AGRICULTURAL BIOTECHNOLOGY AND ORGANIC AGRICULTURE: NATIONAL ORGANIC STANDARDS, LABELING AND SECOND-GENERATION OF GM PRODUCTS

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Abstract – This paper examines the effect of the introduction of labels for products of biotechnology on the markets for GM, conventional, and organic food products. In addition, the paper analyzes the market and welfare effects of the introduction of consumer-oriented, second-generation GM products. Analytical results show that while a no-labeling regime is generally beneficial for the organic sector, when segregation costs are sufficiently high the introduction of labels for GM products *can* enhance the consumption share and growth of the organic sector while driving the conventional products out of the market. The analysis also reveals that the introduction of the consumer-oriented GM products can change the nature of the relationship between GM and conventional and organic products from one of vertical to one of horizontal product differentiation and can enhance both consumer welfare and the market acceptance and growth of agricultural biotechnology. When the value consumers place on the new product is sufficiently high, the introduction of the consumer-oriented GM products can drive the first-generation of GM products and their conventional counterparts out of the market while reducing the consumer demand for organic food. Overall, the market and welfare effects of GM labeling and the introduction of the consumer-oriented GM products are determined by the size of marketing and segregation costs under labeling of GM products, the level of consumer aversion to genetic engineering, the production share of the GM product in the no-labeling case, the structure of the agricultural biotechnology sector, and the benefits consumers perceive from the second-generation of GM products.

Agricultural Biotechnology and Organic Agriculture: National Organic Standards, Labeling and Second-Generation of GM Products

The introduction of genetically modified products (GMPs) into the food system and the significant growth of organic agriculture are among the most notable features of the increasingly industrialized agri-food sector. They have both received significant attention in the agricultural economics literature with the main focus being on the optimal regulatory responses as they relate to the introduction of standards for, and labeling of, GM and organic food products.

Labeling of GMPs has been a contentious issue sparking an ongoing international debate among parties holding significantly different views on the need for regulation of products of biotechnology. While the European Union advocates mandatory labeling (or even banning) of products of biotechnology based on its "precautionary principle" and the vocal consumer opposition to GMPs, the United States (US) have argued the "substantial equivalency" of producer-oriented, first-generation GMPs to their conventional counterparts and have been opposing the labeling of these products. Consumer opposition to the first-generation GMPs has hurt the prospects of the agricultural biotechnology sector and resulted in efforts by life science companies for the development of consumer-oriented, second-generation GMPs.

At the same time, the process of establishing national standards for organic food generated a significant public response in the US with the dialogue among the interest groups extending over a good part of the last decade. The debate over the establishment of the national organic standards ended last year with the introduction of the National Organic Program (NOP). In addition to affecting the organic sector with the provision of a clear understanding as to what an organic label really means, an important feature of the NOP is that it explicitly links the markets for organic and GM products. In particular, one of the provisions of NOP is that food labeled as organic should be free of GM ingredients.

Given the credence nature of the producer-oriented, first-generation GMPs and the consequent inability of the American consumer to observe the nature of the product under the current "no labeling" regime, the introduction of NOP can be expected to have important ramifications for the markets of GM, conventional, and organic food products. The reason is that, under the current regulatory framework, purchase of organic-labeled food provides the only option available to consumers averse to GMPs – the NOP has effectively made the organic label equivalent to a "GM-free" label.

The objective of this paper is to identify the scope and significance of the newly introduced NOP and systematically analyze the effect of the introduction of labels for GMPs on the markets for GM, conventional, and organic food products. In particular, the paper analyzes consumer purchasing decisions and welfare under (i) no labeling and (ii) mandatory labeling of GMPs. The study builds on previous work by Giannakas and Fulton and Giannakas that examine the market and welfare effects of different regulatory and labeling regimes in markets for GM and organic products, respectively. While these studies have examined the two markets in isolation, this paper explicitly considers the demand links between GM and organic food product markets created by the new regulation governing the organic sector. In addition to analyzing the effect of labeling for the markets of organic and first-generation GMPs, the paper also examines the market and welfare effects of the introduction of consumer-oriented, second-generation GMPs (e.g., nutraceuticals).

In analyzing the market and welfare effects of the introduction of labeling and consumer-oriented GMPs in the presence of the new organic standards, this paper explicitly considers differences in consumer preferences for GM, conventional and organic food products. Consumer heterogeneity in terms of preferences for different food products is a key component in our model and it is critical for explaining the coexistence of markets for products with different process attributes (i.e., produced through different production processes).

The rest of the paper is organized as follows. The next section presents a simple model of heterogeneous consumer preferences. The sections following analyze consumer purchasing decisions and welfare with and without labeling of GMPs, and determine the market and welfare effects of the introduction of labels for GMPs. The ramifications from the introduction of consumer-oriented, second-generation of GMPs are considered before the final section summarizes and concludes the paper.

Consumer Characteristics

Consider a product that is available in its GM, conventional (non-GM) and organic form.[1] The GM, conventional and organic versions of this good are treated as *vertically differentiated products* – if offered at the same price all consumers would prefer the organic version of the product, while if only the conventional and GM versions were available and priced the same, all consumers would buy the conventional form of the product. While the GM, conventional and organic forms of the product are, by definition, uniformly quality ranked by consumers, consumers differ in their willingness to pay for the perceived quality differences between the three goods. To capture these elements, consider a consumer that consumes one unit of either the GM, the conventional, or the organic form of the product in question and the purchasing decision represents a small share of her total budget. Her utility function can be written as:

(1)
$$U_{gm} = U - p_{gm} - \gamma\alpha \quad \text{if a unit of GM product is consumed,}$$
$$U_c = U - p_c - \delta\alpha \quad \text{if a unit of conventional (non-GM) product is consumed, and}$$
$$U_o = U - p_o + \beta\alpha \quad \text{if a unit of organic product is consumed}$$

where U_{gm}, U_c and U_o is the utility associated with purchasing one unit of the GM, the conventional and the organic version of the product, respectively. The price of the GM product is p_{gm}, the price of its conventional counterpart is p_c, and the price of the organic product is p_o. The parameter U is the per unit utility from the consumption of the physical product and is common to all consumers (see below). The terms γ and δ are utility discount factors associated with the consumption of GM and conventional products, respectively, while β is a utility enhancement factor associated with the consumption of the organic product. The parameter α takes values between zero and one and differs according to consumer capturing heterogeneous consumer preferences (and thus, heterogeneous willingness to pay) for the three products.[2]

[1] One example of a product that could be supplied in a conventional, GM and organic form is tomato. A second example could be corn chips (made from conventional, organic or GM corn).
[2] Note that consumers with an α value of zero would be indifferent between the GM, organic, and conventional versions of the product if those were offered at the same price. To conform with the assumption of vertical product differentiation, it is assumed that those consumers will prefer the organic version of the product.

In the context of this paper, the characteristic α can be seen as capturing differences in consumer preferences with regards to the process attributes of the three goods – the way they have been produced. The greater is α, the greater is the consumer aversion to (and the discount in utility from the consumption of) goods whose production is facilitated either by genetic engineering (i.e., GM products) or by the application of chemical fertilizers and pesticides (i.e., conventional products), and the greater is the utility derived from the organically grown version of the product.

Put in a different way, the utility function in equation (1) is based on the assumption that the good has two attributes – the first of these is the set of physical characteristics of the good, while the second is the process through which the good is produced. The utility of the good is assumed to be the sum of the utilities associated with each of these two attributes.

The first component of equation (1) – the term $U - p_i$ $(i \in \{gm, c, o\})$ – shows the net consumer benefit derived from the physical characteristics of the product. The parameter U is a per unit willingness to pay for the physical attributes of the product. Subtracting the price of the product from this willingness-to-pay value gives the net utility associated with the physical characteristics.

