Staff Paper

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John P. Hoehn and B. James Deaton

Staff Paper 2003-12 **August 2003**

Department of Agricultural Economics
MICHIGAN STATE UNIVERSITY
East Lansing, Michigan 48824

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John P. Hoehn[1] and B. James Deaton[2]

Department of Agricultural Economics Staff Paper No. 03-12

Michigan State University

August 18, 2003

[1]Professor, Department of Agricultural Economics, Michigan State University, East Lansing, MI 48824; Tel: 517-353-6735; Fax: 517-432-1800; hoehn@msu.edu.

[2]Research Associate, Institute for Food and Agricultural Standards, Michigan State University, East Lansing, Michigan 48823; Tel: 517-355-2384; Fax 517-432-2856; deatonbr@pilot.msu.edu.

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Abstract

Certified labeling for credence attributes is examined using the concepts of pooled and separating equilibria. Credence attributes are product features that cannot be experienced directly by consumer, features such as pesticide-free, dolphin-safe, hormone-free, and organic. Without labeling, the traded good is a mix of credence and conventional goods. With certified labeling, the pooled market is replaced with separate markets for the credence and conventional good. 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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[3]Professor, Department of Agricultural Economics, Michigan State University, East Lansing, MI 48824; Tel: 517-353-6735; Fax: 517-432-1800; hoehn@msu.edu.

[4]Research Associate, Institute for Food and Agricultural Standards, Michigan State University, East Lansing, Michigan 48823; Tel: 517-355-2384 ; deatonbr@pilot.msu.edu.

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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. High costs make individually financed detection of credence attributes uneconomic (Darby and Karni, 1973). Notable examples of credence attributes include dolphin-safe tuna (Teisl, et al., 2002) and the National Organic Program (Agricultural Marketing Service, 2003b). Other examples include origin labeling (Agricultural Marketing Service, 2003a), absence of pesticide residues (Ott, et al., 1991), genetically modified content (Caswell, 1998, Zedalis, 2001), and hormone-free labeling (Kleiner). In this article, we develop a market-level model to evaluate the economic and welfare consequences of labeling.

Labels that identify credence attributes are often viewed as a means to ensure the provision of valued attributes and thereby avoid market failure (Crespi and Marette, 2001). 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 the consumers direct experience, the conventional and credence goods are indistinguishable without labeling.

Crespi and Maretee (2001) suggest that a market failure results from an absence of credence labeling. Market price fails to register a willingness to pay premium for the credence good and lower-cost conventional firms drive higher-cost credence good firms out of the market. As a result, markets fail to provide the credence good. Certified labeling resolves the informational asymmetry and improves efficiency (Crespi and Marette, 2001). Certified labeling distinguishes products by their credence attribute, allowing separate markets to emerge for both credence and conventional goods. Certification by governmental agencies improves the uniformity and reliability of labeling, thereby supporting the accurate valuation of differentiated products (Golan, et al., 2001).

Recent analysis raises doubts about the incentives and efficiency of credence labeling. First, certified labeling may not support a price premium for credence goods. Post-labeling prices may be higher, but equal, for both high- and low-credence sectors when there is excess high-credence supply relative to high-credence demand (Sedjo and Swallow, 2002).

Second, the stark market breakdown where high-credence firms are driven from the market does not seem occur. Some firms meet certifications standards even without labeling (Sedjo and Swallow, 2002). This absence of stark market failure seems particularly relevant to agriculture where more than 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). The market failure of zero credence goods appears to be the wrong baseline for assessing efficiency gains.

Finally, information economics cautions against assuming that more information is better. Asymmetric information produces asymmetric gains from information (Stiglitz, 2002). Individual agents may have a strong self-interest to invest in inefficient signals (Spence, 1973).

Our analysis of labeling develops a mathematical, market-level model to examine the price and welfare consequences of certified labeling. Without labeling, the credence and conventional goods are perfect substitutes. Credence and conventional firms coexist in the initial, pooled equilibrium, since each subsector is an increasing cost industry. 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. Once certified labeling is introduced, credence and conventional goods separate into two distinct markets, one for each pure good. Consumers sort themselves across the markets for the two goods. The sorting decision is endogenous to the markets. Each consumer consumes either the credence good or conventional good to maximize net surplus, the difference between one's reservation price and market price for each product.

