 2 indicates that the potential price increase from the pooled to a labeled, separating equilibrium cannot be determined by merely knowing willingness to pay. Credence price is higher in a separating equilibrium, but willingness to pay alone does not tell us how much higher. Willingness to pay describes only the difference between the credence and conventional prices in the separating equilibrium. It does not describe how much the separating credence price may rise relative to the pooled market price. Moreover, the full question ought to be not just by how much the credence price may rise, but also by how much may the conventional price fall.

To this point, demand for the credence good has been assumed sufficient to generate a willingness to pay premium for the quantity of credence product supplied in the separating equilibrium. This may not be the case. The credence market may become saturated, with the excess being sold in the conventional sector. Proposition 3 addresses this special case of market saturation.

Proposition 3: Let certified labeling costs be less than willingness to pay, $\gamma_1 > \tau$, and let the credence quantity supplied in the separating equilibrium with labeling exceed the market saturation threshold, so $q_g^s > q_g^*$. There is a single separating equilibrium price, $p^s = p_g^s = p_c^s$, and no price premium for the credence product. In addition,

a. With *costless* certification and labeling, prices and quantities are unchanged across the pooled and separating equilibria with labeling.

b. With *costly* certification and labeling,

   i. The aggregate quantity of credence and conventional products is less in the separating equilibrium with labeling than in the pooled equilibrium,

   ii. The conventional market share and quantity are greater, and the credence market share and quantity are less, in the separating equilibrium relative to the pooled equilibrium.

   iii. The single separating equilibrium price, p^s, is greater than the pooled equilibrium price, but the price difference between equilibria is less than the per unit labeling cost increase for credence producers, $\tau > p^s - p_\alpha^p$.

With market saturation, labeling leaves prices and quantities unaffected, at best. At worst, with costly labeling, the market share of credence producers declines while that of conventional producers increases. With costly labeling and market saturation, the credence price increase is less than the increase in per unit certification and labeling costs. The single equilibrium price is higher so conventional consumers lose, while conventional producers gain. Conventional producers gain due both to a higher market price and greater market share. This unexpected distribution of benefits and costs is examined in more detail in the empirical simulation below.

The price and quantity changes described by the theorems are central to understanding the welfare effects of certified labeling. Table 1 lists welfare differences between the separating equilibrium with certified labeling and the pooled equilibrium. The equations are derived for a separating equilibrium where saturation does not occur.   Producer surplus is defined by the area between the price line and sector marginal costs. The change in producer welfare across the equilibria is the producer surplus associated with the separating equilibrium minus the producer surplus associated with the pooled equilibrium.

Consumer surplus is the positive area between a demand curve and a price line for a given quantity. The change in credence consumer surplus is the difference between consumer surplus in the market for the credence product in the separating equilibrium minus the surplus obtaining for the sample units of the mixed product in the pooled equilibrium. Conventional consumer surplus is the consumer surplus associated with the remaining quantities of product, q_c^s, in the separating equilibrium and $Q_\alpha^p - q_g^s$ in the conventional equilibrium. The difference between the latter surplus measures is the change in conventional surplus.

The welfare differences in the credence sector are influenced by the change in credence price relative to the pooled price, the change in consumer willingness to pay, and the unit cost of certified labeling. The change in credence price is, in turn, equal to the marginal cost slope parameter, δ_1, times the change in credence quantities, $q_g^s - q_g^p$, so the welfare effects are related to the change in the availability of the credence product. Proposition 1 indicates that the change in credence quantities is strictly positive in the absence of market saturation, so credence producer surplus is strictly positive. The implied price increase, however, makes consumers worse off. Consumers surplus is also reduced by the total certification cost, but increases by net willingness to pay for the pure product. Net willingness to pay for the pure credence product is reduced by one minus consumers' conjecture about the mixed product. The larger, the more credence, the mixed product conjecture, the smaller is the consumers' gain from certified labeling. The net effect of labeling for credence consumers may be positive or negative. In the credence market as a whole, the same ambiguity holds since the net market effect may be positive or negative. Only credence production is certain to gain.