The second component of equation (1) gives the value placed on the process through which the good is produced – this is the component $-\gamma\alpha$ for the GM product, the component $-\delta\alpha$ for the conventional product, and the component $\beta\alpha$ for the organic product. Thus, for a consumer with attribute α, the terms $\gamma\alpha$ and $\delta\alpha$ give the utility discount from consuming the GM and conventional product, respectively, while the term $\beta\alpha$ is the utility enhancement from consuming the organic version of the product.

To capture the consumer resistance to genetic modification (Hobbs and Plunkett), we assume that $\gamma > \delta$ with the difference $\gamma - \delta$ reflecting the level of consumer aversion to GM products. For tractability, the analysis assumes that consumers are uniformly distributed between the polar values of α. The implications of relaxing this assumption are straightforward and are discussed throughout the text.

Consumer Decisions when GM Products are Not Labeled

Consider first the situation where the GM version of the product is not labeled (while the organic version is). In this case, the GM and conventional products are marketed together, and the price faced by the consumer, p_{nl}, is the same regardless of which product is purchased. Note that when the GM product is not labeled, the information regarding the nature of the offering is asymmetric; while producers know whether the product is GM or conventional, the presence or absence of genetic modification are not detectable by consumers with either search or experience (i.e., genetic modification is a *credence* attribute; see Darby and Karni and Nelson). The lack of information about the type of the product being sold means that consumers are uncertain about the nature of the product they purchase. Assuming a probability of ψ that the non-labeled product purchased is GM, consumer utility is now:[3]

(2)
$$U_{nl} = U - p_{nl} - \phi\alpha \qquad \text{if a unit of non-labeled product is consumed, and}$$
$$U_o = U - p_o + \beta\alpha \qquad \text{if a unit of the certified organic product is consumed}$$

where U_{nl} is the expected utility associated with the unit consumption of the non-labeled product (i.e., $U_{nl} = \psi U_{gm} + (1-\psi)U_c = \psi[U - p_{nl} - \gamma\alpha] + (1-\psi)[U - p_{nl} - \delta\alpha]$) and $\phi = \psi\gamma + (1-\psi)\delta$.

A consumer's purchasing decision is determined by comparing the utilities derived from the non-labeled product and its organic counterpart. Figure 1 illustrates the decisions and welfare of consumers. The upward sloping curve graphs utility levels when the organic product is purchased, while the downward sloping line shows the utility when the non-labeled product is purchased for different levels of the differentiating attribute α. The intersection of the two utility curves determines the level of the differentiating attribute that corresponds to the indifferent consumer. The consumer with differentiating characteristic α_{nl} given by:

[3] The probability that the non-labeled product is GM can be seen as reflecting the share of the GM product in total production of the non-labeled good. The greater is the production share of the GM version of the product, the greater is the likelihood that the non-labeled product is GM.

$$\text{(3)} \qquad \alpha_{nl} : U_{nl} = U_o \Rightarrow \alpha_{nl} = \frac{p_o - p_{nl}}{\beta + \phi}$$

is indifferent between consuming a unit of non-labeled product and a unit of the organic – the utility of consuming these two products is the same. Consumers "located" to the left of α_{nl} (i.e., consumers with $\alpha \in [0, \alpha_{nl}))$ purchase the non-labeled product while those located to the right of α_{nl} (i.e., consumers with $\alpha \in (\alpha_{nl}, 1])$ buy its organic counterpart. Aggregate consumer welfare is given by the area underneath the effective utility curve shown as the (bold dashed) kinked curve in Figure 1.

When consumers are uniformly distributed with respect to their differentiating attribute α, the level of α corresponding to the indifferent consumer, α_{nl}, also determines the market share of the non-labeled product. The market share of the organic is given by $1-\alpha_{nl}$. By normalizing the mass of consumers at unity, the market shares give the consumer demands for the non-labeled, x_{nl}, and the organic version of the product, x_o, respectively (Mussa and Rosen). In what follows, the terms "market share" and "demand" will be used interchangeably to denote x_{nl} or/and x_o. Formally, x_{nl} and x_o can be written as:

$$\text{(4)} \qquad x_{nl} = \frac{p_o - p_{nl}}{\beta + \phi} \left(= \alpha_{nl} \right), \text{ and}$$

$$\text{(5)} \qquad x_o = \frac{\beta + \phi - \left(p_o - p_{nl} \right)}{\beta + \phi} \; .$$

Note that because the products are vertically differentiated, if $p_o \leq p_{nl}$ all consumers will buy the organic product (i.e., $x_o = 1$ and $x_{nl} = 0$). Put in a different way, for any (positive) quantity of the non-labeled product to be demanded (i.e., for x_{nl} to be positive), p_{nl} should be less than p_o. In fact, there are two reasons why the non-labeled product will be priced lower than its organic counterpart. First, organic food producers must incur certification costs that have been estimated to account for 2% to 5% of total sales value (FAO). Furthermore, labeling of organic foods means increased segregation costs incurred by organic producers in keeping their produce separate from conventional and GM produce. The costs associated with product certification and identity preservation cause consumer price to rise. Second, it is assumed that the supply of organic food entails increased production costs. Some, if not all, of the additional cost will be transferred to the consumer of the organic product.

Comparative statics results can be shown graphically. A reduction in p_o shifts the U_o curve upwards and increases x_o, while a reduction in p_{nl} causes an upward shift of the U_{nl} curve and a reduction in x_o (i.e., $\frac{\partial x_o}{\partial p_o} < 0$ and $\frac{\partial x_o}{\partial p_{nl}} > 0$). An increase in the utility discount factor ϕ (due to an increase in the production share of the GM product ψ and/or an increase in the consumer aversion to GM products γ-δ) causes a rightward rotation of the U_{nl} curve through the intercept at $U - p_{nl}$, which increases the consumer demand for the organic product (i.e., $\frac{\partial x_o}{\partial \phi} > 0$).

The analysis can be easily modified to examine cases where consumers are not uniformly distributed with respect to their value of α. When the distribution of consumers is continuous (but not uniform), the consumer demand for the different products depends on its skewness, i.e., the more skewed is the distribution towards 1, the greater is the market share of, and the demand for, the organic product when the GM and conventional products are marketed together (i.e., GM products are not labeled).

Consumer Decisions under Labeling of GM Products

Consider now the consumer choice problem in an institutional arrangement with a mandatory GM labeling regime in place. In this case, conventional and GM products are segregated and marketed separately and consumers have a choice between the conventional product, the GM-labeled product, and their certified organic counterpart.[4] Consumer utility in this case is given by equation (1) and a consumer's purchasing decision is determined by the relative utilities derived from the consumption of the three goods.

[4] While the analysis assumes that only the GM product is legally required to be labeled, the results are more general and apply to the cases where only the conventional or both the GM and conventional products have to be labeled. Specifically, when only GM products are labeled, unlabeled products will be perceived as conventional. Similarly, if conventional products are legally required to be labeled as such, unlabeled products will be perceived as being GM.

Note that the GM and conventional products are not necessarily priced the same. Given the vertical differentiation of the three products and the uniform quality ranking by consumers, for any positive quantity of the GM-labeled product to be demanded, p_{gm} should be less than p_c. Similarly, for any positive quantity of the conventional product to be demanded, p_c should be less than p_o. As pointed out by Giannakas and Fulton, there are two reasons why the GM product will be priced lower than its conventional counterpart. First, mandatory labeling means increased marketing and segregation costs. These transaction costs associated with identity preservation cause consumer prices to rise. The majority of these costs are incurred in the conventional product chain (see Bullock and Nitsi and Giannakas and Fulton), which, in turn, implies that consumers of the conventional product face a greater price increase.[5]

Second, the producer-oriented, first-generation GM technology generates production cost savings at the farm level. Some, if not all, of the cost savings may be transmitted to the consumer of the GM product. While the conventional product is expected to be priced higher than the GM product, it is expected to be priced lower than its organic counterpart for the reasons mentioned in the previous section (i.e., certification, segregation and higher production costs incurred in the organic product supply chain).