The analysis examines the price, quantity, and welfare consequences of labeling. We derive both the general properties of the equilibria and subsequent welfare effects. Costless labeling improves the welfare, but the incidence of benefits and costs is highly asymmetric. Unless market saturation occurs, certified credence producers are certain to gain and conventional producers are certain to lose. In our simulations, the net gain is small relative to the distribution effects across conventional and credence producers. In this sense, labeling is a double edged sword, resulting in sizable benefits for some producers and definite losses for others. With costly labeling, the asymmetry of gains and losses may create a Spence-like result where credence producers have an incentive to press for certified labeling even when labeling is Pareto inefficient relative to the pooled equilibrium.

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, conventional and credence 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 the market components 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 conventional and credence 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 conventional and credence demands differ by a constant that represents the willingness to pay premium for the credence good (Blend and van Ravenswaay, 1999, Ott, et al., 1991).

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

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

where q_c is the quantity of the conventional good, $\beta_0,\ \beta_1 > 0, r_c$ 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 unconditional demand since it does not allow for the market availability of the green product. The conditional demands are derived below.

The unconditional reservation price schedule for the conventional good is the mathematical inverse of equation (1). The reservation price schedule describes the maximum price that demanders are willing to pay for a specified quantity of the conventional good. It is,

$$\textbf{(2)} \qquad \begin{aligned} r_c &= \gamma_0 - \gamma_2 q_c \\ &= r_c(q_c) \end{aligned}$$

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 credence good is referred to as the green product. The unconditional aggregate demand for the green product is

$$
\begin{aligned}
q_g &= \beta_0 + \beta_1 - \beta_2 r_g \\
&= q_g(r_g)
\end{aligned}
\qquad \textbf{(3)}
$$

where $\beta_1 > 0$ for $q_g \le q_g^*$ and $\beta_1 = 0$ for $q_g > q_g^*$. The quantity q_g^* is the threshold in sales of where the demand premium vanishes and the high valued demand shifts to the conventional demand. The threshold condition incorporates the Sedjo and Swallow (2002) characterization of a market composed of limited demand for the green product where only a subset of consumers who care about the perceived difference between the green and conventional products. Since limited demand is only interesting in the case of the labeled market, it will be assumed that the quantity of product exchanged is less than the threshold, q_g^*, unless stated otherwise.

Analogous to equation (2), the market reservation price schedule for the green product is

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

where $\gamma_1 = \beta_1/\beta_2 > 0$ for $q_g \le q_g^*$ 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 green product.

Within each sector, production functions at the firm-level are constant returns to scale. Inelastic input supply results in increasing sector costs. 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 a fixed component 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 green sector is

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

where $\delta_0 > 0$ is a fixed component, $\delta_1 > 0$ 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 and separating equilibrium with costless labeling described below, so $\tau = 0$ in these cases. In a separating equilibrium with costly labeling, the green industry incurs a certification cost and $\tau > 0$.

In an unlabeled market, demanders are unable to distinguish the conventional product from the green product, so separate conventional and green price signals do not emerge and there is a single pooled market for both types of goods. Aggregate supply in this market is the horizontal summation of each sector's marginal costs,

$$\begin{aligned} mc &= \varphi_0 + \varphi_1 Q \\ &= mc(Q) \end{aligned} \tag{7}$$

where $Q = q_c + q_g$, $\varphi_0 = \dfrac{\delta_1\mu_0 + \mu_1\delta_0 + \mu_1\tau}{\delta_1 + \mu_1}$, $\varphi_1 = \dfrac{\mu_1\delta_1}{\delta_1 + \mu_1}$, 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

Demanders in a pooled market are unable to match their willingness to pay to a pure conventional or pure green product. Rather, they purchase a mixed product. The mix exists because conventional and green producers are competitive even prior to labels. The relative mix of conventional and green 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 conventional and green products exists, consumers formulate a conjecture about the proportions of conventional and green products contained in the mix. The conjectured proportion of green product in the market mix is α, $0 < \alpha < 1$. In the pooled market, market demand is conditioned on the conjecture. Demand is a α-weighted sum of the unconditional conventional and green demands,