The change in conventional producer surplus is composed of two terms in Table 1. The second term is certain to be negative. The first term states convention price change as $-\mu_1(q_c^p - q_c^s)$ and is certain to be negative when Theorem 1 holds. Thus, conventional production is certain to sustain a loss with certified labeling. The reservation price schedule the conventional product shifts down relative to the mixed good, and conventional price declines, with a concomitant decline in conventional producer surplus.

The effect of labeling on consumers of the conventional product in the separating equilibrium is unclear. If the aggregate quantity of product sales expands in the separating equilibrium relative to the pooled case, the first term in the welfare change equation is positive, but it is not clear whether the positive term is large enough to offset the two negative terms. If aggregate sales decline, conventional consumers are certain to be worse off with labeling.

The qualitative results of Table 1 leave the aggregate effects of labeling unclear. Credence producer surplus is definitely positive under the conditions of Theorem 1, and conventional producer surplus is certain to be negative. The impact of labeling on consumers, however, may be positive or negative. Conventional consumer surplus is certain to be negative only when aggregate sales decline with labeling. The net effect of these welfare impacts is unclear, leaving the aggregate welfare effect of labeling to quantitative analysis.

Market Simulations

Numeral simulations were carried out to characterize the quantitative changes that may arise with certified labeling. The initial step in simulations was to identify a set of parameters that are representative of major agricultural markets. Parameters ranges were obtained from the existing research and policy literature. Eight thousands different combinations of parameter values were obtained by selecting from each range randomly, using a psuedo-random uniform distribution for each parameter. Each of the 8,000 sets of parameter values were used to compute quantities, prices, and surpluses for the pooled and separating equilibrium. Two different sets of separating equilibria were generated, the first for costless labeling where labeling costs were reset to zero and the second with costly labeling where labeling costs were left at their randomly selected levels.

Initial pooled price and quantity parameters were selected to represent the range of prices and quantities found in wholesale markets for the five largest non-citrus fruit crops in the United States. These crops, in order of quantities sold, are apples, grapes, strawberries, peaches, and pears (Economic Research Service 2003). Table 2 shows the annual quantity of sales for these five crops range from 547 to 2,771 thousand tons in 2001. Price per ton varies from $364 to $1,514 per ton.

Conjectures were set equal to credence market share in the initial, pooled equilibrium.[4] Initial conditions for credence market shares were selected to represent the variation in initial conditions found in agricultural markets. The lower endpoint was 2 percent and was based on the market share of organic produce prior to the organic program (Greene 2001). The upper endpoint was 40 percent and reflected the approximate quantity of non-genetically engineering corn grown in the United States (McBride and Books 2000).

Demand parameters were based on research literature (Brown and Lee 2002; Huang and Lin 2000; You, Epperson, and Huang 1998). The demand elasticity range was based on econometric research showing that recent fruit and vegetable elasticity estimates varied from just less than -.3 to a little over -1.1. The formula for price elasticity was used to calculate the slope of reservation price schedule for randomly drawn combination of demand elasticity, price, and quantity. Willingness to pay values were selected to incorporate mean estimates, as well as to examine the somewhat higher willingness to pay values that may be found in limited segments of a market (Blend and van Ravenswaay 1999; Buzby, Ready, and Skees 1995; Hammitt 1990; Ott, Huang, and Misra 1991).

Supply elasticities and the cost of certified labeling were also selected to reflect the existing literature. The supply elasticity range was selected to mirror the range of estimates for the aggregate supply of fruits and vegetables supplies as well as for individual crops (****USDA, Shumway; Lichtenberg)the range for the demand elasticities, as well as including judgements by other researchers (National Food and Agriculture

Project 1999). Special fees for placing branded and bagged vegetable items provide some guides as to the possible costs of placing credence label items in the supply chain, but the types of fees vary widely and data is limited. However, a recent study reports slotting fees in the range from one to eight percent (Calvin et al. 2001). Given these data, labeling costs were set within a range from zero to five percent, so as to determine the sensitivity of the simulation results to modest cost levels.