Figure 2 depicts the consumption decisions under mandatory labeling of GMPs when $p_{gm} < p_c < p_o$ and the consumer preferences are such that all three products enjoy positive shares of the market. In this case, the consumption share of the GM product, x_{gm}, is determined by the intersection of the U_{gm} and U_c utility curves (i.e., $x_{gm} : U_{gm} = U_c$) and equals:

(6) $$x_{gm} = \frac{p_c - p_{gm}}{\gamma - \delta}$$

while the demand for the organic product, $x_o^{'}$, is given by $1 - \alpha_T$ where α_T corresponds to the consumer who is indifferent between consuming the conventional product and its organic counterpart (i.e.,

[5] As Giannakas and Fulton point out, "when any type of labeling occurs, traditional and GM products will have to be segregated. The segregation costs will always be higher for producers of the traditional product due to the effort required to preserve the identity of their produce by keeping it separate from the GM product that consumers regard as being inferior."

$\alpha_T : U_c = U_o \Rightarrow \alpha_T = \dfrac{p_o - p_c}{\beta + \delta}$). Thus,

(7) $$x_o^{'} = \frac{\beta + \delta - (p_o - p_c)}{\beta + \delta}$$

Finally, the market share of, and the demand for the conventional product, x_c, is given by $1 - \left(x_{gm} + x_o^{'}\right)$ or

(8) $$x_c = \frac{\gamma(p_o - p_c) - \delta(p_o - p_{gm}) - \beta(p_c - p_{gm})}{(\beta + \delta)(\gamma - \delta)}$$

The preceding analysis indicates that the market shares of the three products are determined by the consumer attitudes towards GM, conventional, and organic products and their relative prices which are determined, in turn, by the relative size of the segregation and labeling costs, the cost savings associated with the GM technology, and the market power in the GM product supply chain (which determines the extent to which production costs savings are transferred to the consumers).

Equation (8) indicates that when the price of the GM version of the product is significantly lower than the price of its conventional counterpart and/or when the price premium paid for the organic product is relatively low and/or when the consumer aversion to GM products is not significant, the conventional product will be driven out of the market (i.e., $x_c = 0$) – consumers with relatively low values of the differentiating attribute α will opt buying the cheaper GM product while consumers with relatively high values of α will prefer consuming the organic.

Formally, when the combination of prices (p_{gm}, p_c, and p_o) and preference parameters (γ, δ, and β) are such that the expression in equation (8) is less than or equal to zero, the utility curve U_c in Figure 2 lies underneath the curves U_{gm} or/and U_o for all consumers (i.e., $\forall\alpha$) and $x_c = 0$. In this case, the demand for the GM product, x_{gm}^{+}, is determined by the intersection of U_{gm} and U_o (i.e., $x_{gm}^{+} : U_{gm} = U_o$) and equals:

(9) $$x_{gm}^{+} = \frac{p_o - p_{gm}}{\beta + \gamma}$$

The demand for the organic product, x_o^+, is then given by $1 - x_{gm}^+$ or:

(10) $$x_o^{+} = \frac{\beta + \gamma - (p_o - p_{gm})}{\beta + \gamma}$$

In this case, the consumer demand for the GM (organic) product falls (increases) as p_{gm} and/or the preference parameters γ and β increase, and rises (falls) as the price of the organic product increases (i.e., $\frac{\partial x_{gm}^+}{\partial p_{gm}} < 0$, $\frac{\partial x_{gm}^+}{\partial \gamma} < 0$, $\frac{\partial x_{gm}^+}{\partial \beta} < 0$, $\frac{\partial x_{gm}^+}{\partial p_o} > 0$, $\frac{\partial x_o^+}{\partial p_{gm}} > 0$, $\frac{\partial x_o^+}{\partial \gamma} > 0$, $\frac{\partial x_o^+}{\partial \beta} > 0$ and $\frac{\partial x_o^+}{\partial p_o} < 0$).

The Welfare and Market Effects of GM Labeling

After having analyzed the consumer purchasing decisions and welfare under the no-labeling and labeling regimes, we can now determine the ramifications of GM labeling for the welfare of consumers and the demand for the GM, the conventional and organic food products. Figure 3 depicts the effective utility curves under no labeling (dashed kinked curve) and mandatory labeling (solid kinked curve) when the marketing and segregation costs associated with mandatory labeling of GMPs are relatively low. In this case, the relative prices are $p_{gm} < p_{nl} < p_c < p_o$, the utility curve U_c lies above U_{gm} and U_o over some values of α and $x_c > 0$.

When segregation costs are relatively low, the introduction of labels increases consumer welfare by the shaded area *ΔCW* in Figure 3 while reducing the consumer demand for the organic product. In particular, consumers will relatively low aversion to interventions in the production process (i.e., consumers with $\alpha \in [0, \alpha_{gm})$) realize an increase in their welfare because the utility increase from the purchase of the cheaper GM product outweighs the utility discount from its consumption. At the same time, for consumers with intermediate values of α (i.e., consumers with $\alpha \in (\alpha_{gm}, \alpha_{nl})$) the utility increase from the consumption of the (identity preserved) conventional product exceeds the utility discount from its higher price.

In addition, the availability of the conventional non-GM product in the labeling case eliminates the exclusivity of the organic sector in the supply of GM-free product and results in some consumers that would purchase the organic product under the no-labeling regime switching to its conventional counterpart. In particular, when segregation and labeling costs are relatively low, consumers with $\alpha \in (\alpha_{nl}, \alpha_T)$ find it optimal to switch their consumption from the organic to the cheaper conventional product.[6] Overall, when segregation and labeling costs are relatively low, the introduction of labels enhances consumer welfare, reduces the demand for organic products while sustaining a consumer demand for all three products – GM, conventional, and organic.

Obviously, when the assumption of a uniform distribution of consumers is relaxed, the welfare and market effects of mandatory labeling depend on the skewness of the distribution. In general, the greater is the number of consumers that are characterised by a relatively low aversion to interventions in the production process (i.e., the more skewed towards zero is the distribution of consumers with respect to their value of α), the greater are the welfare gains from the introduction of labels and the lower are the consumer demands for conventional and organic food products.

Comparative statics results can easily be derived from Figure 3. For instance, an increase in the likelihood that the non-labeled product is GM (i.e., an increase in ψ) causes a clockwise rotation of the U_{nl} curve that increases both ΔCW and the portion of consumers that switch their consumption from the organic product to its conventional counterpart under labeling of GMPs. Similarly, an increase in the market power in the GM supply chain will increase p_{gm} and will shift the U_{gm} curve downwards. The outcome is reduced consumer benefits from the introduction of labels and increased demand for the conventional product. Finally, an increase in the marketing and segregation costs associated with labeling

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[6] Implicit in the analysis is the presumption of supply adjustments to market demands i.e., the reduction in demand for organic food is "matched" by a move of productive resources away from the organic sector. Note that p_o also remains unaffected when the supply of the organic product is perfectly elastic.

of GMPs will increase the prices of the GM and conventional products which will shift the U_c and U_{gm} curves downward and will reduce *ΔCW*.