(8)
$$\begin{aligned} Q_\alpha &= (1 - \alpha)q_c + \alpha q_g \\ &= \beta_0 + \alpha\beta_1 - \beta_2 r_\alpha \\ &= Q_\alpha(r_\alpha) \end{aligned}$$

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

(9)
$$
\begin{aligned}
r_\alpha &= \gamma_0 + \alpha\gamma_1 - \gamma_2(Q_\alpha) \\
&= r_\alpha(Q_\alpha)
\end{aligned}
$$

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

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 conventional and green 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 profit,

(10)
$$
\begin{aligned}
q_c^p + q_g^p &= Q(p_\alpha^p) \\
p_\alpha^p &= mc_c(q_c^p) \\
p_\alpha^p &= mc_g(q_g^p)
\end{aligned}
$$

where, for simplicity of notation, the conditionality of the equilibrium quantities is left implicit. In terms of aggregate supply, the pooled equilibrium conditions are

(11)
$$
\begin{aligned}
Q^p &= Q(p_\alpha^p) \\
p_\alpha^p &= mc(Q_\alpha^p)
\end{aligned}
$$

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 .

A Separating Equilibrium with Certified Labeling

Once certified labeling is introduced, buyers can identify the green product from the conventional product. Certified labeling permits buyers the choice between two pure products, the conventional and the green product. Demands may be conditional on the availability of the related product, in the sense that once a buyer purchases a unit of the green product, demand for that unit is lost to conventional market. Demand for the conventional product in a labeled market is a conditional, residual demand.[1]

Residual demand is the unconditional demand for the conventional product, equation (3), minus purchases of the green product at the prices prevailing in the labeled situation,

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

where p_g is the green product price prevailing in an labeled market. The residual reservation price schedule is conditional on the quantity of the high valued product exchanged,

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

One approach to defining a separating equilibrium with certified labeling is to set quantities demanded so that prices are equal to marginal costs in separate conventional and green markets. In this situation, the equilibrium conditions are

(14)
$$
\begin{aligned}
q_h^i &= q_h(p_h^i) \\
p_h^i &= mc_h(q_h^i) + \tau \\
\tilde{q}_c^i &= \tilde{q}_c(p_c^i | p_h^i) \\
p_c^i &= mc_c(q_c^i)
\end{aligned}
$$

where the superscript *i* indicates prices and quantities pertaining to the proposed equilibrium. The problem with equations (15) is that they cannot describe an equilibrium. There is at least one green consumer who would gain surplus by shifting consumer to the conventional product.

Consider the consumer who purchases the marginal unit of the green product where $p_g^i = mc_g(q_g^i) + \tau$. This consumer obtains no consumer surplus from the green product since the consumer's reservation price, $r_g(q_g^i)$, is just equal to market price at this marginal unit. But this marginal high value consumer is a infra-marginal consumer in the conventional market; this individual would have the highest reservation price in the conventional market. The latter's reservation price for the conventional product is $\tilde{r}_c(0 | q_g^i) = r_c(q_g^i)$ and this is greater than the conventional market price, $p_c^i = r_c(q_c^i + q_g^i)$. This marginal green consumer gains $r_c(q_g^i) - p_c^i > 0$ by switching the marginal purchase to the conventional market. This cannot be an equilibrium.

Green product consumers take into account the opportunity cost of foregoing consumption of the conventional product. Consumers in the conventional market also take into account their opportunity cost. The marginal green consumer is only content to remain in the high value market as long as the net surplus from consumption, reservation prices less market price, is greater or equal to the surplus forgone by purchasing the conventional product. The infra-marginal conventional consumers obtains net surplus that is also great or equal to the opportunity in the green market.[2]

In a labeled equilibrium, net surplus for marginal high value consumer is equal to net surplus for the first incremental quantity of the conventional product. The equilibrium conditions are,

(15)

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

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 green 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.

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 1 describes the supply and demand conditions that support both a pooled equilibrium and a separating equilibrium with labeling. The aggregate pooled reservation price schedule, r_α, is the alpha-weighted combination of the unconditional conventional schedule, r_c, and the unconditional green schedule, r_g. Figure 1 is a special case where the conventional supply is perfectly elastic, while the green supply is inelastic. The green subsector also has a cost advantage from zero to q_g^p, but the conventional subsector has the cost advantage for market quantities greater than q_g^p. The aggregate supply function is therefore the lower frontier of the subsector supply curves: mc_g for quantities less than q_g^p and mc_c thereafter. If δ_0 were greater than μ_0, no green firm would persist in the pooled equilibrium. In this analysis, cost structures are such that both subsectors are competitive in the initial equilibrium, consistent with the stylized facts of agricultural products cited above.