The bottom half of Table 2 describes the quantity and price effects of costless and costly labeling. Labeling performs exactly as anticipated in Theorems 1 and 2. Costless labeling results in a one-thousand ton increase in the mean aggregate quantity, resulting from a 46-thousand ton mean decrease in conventional production and a 47-thousand ton mean increase in credence production. At the mean, credence market share rises three point to 24 percent in the separating equilibrium from 21 percent in the pooled equilibrium. The mean conventional price is six percent less than the pooled equilibrium and the mean credence price is 22 percent greater in the separating equilibrium than in the pooling equilibrium. The mean credence price premium is 27 percent of the initial pooling price, consistent with Theorem 2. The range of price and quantity effects vary with the parameter values. For instance, change in the conventional quantity may be almost zero in some cases and over 300 thousand tons in other cases.

Costly labeling differs from costless labeling in two important ways. First, the mean aggregate quantity in a separating equilibrium is less than that of the pooling equilibrium. This suggests that the welfare effect for conventional consumers may be negative, at least at the mean when labeling is costly. Second, the mean credence and conventional prices in the separating equilibrium with costly labeling are slightly higher than the prices in the costless labeling simulations. Since only credence production experiences the direct costs of labeling, the higher prices for conventional producers may reduce their certain loss. The mean credence price increase is not enough to offset mean labeling costs, so labeling costs reduce credence producers surplus.

Table 3 lists the welfare impacts of costless and costly labeling. The welfare changes were calculated using the equations of Table 1 for each of the 8,000 simulated equilibria. The results are reported as the mean and range for each of the welfare measures.

Costless labeling always has a positive welfare impact, but the benefits and costs are highly asymmetric, especially across production sectors. The aggregate market mean is a net benefit of $7.4 million with a range of approximate zero to $83 million. The mean effects on credence and conventional consumers are $0.6 million and $1.1 million, but the welfare impacts of costless labeling range as low as $-122 million for conventional consumers and $-82 million for credence consumers. The welfare outcome for conventional producers is negative, with a mean of $-65 million and a range from $-486 million to a loss of a several hundred thousand dollars. Credence producers are the certain gainers from labeling, with benefits ranging from $1 million to $530 million and a mean benefit of almost $71 million.

It is also notable that the naive rules-of-thumb are highly misleading with respect to the welfare impacts. Multiplying the pooling equilibrium credence quantity times consumer willingness to pay results in a mean result of $89.5 million. This is more than 12 times the aggregate market impact of $7.4 million. Multiplying the pooling equilibrium aggregate quantity time consumer willingness to pay yields an even more misleading number if interpreted as a ballpark measure of welfare change.

The costly certification simulations included unit labeling costs for credence producers that ranged from zero to five percent of the initial pooling price. With this modest level of costs, the mean aggregate impact is negative and the range of aggregate welfare impacts widens to include a significant negative region. The pattern of results across the different groups remains similar to costless labeling, but the range of results for each group becomes slightly more negative. The results show that even credence producers may be worse off in some costly labeling scenarios.

The pattern of mean results for costly labeling suggests the Spence result; that asymmetric information can create an incentive for inefficient provision of information (Spence 1973). In this case, the mean result for credence producers is clearly positive, while the aggregate mean and the means for other market groups are clearly negative. Inspection of individual cases showed that this conflict between positive net benefits in the credence sector and net welfare losses overall occurred in about 60 percent of the simulations with costly labeling.

Additionally, labeling gives the credence production sector routine incentives to realize gains as the expense of other market groups. In all cases where the credence producer impact is positive, the net impact on conventional producers and all consumers is negative. Correlation analsysis suggested that the conflict in interests was strongest between credence and conventional producers, and relatively weak between credence producers and consumers. The Pearson correlation coefficient for the credence and conventional producer impacts was -0.9, while it was only -0.15 between credence producers and conventional consumers and -0.16 between credence producers and credence consumers.