As mentioned earlier, the price effect of the increased segregation costs will be more profound in the conventional product supply chain (i.e., the downward shift of U_c will exceed the one of U_{gm}) which will result in reduced demand for the conventional product and increased demand for its organic counterpart. The greater are the marketing and segregation costs, the lower are the consumer welfare gains from the introduction of labels, the lower is the consumer demand for the (identity preserved) conventional product, and the greater is the demand for the organic product. For sufficiently high segregation costs the conventional product is driven out of the market (i.e., U_c lies underneath U_{gm} or/and U_o $\forall \alpha$ and $x_c = 0$), and the demand faced by the organic sector can exceed the one under no-labeling of GMPs. Figure 4 depicts the consumer decisions and welfare under this scenario. The dotted and hatched areas in Figure 4 represent the gains and losses, respectively, in consumer welfare due to labeling of GMPs.

The reasoning behind this (counterintuitive) increase in the demand for the organic product under labeling of GMPs is as follows. The exit from the market of the conventional product when marketing and segregation costs are high, restores the exclusivity of the organic sector in supplying a product free of GM ingredients (an exclusivity that is lost when conventional (non-GM) product is present). In addition to avoiding the loss of consumers to the conventional product (consumers with $\alpha \in (\alpha_{nl}, \alpha_T)$ in Figure 3), the increased segregation costs make the (*ceteris paribus*) least desired GM alternative more costly. For certain values of the prices and preference parameters, U_{gm} lies below U_{nl} at the point of intersection with the U_o curve which results in increased demand for the organic product under labeling of GMPs.

In Figure 5, p_c is graphed against γ, the utility discount from the consumption of the GM product. The shaded area *NC* in Figure 5 shows those combinations of p_c and γ that result in a lack of demand for the conventional product, i.e., $x_c = 0$. The size and shape of this area is determined by the position of its lower boundary (i.e., curve $p_c = \frac{(\gamma - \delta)p_o + (\beta + \delta)p_{gm}}{\gamma + \beta}$) which, in turn, is determined by the prices of the GM and organic products, and the preference parameters β and δ. In general, the likelihood that there will be no demand for the identity preserved conventional product increases with a reduction in p_{gm}, p_o and δ, and falls with a reduction in β.

Finally, Figure 6 depicts the combinations of the price of the organic product, p_o, and the preference parameter associated with its consumption, β, that result in increased demand for the organic product in the GM labeling regime. The combinations of p_o and β that result in increased x_o are shown by the shaded area OG in Figure 6. The size and shape of this area depend on p_c, p_{nl}, the share of the GM product to total production of the non-labeled good, ψ, and the preference parameters γ and δ. In general, the likelihood that the organic sector will benefit from the introduction of labels for GMPs increases with an increase in the price of the conventional product (due to high segregation costs) and the consumer aversion to GM products (due to an increase in γ or/and a reduction in δ), and falls with an increase in the price of the non-labeled product, p_{nl}.

Ramifications from the Introduction of Consumer-Oriented, Second Generation of GMPs

While the previous analysis applies to the producer-oriented, first-generation of GM products, the model can be extended, with some modification, to analyze the consequences from the introduction of consumer-oriented GM food. Since, by definition, the consumer-oriented, second-generation GM technology focuses on altering the characteristics of the product (by adding vitamin A to rice for instance), the "substantive equivalency" between GMPs and conventional products breaks down and so does the US argument that has sustained the current no-labeling of products of biotechnology. Consequently, it is reasonable to assume that the second-generation of GMPs (new-GMPs, hereafter) will be governed by a labeling regime. In this context, we will proceed in analyzing the market and welfare effects of the introduction of labeled new-GMPs relative to the current no-labeling regime.

With the introduction of new-GMPs there are three goods in the market – the new-GMP, the non-labeled product,[7] and the organic product. If the new generation of GM products manages to possess attributes valued by consumers, the consumer utility function becomes:

$$U_{gm}^{N} = U + V - p_{gm}^{N} - \gamma\alpha \qquad \text{if a unit of the new-GMP is consumed,}$$

$$(11) \qquad U_{nl} = U - p_{nl} - \phi\alpha \qquad \text{if a unit of the non-labeled product is consumed, and}$$

$$U_{o} = U - p_{o} + \beta\alpha \qquad \text{if a unit of the certified organic product is consumed}$$

where U_{gm}^{N} is the utility associated with the unit consumption of the new consumer-oriented GM product, V is the value consumers place on the new product attribute (e.g., vitamin A in rice), and p_{gm}^{N} is the price of the new-GMP. All other variables are as previously defined. Note that the utility discount factor associated with the consumption of the GM product, γ, is not affected from the introduction of the new-GMPs since it reflects consumer attitudes towards genetic engineering – the process through which (first- and second-generation) GMPs are produced.

What the introduction of the consumer-oriented GMPs does change, however, is the utility associated with their consumption – the value consumers place on the (enhanced) physical characteristics of the product. For simplicity and without loss of generality, the utility increase from the introduction of consumer-oriented GMPs is assumed to be constant across consumers. Obviously, if the value consumers place on the new product attribute increases (decreases) with the differentiating characteristic α, the outcome will be a reduction (increase) in the effective utility discount factor associated with the consumption of the new-GMP.

It is important to note that the introduction of the consumer-oriented, second-generation of GMPs alters the nature of the relationship between the (new) products of biotechnology and their conventional and organic counterparts. In particular, for certain values of the preference parameters, β, γ, δ, and V, the

[7] Due to the "substantive equivalency" between the first-generation GMP and the conventional product, these two offerings are marketed together (i.e., they are not labeled).

inclusion of the new product attribute that confers value to consumers results in the new-GMPs being horizontally (rather than vertically) differentiated with respect to their conventional and organic counterparts. In this case, unlike the first-generation GMPs that are uniformly quality ranked by consumers relative to the conventional and organic products, the new-GMPs are not uniformly quality ranked neither with the conventional products nor with their organic counterparts.[8]

The market and welfare effects of the introduction of the second-generation of GMPs are straightforward and depend on the value consumers place on the new product attribute V, the price of the new-GMP, p_{gm}^{N} (which is determined by the structure of the biotechnology sector and the segregation costs required in keeping the new-GMP separate from the first-generation GM and conventional produce), the level of consumer aversion to genetic engineering, γ-δ, and the share of the first-generation GMP to the total production of the non-labeled product, ψ. Figure 7 depicts the case in which V exceeds the price difference between the new-GMP and the non-labeled product, $p_{gm}^{N} - p_{nl}$, and the parameters γ, δ, and ψ are such that all three products (i.e., the new-GMP, the non-labeled, and the organic product) enjoy positive market shares.

In such a case, the new-GMP attracts consumers with relatively low values of α (i.e., consumers with $\alpha \in [0, \alpha_{gm}^{N})$) and the consumption share for the non-labeled product falls by the same amount (i.e., the demand for the new-GMP). The market for the organic product remains unaffected in this case since the introduction of the new-GMP results in consumers switching their consumption from the non-labeled good to the new-GMP. Formally, the consumption shares of (and the demands for) the new-GMP, x_{gm}^{N}, the non-labeled, $x_{nl}^{''}$, and the organic products, $x_{o}^{''}$, are given by:

[8] It can be shown that, when only new-GMPs and conventional products are available and they are offered at the same price, consumers with relatively low aversion to process interventions (consumers with $\alpha \in [0, \frac{V}{\gamma - \delta})$) will prefer the new-GMPs while the rest of the consumers (i.e., consumers with $\alpha \in [\frac{V}{\gamma - \delta}, 1)$ will prefer the conventional product. Similarly, when only new-GMPs and organic products are available and offered at the same price, consumers with $\alpha \in [0, \frac{V}{\beta + \gamma})$ will purchase the new-GMP and the rest (i.e., consumers with $\alpha \in [\frac{V}{\beta + \gamma}, 1)$ will buy the organic product.