Price and quantity in the pooled equilibrium are determined by the pooled, alpha-weighted reservation price and aggregate supply. The pooled reservation price schedule meets aggregate supply where the reservation price equals μ_0, so the pooled equilibrium price, p_α^p, equals μ_0, and the aggregate equilibrium quantity is Q_α^p. The quantity produced by the green and conventional subsectors equates the marginal costs of each subsector with the pooled price, so the green subsector produces q_g^p and the conventional subsector produces $q_c^p = Q^p - q_g^p$.

The pooled equilibrium is conditioned on the conjecture α, so a different conjecture would result in a different pooled equilibrium. For instance, if the conjecture were zero, the pooled price and quantity would be consistent with point e in Figure 1. If the conjecture were one, the pooled price and quantity would be consistent with point g. At this point, the conjecture is assumed to equal the green market share.   The welfare consequences of an incorrect conjecture are considered at the end of this section.

Prices and quantities in the separating equilibrium with labeling are determining the subsector supplies, the green reservation price schedule, and the conditional conventional reservation price schedule. The equilibrium green quantity, q_g^s is determined by the point where the net surplus of consuming a unit of the green product is equal to the net surplus of consuming a unit of conventional product. Since green firms behave competitively, the equilibrium green price, p_g^s, is equal to marginal sector costs at the equilibrium quantity.

The separating equilibrium quantity of conventional product is determined by the point where the conditional conventional reservation price schedule is equal to the conventional subsector supply cure. The latter is point e in Figure 1, so that the conventional quantity in the separating equilibrium is q_c^s and the conventional price, p_c^s, remains unchanged from the pooled equilibrium due to the elasticity of conventional supply.

Comparison of the pooled and separating equilibrium in Figure 1 illustrates several important points. First, when the market is not saturated, a green price premium emerges in the separating equilibrium with labeling. Notably, with a perfectly elastic conventional supply, the price premium emerges that is exactly equal to the willingness to pay premium for the green good, $\gamma_0 = p_g^s - p_c^s$.[3]   Second, credence labeling, in itself, is a double-edged sword that defines both the green product and its complement, the conventional product, for consumers. What was a single market for a mixed good becomes two separate markets for two pure goods, one with the credence attribute and the one without. The economic consequence is that the green good is higher in value, and the conventional good lower (weak inequality) in value to demanders than the mixed good produced in the pooled equilibrium.

Third, the change from mixed to pure products affects the equilibrium quantities of both the green and conventional products. The quantity supplied by the green subsector increases from q_g^p to q_g^s. The quantity supplied of the conventional good falls from q_c^p to q_c^s. With perfectly elastic conventional supply, the aggregate quantity of product also declines from $q_c^p + q_g^p$ to $q_c^s + q_g^s$. In the general case with inelastic conventional supply, the aggregate quantity may rise or fall.

The consequences for the green and conventional quantities are general to the defined pooled and separating equilibria, resulting in the following theorem:[4]

Theorem 1:[3]. Let certified labeling costs be less than willingness to pay, $\tau < \gamma_1$, and let the green quantity supplied be less than the market saturation level, $q_g^s < q_g^*$. The green product quantity supplied in the separating equilibrium with labeling is greater than green 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

Figure 1 suggests that the price premium for the green product is equal to the willingness to premium, γ_1, and Theorem 2 generalizes this result. Importantly for price analysis, however, this equilibrium price premium is *not* the difference between the green price with labeling and the pooled price.

Theorem 2:[3] Let certified labeling costs be less than willingness to pay, $\gamma_1 > \tau$, and let the labeled equilibrium quantity of the green product be less or equal to the market saturation threshold, so $q_g^s \leq q_g^*$. Then

a. The price premium for the green product relative to the conventional product in the labeled equilibrium is equal to $\gamma_1 = p_g^s - p_c^s > 0$;

b. The conventional price in the separating equilibrium is less or equal to the pooled equilibrium price and the green price in the separating equilibrium is greater than the pooled equilibrium price.

c. The difference between the green price in the separating equilibrium and the pooled price is less than or equal to per unit willingness to pay for the credence attribute. The equality holds only when the conventional supply is perfectly elastic.