Conclusion

The analysis developed the theoretical consequences of labeling as well as an applied benefit-cost framework for policy evaluation. The applied framework is easily implemented given the initial conditions of a pooled market, demand and supply elasticities, and willingness to pay for the credence characteristic. The framework fits a situation where demand for a credence good differs from demand for a conventional good by willingness to pay for the credence characteristic. Thus, the latent demands for the credence and conventional goods have the same slope, but different intercepts.

The theoretical analysis shows that the price differences due to labeling cut two ways. The price for the credence product with labeling is higher than the initial pooled market price, but the price for the conventional product is lower with labeling than without. Moreover, the credence price change with labeling cannot be determined from willingness to pay alone; marginal willingness to pay describes the price difference between the credence and conventional products with labeling, but it does not describe the credence price premium relative to the initial, pooled equilibrium. The simulations underscore the highly asymmetric consequences for credence and conventional products. Conventional producers are certain to lose from labeling and credence producers are certain to gain. Consumers may gain or lose, but by relatively modest amounts that depend mostly on the level of certification costs.

Changes in consumer welfare, average consumer willingness to pay for labeling, and gains to high credence producers are all unreliable indicators, by themselves, of potential Pareto improvements. Willingness to pay studies, alone, are not enough to determine price changes and welfare effects. Gains for credence producers do not predict general efficiency gains. The aggregate welfare effects of labeling may be negative even when credence producer surplus is large and positive. As in Spence (1973), credence producers may have an interest in inefficient signals.

Net welfare gains of labeling may be small relative to gross gains and losses with subsectors. When sizable subsector gains and losses are likely to occur, compensatory strategies may be appropriate. Also, informational strategies other than labeling may prove to be more benign. For instance, if consumer conjectures are incorrect, a market-level information policy about the level of credence attribute in the pooled market may reduce deadweight loss without disrupting returns to producers.[5]

The results suggest a pragmatic and cautious approach to certified labeling proposals in agricultural markets. Empirical analysis of labeling's consequences requires good estimates of the supply and demand elasticities, in addition to willingness to pay for labeled products. Moreover, while willingness to pay research is well established, more clarity is needed on the distribution of willingness to pay across consumers, since willingness to pay at the margin of price determination is crucial in determining the size and distribution of welfare gains and losses.

Endnotes

1. The idea of inelastic agricultural supply has been a central feature of theory since Ricardo and remains consistent with empirical estimates of supply elasticities.

2. Residual demands are analytically common in analyzing imperfect competition, and the concept also proves informative in this case of a competitive market with certified labeling (Varian, 1992).

3. Mathematical proofs of the theorems are available upon request to the authors. Also, unless stated otherwise, the theorems assume that (a) the conjectured credence market share is strictly greater than zero and less than one and (b) demand and supply functions are inelastic. Similar theorems may be derived without the latter two assumptions, but the narrative is complicated by weak inequalities that require additional explanation.

4. Additional analysis could assume incorrect conjectures, but this would mix the informational consequences of labeling with the consequences of correcting incorrect conjectures. Darby and Karni (1973) consider the issue of incorrect conjectures and develop a distinct deadweight loss measure to evaluate to the costs of mistaken conjectures.

5. See Darby and Karni (1973) for a discussion of deadweight loss in the context of credence goods.

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Figure 1. Pooled Market Equilibrium Price and Quantities