(12) $$x_{gm}^{N} = \frac{V - \left(p_{gm}^{N} - p_{nl}\right)}{\gamma - \phi}$$

(13) $$x_{nl}^{"} = \frac{(\gamma - \phi)(p_o - p_{nl}) - (\beta + \phi)\left[V - \left(p_{gm}^{N} - p_{nl}\right)\right]}{(\beta + \phi)(\gamma - \phi)}$$

(14) $$x_{o}^{"} = \frac{\beta + \phi - (p_o - p_{nl})}{\beta + \phi}$$

The greater is the value consumers place on the new attribute of the new-GMP, or/and the smaller is the price difference between the new-GMP and the non-labeled product, or/and the lower is the consumer aversion to genetic engineering, or/and the higher is the share of the first-generation GM product to the total production of the non-labeled good, the greater is the share of the new-GMP and the lower is the share of the non-labeled product. When $V \geq \left(p_{gm}^{N} - p_{nl}\right) + \frac{\gamma - \phi}{\beta + \phi}(p_o - p_{nl})$, the non-labeled products (i.e., first-generation GM and conventional products) are driven out of the market since consumers with relatively low values of the differentiating attribute α will opt buying the new-GMP while consumers with relatively high values of α will prefer consuming the organic.

Formally, when $V \geq \left(p_{gm}^{N} - p_{nl}\right) + \frac{\gamma - \phi}{\beta + \phi}(p_o - p_{nl})$, the utility curve U_{nl} in Figure 7 lies underneath the curves U_{gm}^{N} or/and U_o for all consumers (i.e., $\forall \alpha$) and $x_{nl}^{"} = 0$. In this case, the demand for the new-GMP, $\bar{x}_{gm}^{N}$, is determined by the intersection of U_{gm}^{N} and U_o and equals:

(15) $$\bar{x}_{gm}^{N} = \frac{V + p_o - p_{gm}^{N}}{\beta + \gamma}$$

while the demand for the organic product falls to:

(16) $$\bar{x}_{o}^{"} = \frac{\beta + \gamma - \left(V + p_o - p_{gm}^{N}\right)}{\beta + \gamma}$$

Equations (15) and (16) show that the demand for the new-GM (organic) product falls (increases) as p_{gm}^{N} and the preference parameters γ and β increase, and rises (falls) with an increase in V and/or p_o (i.e., $\frac{\partial \overline{x}_{gm}^{N}}{\partial p_{gm}^{N}} < 0$, $\frac{\partial \overline{x}_{gm}^{N}}{\partial \gamma} < 0$, $\frac{\partial \overline{x}_{gm}^{N}}{\partial \beta} < 0$, $\frac{\partial \overline{x}_{gm}^{N}}{\partial V} > 0$, $\frac{\partial \overline{x}_{gm}^{N}}{\partial p_o} > 0$, $\frac{\partial \overline{x}_{o}^{''}}{\partial p_{gm}^{N}} > 0$, $\frac{\partial \overline{x}_{o}^{''}}{\partial \gamma} > 0$, $\frac{\partial \overline{x}_{o}^{''}}{\partial \beta} > 0$, $\frac{\partial \overline{x}_{o}^{''}}{\partial V} < 0$, and $\frac{\partial \overline{x}_{o}^{''}}{\partial p_o} < 0$). Obviously, when $V \geq \beta + \gamma - \left(p_o - p_{gm}^{N}\right)$, all consumers will prefer the new-GMP.

Before concluding the paper, it should be noted that, no matter what the market effects are, the introduction of the new-GMP has an unambiguous positive effect on aggregate consumer welfare. In particular, relative to the *status quo* case of no-labeling, the introduction of consumer-oriented, second-generation of GM products increases the welfare of consumers with relatively low aversion to production process interventions. Interestingly, the consumers who gain from the introduction of the new-GMPs are exactly those who find it optimal to consume the new product. In this context, the parameters affecting the market demand for the new-GMP also affect the consumer welfare gains from the new technology. Thus, consumer gains rise with an increase in the value added to the product from the new technology, and fall with an increase in the price of the new-GMPs, the consumer aversion to genetic modification, and the production share of the first-generation GM product.

Summary and Concluding Remarks

This paper develops a model of heterogeneous consumer preferences to examine the effect of the introduction of labels for products of biotechnology on the markets for GM, conventional, and organic food products. In addition to analyzing the market and welfare effects of labeling the first-generation of GM products, the paper also examines the economic consequences from the introduction of consumer-oriented, second-generation GMPs (e.g., nutraceuticals).

Analytical results show that the introduction of labels for the first-generation of GMPs has important ramifications for the markets of organic, conventional and GM products. The market and welfare effects of labeling are shown to depend on the size of the marketing and segregation costs under mandatory labeling of GMPs, the distribution of consumer preferences and the level of aversion to GMPs, the production share of the GM product in the no-labeling case, and the structure of the agricultural biotechnology sector.

It is shown that, while a no-labeling regime for products of biotechnology is generally beneficial for the organic sector, when segregation costs are sufficiently high the introduction of labels for GMPs can enhance the consumption share and growth of the organic sector while driving the conventional products out of the market. While high segregation costs associated with labeling of GMPs may benefit the organic sector, they have the opposite effect on consumer welfare since, the greater are these costs, the lower are the consumer welfare gains from the introduction of labels.

The analysis also reveals the potential for significant benefits from the introduction of the consumer-oriented, second-generation of GM products both for consumer welfare and the market acceptance and growth of agricultural biotechnology. The introduction of the new-GMPs can change the nature of the relationship between the GM and the conventional and organic products from one of vertical to one of horizontal product differentiation and results in an unambiguous increase in aggregate consumer welfare. The magnitude of this welfare increase is shown to depend on the value consumers place on the new product, the price of the new-GMP, the level of consumer aversion to genetic engineering, and the production share of the first-generation of GMPs under the no-labeling regime.

Finally, the analysis shows that when the value consumers place on the new product is sufficiently high, the introduction of the new-GMPs can drive the first-generation of GMPs and their conventional counterparts out of the market while reducing the consumer demand for organic products. In this context, while the development of the second-generation, consumer-oriented GMPs can provide the boost desired (and needed) by the agricultural biotechnology sector, it can eliminate the conventional and first-generation GM products, and slow down the significant growth experienced by organic agriculture.