Theorem 2 clarifies the nature of a price premium in the separating equilibrium. The price premium is a difference that arises within a separating equilibrium, not across the separating and pooled equilibria. In policy analyses of labeling, potential certified producers may want to know the price increase that they may expect. This potential price increase across cannot be determined by merely knowing willingness to pay. The price increase that producers may get from labeling is the difference between the green price in the separating equilibrium and the pooled price. This across-equilibria price increase is determined only in part by willingness to pay. Other market parameters also influence the potential price increase, parameters such as the elasticities of demand, green supply, and conventional supply. Willingness to pay alone is informative only is the special case of perfectly elastic conventional supply. In the inelastic case, the across-equilibria price premium and discount can only be determining by solving for the separating equilibrium prices and quantities and comparing these with the initial pooled equilibria.

The discussion has assumed to this point that demand for the green good is sufficient generate a willingness to pay premium for the quantity of green product supplied in the separating equilibrium. This may not be the case. The green market may become saturated, with the excess being sold in the conventional sector. Theorem 3 addresses this case.

Theorem 3:[3] Let certified labeling costs be less than willingness to pay, $\gamma_1 > \tau$, and let the green 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 green 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 green 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 green 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 green producers, $\tau > p^s - p_\alpha^p$.

With market saturation, costly certification appears to reduce the economic surpluses in the green subsector. Green production costs rise, but the green 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 green consumer surplus is the difference between consumer surplus in the market for the green 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 green sector are influenced by the change in green price relative to the pooled price, the change in consumer willingness to pay, and the unit cost of certified labeling. The change in green price is, in turn, equal to the marginal cost slope parameter, δ_1, times the change in green quantities, $q_g^s - q_g^p$, so the welfare effects are related to the change in the availability of the green product. When unit willingness to pay is greater than certified labeling cost, Theorem 1 holds and the change in availability is positive. In the latter case, green 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 green product is reduced by one minus consumers' conjecture about the mixed product. The larger, the more green, the mixed product conjecture, the smaller is the consumers' gain from certified labeling. The net effect of labeling for green consumers may be positive or negative. In the green market as a whole, the same ambiguity holds since the net market effect may be positive or negative. Only green 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. Green 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. Two sets of simulations were generated. The first set examined the price, quantity, and welfare effects of labeling without market saturation. Regression analysis was used to examine how parameters such as initial pooled price, demand elasticity, and supply elasticities affected the welfare differences across the pooled and separating equilibria. The second examined the same effects with green market saturation.

Labeling in Without Market Saturation

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 green market share in the initial, pooled equilibrium.[5] Initial conditions for green 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.

Demand parameters were based on research literature (Brown and Lee, 2002, Huang and Lin, 2000, You, et al., 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, et al., 1995, Hammitt, 1990, Ott, et al., 1991).

Little guidance was available in the literature regarding supply elasticities and the cost of certified labeling. The supply elasticity range was selected to mirror 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 green production. At the mean, green 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 green price is 22 percent greater in the separating equilibrium than in the pooling equilibrium. The mean green 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 green and conventional prices in the separating equilibrium with costly labeling are slightly higher than the prices in the costless labeling simulations. Since only green production experiences the direct costs of labeling, the higher prices for conventional producers may reduce their certain loss. The mean green price increase is not enough to offset mean labeling costs, so labeling costs reduce green 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 conventional and green 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 green 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. Green 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 green 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 green 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 green 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 green 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 green sector and net welfare losses overall occurred in about 60 percent of the simulations with costly labeling.

Additionally, labeling gives the green production sector routine incentives to realize gains as the expense of other market groups. In all cases where the green 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 green and conventional producers, and relatively weak between green producers and consumers. The Pearson correlation coefficient for the conventional and green producer impacts was -0.9, while it was only -0.15 between green producers and conventional consumers and -0.16 between green producers and green consumers.