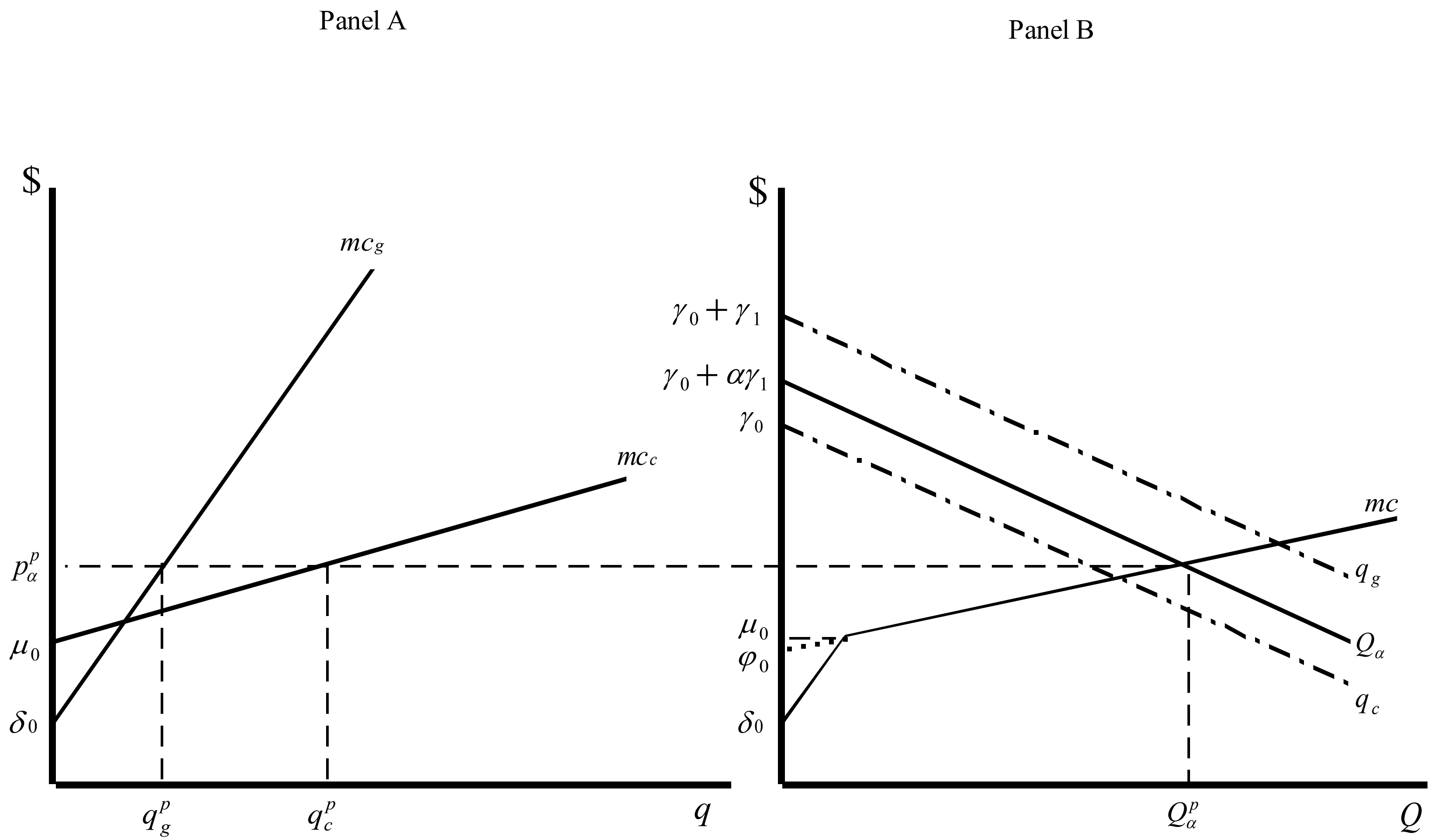

Figure 2. Separating Market Equilibrium Prices and Quantities

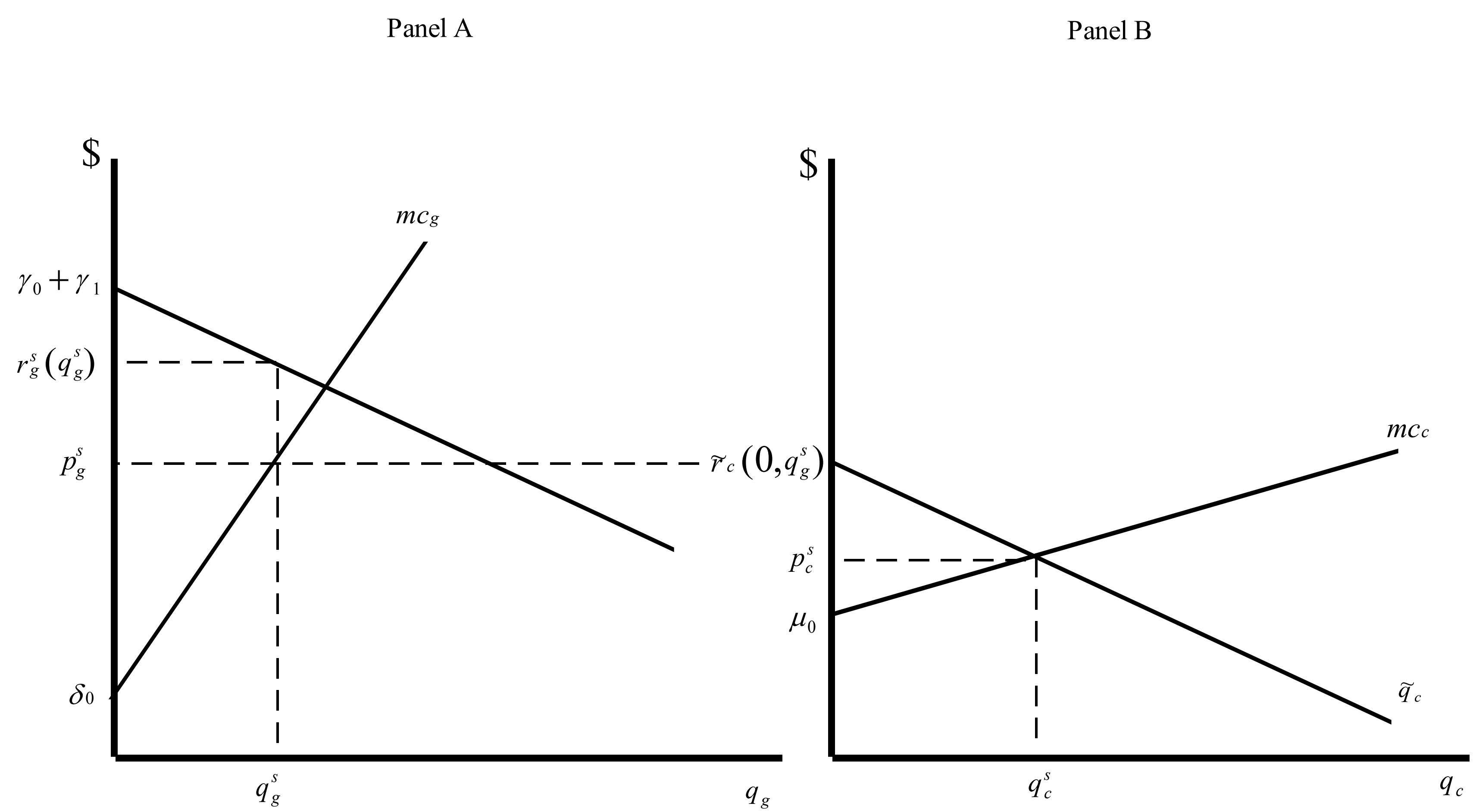

Table 1: Welfare Differences between the Separating Equilibrium with Certified Labeling and the Pooling Equilibrium[a]