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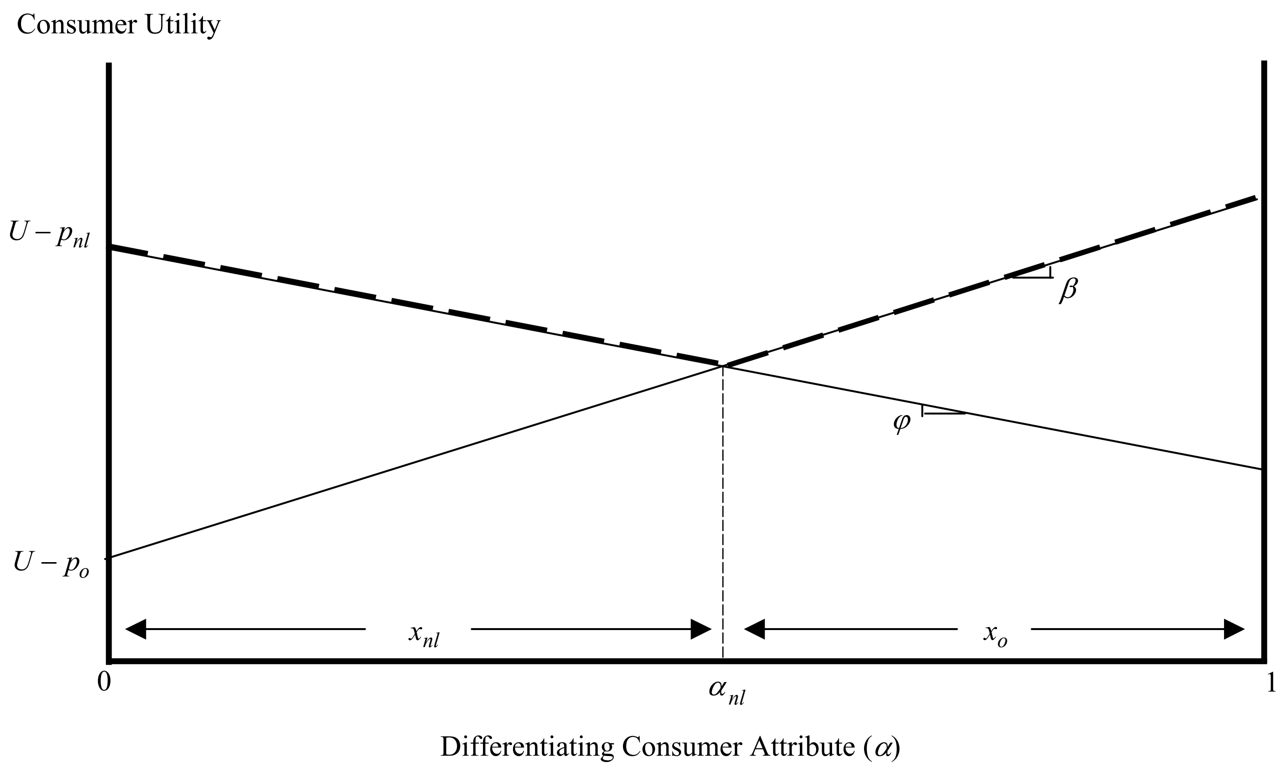

Figure 1. Consumption Decisions and Welfare under No Labeling of GM Food.

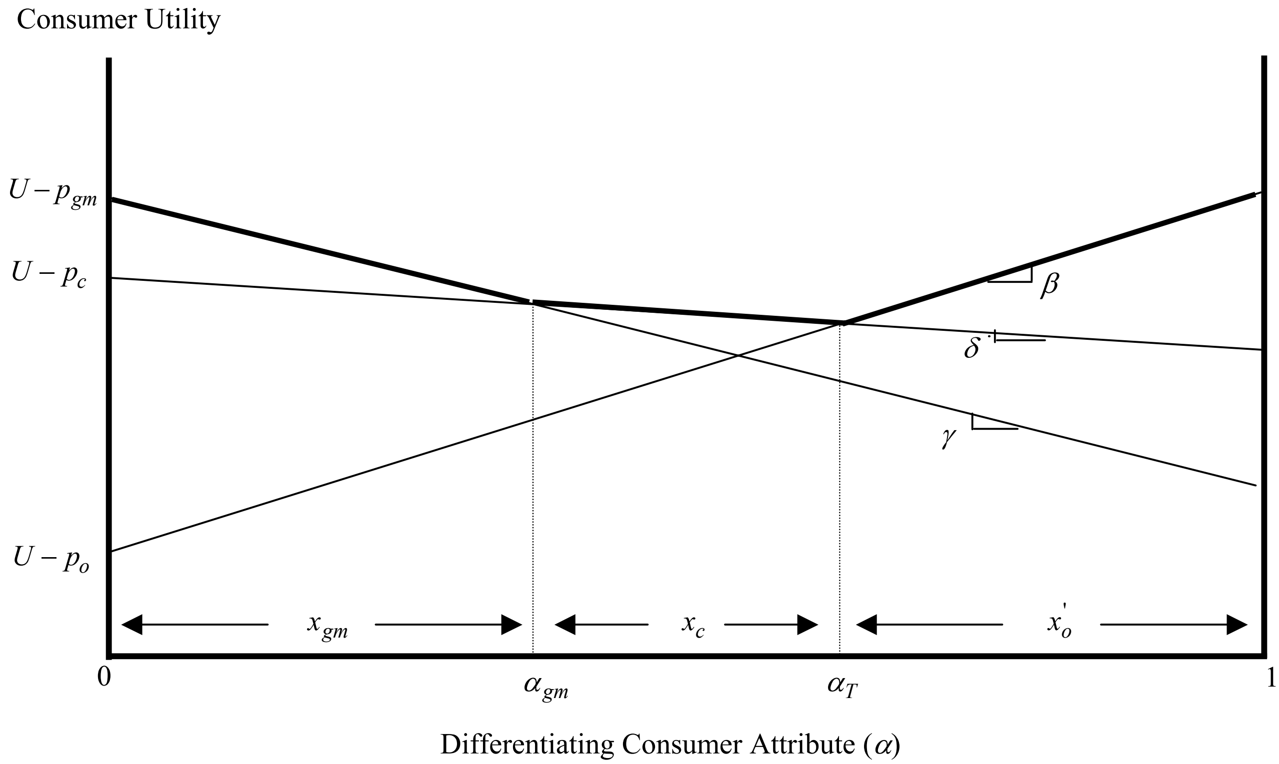

Figure 2. Consumption Decisions and Welfare under Labeling of GM Food.

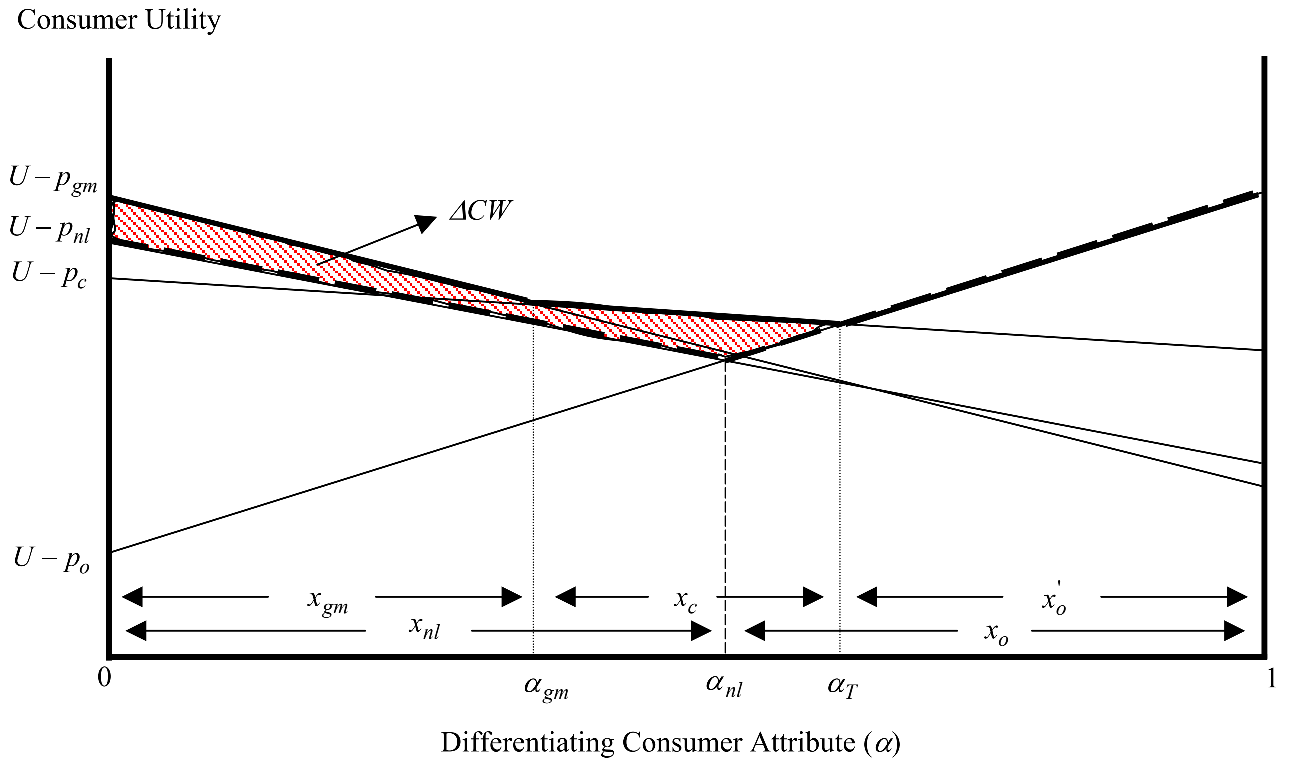

Figure 3. Labeling vs. No Labeling of GM Food (Low Segregation Costs).