Regression analysis was used to determine how initial conditions affected the aggregate welfare changes and the welfare changes for market participants. Table 4 displays the estimated coefficients. The dependent variables were the welfare change measures in millions of dollars for the aggregate market and the market groups. The independent variables were the variables determining the initial conditions (Table 1) measured in standard deviation units. The estimated coefficients therefore express the change in a welfare measure in millions of dollars given a one standard deviation change in the independent variable. The estimated coefficients were all significantly different from zero at the 95 percent level, except where noted by a footnote.

The coefficients show that the conditioning variables do varying significantly in their effects. A one standard deviation change in pooled aggregate quantity, green market share, pooled price, or willingness to pay has large and asymmetric impacts on producers, with conventional producers tending to lose $22 to $30 million in surplus and green producers gaining $23 to 35 million. The green and conventional supply elasticities have the largest impacts on consumers. An one standard deviation unit increase in conventional supply reduces conventional consumers welfare by $10 million and green consumer surplus by $4 million. An increase in the green supply elasticity has a positive effect on both sets of consumers. Changes in supply elasticities have effects on producers that are opposite in sign to their effects on consumers.

Given the conflicts of interest pointed out, it is not surprising that five of the eight independent variables have effects on aggregate welfare that are opposite in sign to their effects on green producer welfare.

Pooled aggregate quantity, green market share, and pooled price have a small negative effect on aggregate welfare and a large positive effect on green producer welfare. Demand elasticity and green supply elasticity have small positive effects on aggregate welfare, and green supply elasticity has a small negative effects on green producer welfare. The demand elasticity coefficient for producer surplus is also negative, but not significantly different from zero at the 90 percent level.

Labeling with Market Saturation

When market saturation occurs with labeling, consumers are able to match their preferences to the pure good they prefer, but price is determining by demanders who do not have a willingness to pay for credence attribute. The latter consumer group is indifferent between the conventional and green goods. Hence, price is equalized across the two markets. With costless label, green consumers experience a welfare improvement welfare gain without paying a price premium or a higher price.

Table 5 lists the welfare consequence of labeling with and without market saturation. As a point of reference, the column labeled None lists welfare changes at the mean level of the initial conditions[6] in Table 1, but with no market saturation. The two other results columns report welfare changes with saturation at five and ten percent of the pooled aggregate quantity.

The results for costless certification and labeling highlight the impact of market saturation. Without market saturation, conventional producer lose $53.6 million in surplus with labeling while green producers gain $57.6 million. The aggregate impact is a net gain of $4 million. Green and conventional consumer welfare is unaffected by costless labeling since the equilibrium price and quantity remain unaffected by the green consumers' shift in demand. With market saturation, there are too few green consumers to affect market price. With market saturation, green consumers gain $13 million, with no welfare costs to conventional consumers, conventional producers, and green producers. Costless labeling with market saturation simply allows green consumers to match their preferences with the appropriate product.

Costly labeling changes the results once again, and somewhat paradoxically. Certification costs increase supply costs for green producers. However, with market saturation, no price premium emerges to compensate for the additional costs. Green and conventional producers compete at a price determined by demand for the conventional product. Higher costs in the green subsector result in a loss of market share for green producers and a higher price for the conventional and green product. Conventional producers gain from the higher price and greater market share.

Green consumers gain from matching their preferences to the green product, while paying only a portion of the cost of certification. Conventional consumers lose due to the increase in price.
As long as market saturation occurs, green consumer welfare rises linearly with the percentage of green consumers. Of course, at some point the number of green consumers would reach a point where there is no market saturation and the equilibrium would shift to one without market saturation.

Conclusion

The analysis developed the theoretical consequences of labeling as well as an applied benefit-cost framework for policy evaluation. With respect to credence and conventional producers, labeling has highly asymmetric consequences. Without market saturation, credence producers are certain to gain and conventional producers are certain to lose. Conventional and green consumers may gain or lose, but by relatively modest amounts that depend largely on the level of certification costs. Costless labeling is certain to generate potential Pareto improvements, but costly labeling may reduce welfare.

Paradoxically, costless labeling is free of adverse impacts when the market saturation occurs. Market saturation occurs when credence production exceeds the credence quantity demanded by those consumers who care about the credence attribute. With market saturation, certified production is priced at the margin by consumers who are *not* willing to pay for the credence characteristics. A price premium fails to emerge and those who care about the credence attribute get the credence good at the conventional good price. The net welfare effect of labeling is positive as long as certification costs are not too high.