Market Groups	Welfare Differences: Surplus in Separating Equilibrium Minus Surplus in Pooling Equilibrium
Credence	
Producers	$\Delta ps_g = \delta_1(q_g^s - q_g^p)q_g^p + 0.5\delta_1(q_g^s - q_g^p)^2$
Consumers	$\Delta cs_h = -\delta_1(q_g^s - q_g^p)q_g^s + (1-\alpha)\gamma_1 q_g^s - \tau q_g^s$
Credence market	$\Delta s_g = (1-\alpha)\gamma_1 q_g^s + 0.5\delta_1(q_g^s - q_g^p)^2 - \tau q_g^s$
Conventional	
Producers	$\Delta ps_c = -\mu_1(q_c^p - q_c^s)q_c^s - 0.5\mu_1(q_c^s - q_c^p)^2$
Consumers	$\Delta cs_c = 0.5\gamma_2[q_c^{s2} - (Q_\alpha^p - q_g^s)^2]$
Conventional market	$\Delta s_c = -\mu_1(q_c^p - q_c^s)q_c^s - 0.5\mu_1(q_c^s - q_c^p)^2 + 0.5\gamma_2[q_c^{s2} - (Q_\alpha^p - q_g^s)^2]$

a. The equations are derived for the situation where $q_g^s < q_g^*$. The welfare differences for market saturation are available upon request to the authors.

Table 2. Initial Conditions and Results for Simulated Separating Equilibria[a]

Market Quantities	Mean	Standard Deviation	Range
Initial Market Conditions and Parameters			
Aggregate quantity, 1,000 tons	1,655	645	547 to 2,771
Credence market share, %	21	11	2 to 40
Price per ton, $	944	333	364 to 1,514
Demand elasticity	-0.7	0.29	-0.2 to -1.2
γ_1 as percent of pooled price	27.4	13	5 to 50
Conventional supply elasticity	0.7	0.29	0.2 to 1.2
Credence supply elasticity	0.7	0.3	0.2 to 1.2
Certification cost as a percent of price, %	2.5	1.4	0 to 5
Costless certification, separating equilibrium			
Aggregate quantity, 1000 tons	1,656	646	537 to 2,839
Change in conventional quantity, 1000 tons	-46	42	-318 to ~0
Change in credence quantity, 1000 tons	47	44	~0 to 326
Credence market share, %	24	12	2 to 51
Conventional price per ton, $	889	317	280 to 1,509
Credence price per ton, $	1,147	419	389 to 2,235
Costly certification, separating equilibrium			
Aggregate quantity, 1000 tons	1,653	645	536 to 2,828
Change in conventional quantity, 1000 tons	-42	41	-318 to -10
Change in credence quantity, 1000 tons	44	41	-5 to 326
Credence market share, %	24	12	2 to 51
Conventional price per ton, $	892	318	283 to 1,510
Credence price per ton, $	1,150	419	389 to 2,235

a. The simulations were based on 8,000 sets of parameters drawn from the range of parameters listed as initial conditions. The costless certification results reset each of the unit cost parameter to zero, while the costly certification results left unit certification costs at the randomly drawn values. Initial quantities and prices were representative of annual data for five largest non-citrus fruit crops in 2001 (see Economic Research Service, 2003).

Table 3. Welfare Impacts of Costless and Costly Certified Labeling[a]

Welfare Measure	Welfare Change due to Certified Labeling in Millions of Dollars			
	Costless Certification		Costly Certification	
	Mean	Range	Mean	Range
Aggregate market	7.4	0 to 83	-1.9	-61.9 to 71.2
Conventional				
Consumers	1.1	-122 to 163	-1.9	-133 to 147
Producers	-65.0	-486 to ~0	-62.0	-481 to ~0
Credence				
Consumers	0.6	-82 to 107	-0.8	-88 to 100
Producers	70.8	1 to 530	62.8	-3 to 306
Rules-of-Thumb				
$q_g^p(\gamma_1 - \tau)$	89.5	1 to 693	81.2	0 to 668
$Q^p(\gamma_1 - \tau)$	427.4	16 to 1,972	388.0	1 to 1,893

a. The welfare measures for costless and costly labeling were based on 8,000 pairs of simulated pooled and separating equilibria. The initial conditions, price, and quantity results are described Table 2. The costless certification results reset each of the unit cost parameter to zero, while the costly certification results left unit certification costs at the randomly drawn values.