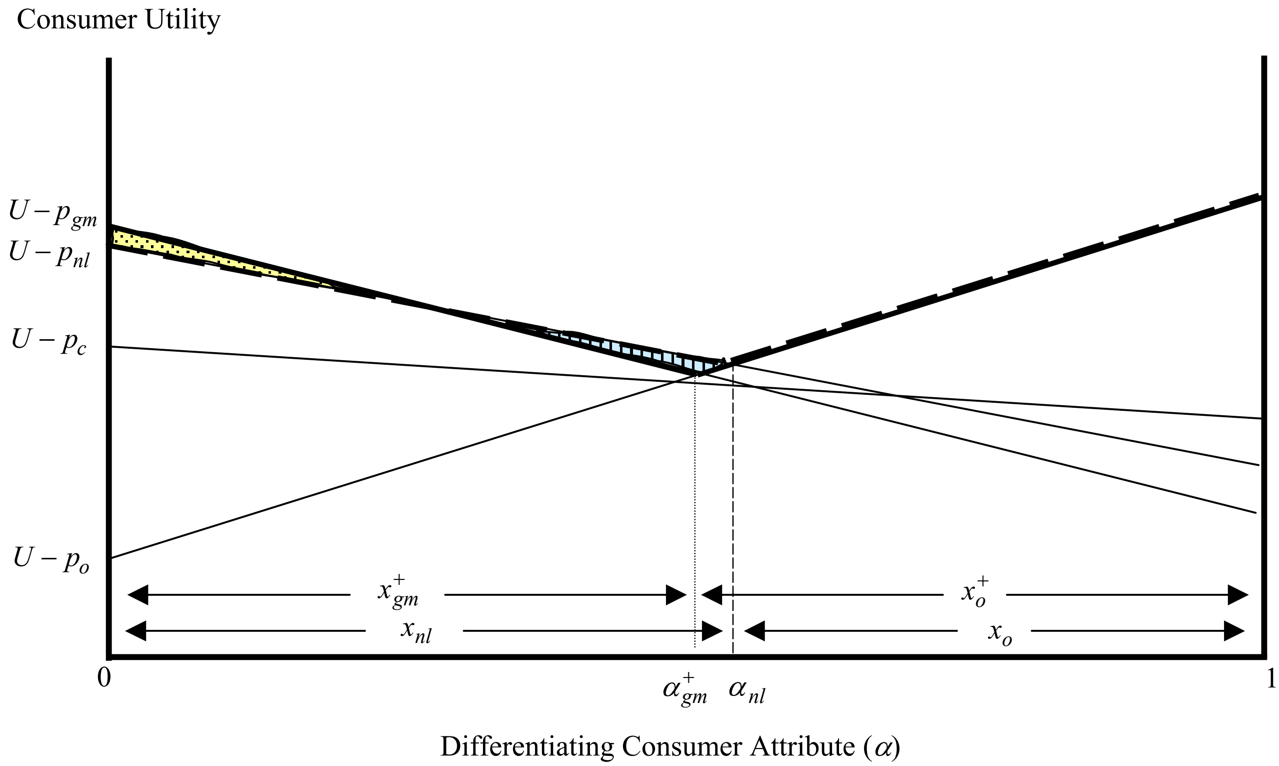

Figure 4. Labeling vs. No Labeling of GM Food (High Segregation Costs).

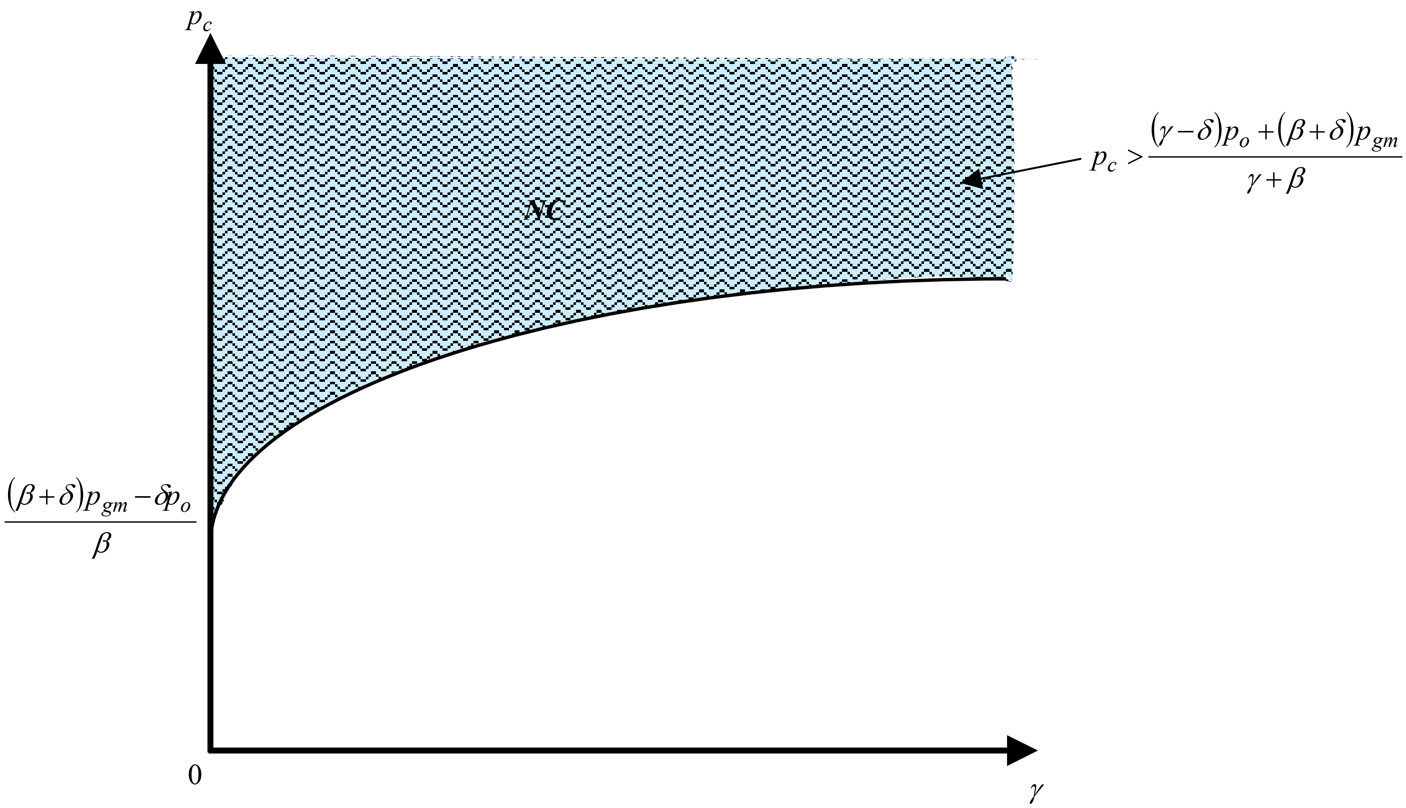

Figure 5. Labeling of GMPs and the Demand for Conventional Products.