Neither average willingness to pay in excess of average labeling costs, nor anticipated gains to credence producers, are reliable indicators of potential Pareto improvements. Average willingness to pay is only one of the factors that determines price and welfare effects. Gains for credence producers do not predict general efficiency gains. The net 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. Furthermore, with market saturation, the net welfare effects of labeling may be positive, even though a price premium fails to emerge for the credence good and credence producers sustain both a loss of market share and welfare.

Certified labeling can cut deeply into the economic returns of a market subsector. Net welfare gains of labeling may be small relative to gross gains and losses. When sizable gains and losses are likely to occur, compensatory strategies may be appropriate. 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.[7]

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. 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.

2. The weighing of surpluses of price, surplus, and opportunity cost appears to be second nature at an early age. A California elementary school began sales of organic lunch items, but sales were thin. The news report quotes a ten-year old as saying that the organic items are “pretty expensive”, with the student preferring a complete conventional lunch of a pizza, raisins, carrots, an orange, and chocolate milk over the single organic enchilada available at the same price (Wong, 2002).

3. To set that the price premium is equal to the willingness to pay premium, note that the willingness to pay premium is the vertical distance ac. The vertical distances ab and cd are equal by definition of the separating equilibrium. Adding the vertical distance bc to each of the latter results in ab plus bc and bc plus cd. Clearly, ab plus bc equals bc plus cd, showing that the price premium, ab plus bc, equals the price premium, bc plus cd.

4. Mathematical proofs of the theorems are available upon request to the authors. Also, unless stated otherwise, the theorems assume that (a) the conjectured green 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.

5. 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.

6. To avoid confusion, we note that the welfare effect of the mean initial conditions in Table 5 is not equal to the mean welfare effect in Table 3 since the equilibrium and welfare equations are non-linear in the initial parameters.

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

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Figure 1. Equilibria With and Without Certified Labeling