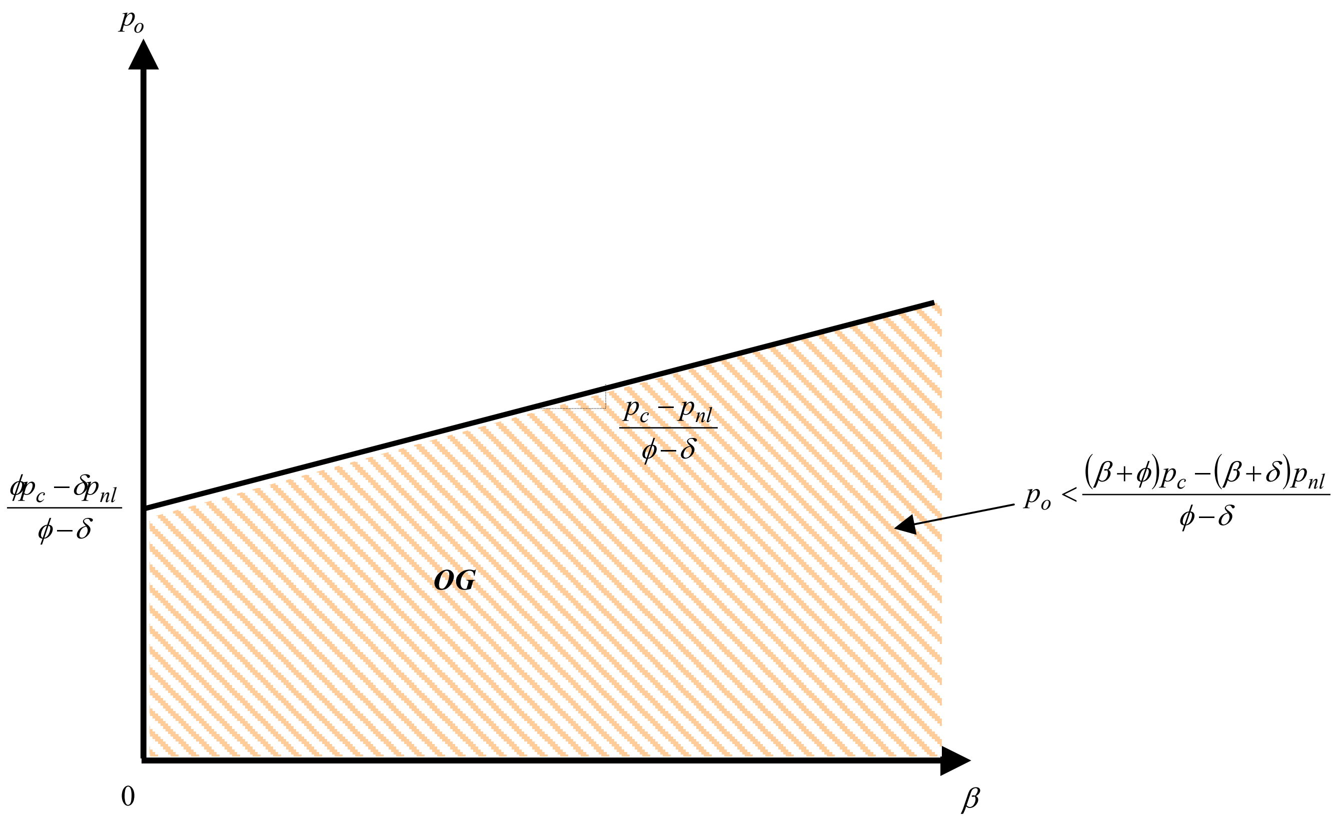

Figure 6. Labeling of GMPs and Changes in the Demand for Organic Products.

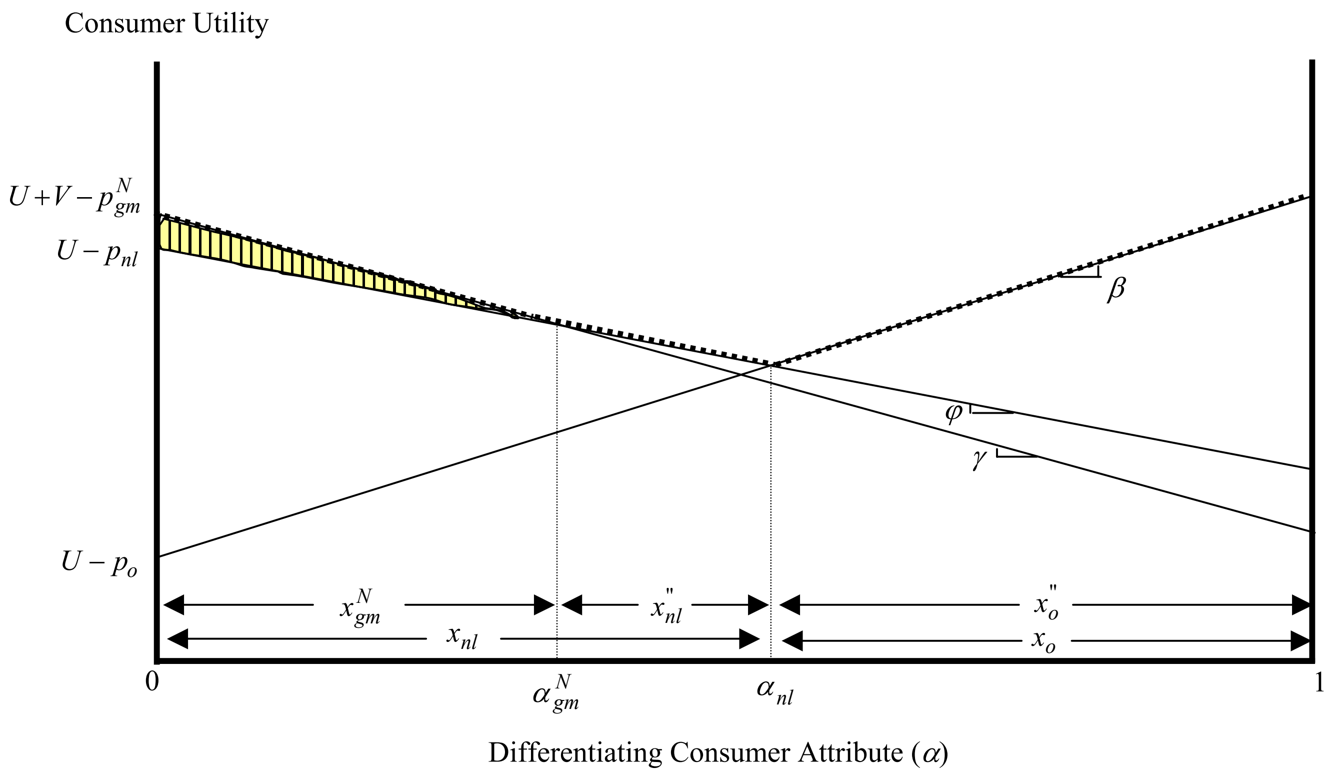

Figure 7. Market and Welfare Effects of the Introduction of New-GMPs (Relative to the Current No-Labeling Regime).