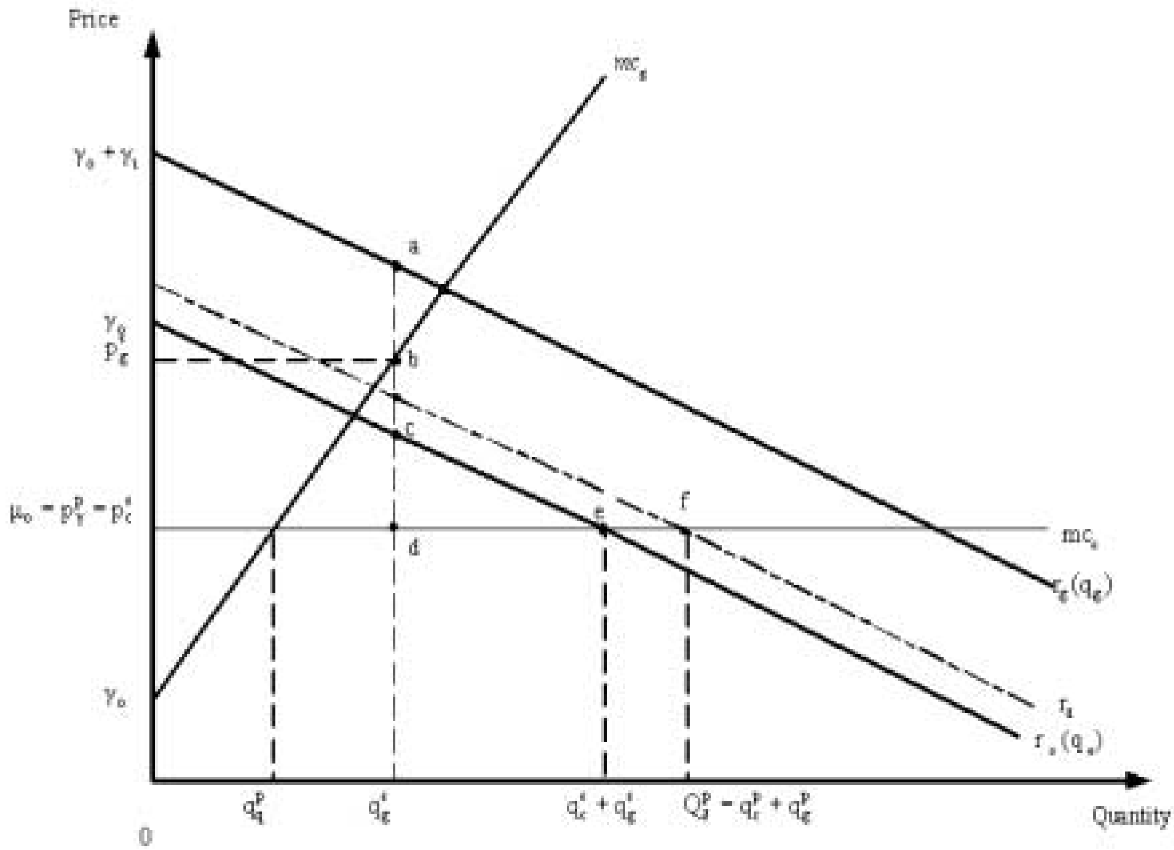

Table 1: Welfare Differences between the Separating Equilibrium with Certified Labeling and the Pooling Equilibrium[a]

Market Groups	Welfare Differences: Surplus in Separating Equilibrium Minus Surplus in Pooling Equilibrium
Green	
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	$\Delta cs_h = -\delta_1(q_g^s - q_g^p)q_g^s + (1-\alpha)\gamma_1 q_g^s - \tau q_g^s$
Green 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
Green 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
Green 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 green quantity, 1000 tons	47	44	~0 to 326
Green market share, %	24	12	2 to 51
Conventional price per ton, $	889	317	280 to 1,509
Green 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 green quantity, 1000 tons	44	41	-5 to 326
Green market share, %	24	12	2 to 51
Conventional price per ton, $	892	318	283 to 1,510
Green 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
Green				
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.

Table 4. Regression of Welfare Impacts of Certified Labeling on Initial Market Conditions

Independent Variables[a]	Estimated Coefficients by Dependent Variable in $Millions[b]				
	Conventional Surplus		Green Surplus		Aggregate Market Surplus
	Consumers	Producers	Consumers	Producers	
Pooled aggregate quantity	-.8	-24.2	-.3	24.6	-.7
Green market share	-1.3	-24.9	-.8	25.3	-1.7
Pooled price	-.7	-22.3	-.3	22.7	-.6
Demand elasticity	.1[c]	.1[c]	.2	-.3[c]	.1
WTP as % of pooled price	.4	-30.4	.2	35.1	5.3
Conventional supply elasticity	-10.0	10.9	-4.1	4.0	.8
Green supply elasticity	9.0	-8.8	3.7	-1.9	1.9
Certification costs	-1.8	2.4	-.8	-5.1	-5.4
Intercept	-1.9	-62.0	-.8	62.8	-1.9
R^2	.53	.75	.37	.76	.60

a. Independent variables were measured as deviations from mean in standard deviation units.
b. Dependent variables were measured in millions of dollars.
c. The variable is not significantly different from zero at the 10%

Table 5. Welfare Gains from Certification with Certification Costs and Market Saturation, Millions of Dollars

Cost Levels and Market Subsector	Market Saturation Level		
	None	At 5%	At 10%
Costless Certification			
Conventional Producers	-53.6	0.0	0.0
Conventional Consumers	0	0.0	0.0
Green Producers	57.6	0.0	0.0
Green Consumers	0.0	13.0	25.9
Aggregate	*4.0*	*13.0*	*25.9*
Certification Cost at 5% of Pooled Price			
Conventional Producers	-47.3	6.5	6.5
Conventional Consumers	-6.3	-7.8	-7.4
Green Producers	41.4	-14.5	-14.5
Green Consumers	-1.9	12.5	25.1
Aggregate	*-14.1*	*3.2*	*9.8*
Certification Cost at 10% of Pooled Price			
Conventional Producers	-41.0	13.0	13.0
Conventional Consumers	-12.7	-15.5	-14.6
Green Producers	25.7	-28.4	-28.4
Green Consumers	-3.6	12.1	24.3
Aggregate	*-31.6*	*18.8*	*-5.8*

a. When market saturation occurs, the welfare results for conventional producers, conventional consumers, and green producers do not vary with the level of saturation, only the level of certification costs.