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THE MARKET AND WELFARE EFFECTS OF GMP LABELING AND SECOND GENERATION GMPS

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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 consumer 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 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 consumer-oriented GM products can drive the conventional and first-generation GM products out of the market and jeopardize the prospects of the fast-growing organic sector. Overall, the market and welfare effects of GM labeling and the introduction of consumer-oriented GM products are determined by the size of marketing and segregation costs, the distribution of consumer preferences and level of 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.

Keywords: agricultural biotechnology, genetically modified products, labeling, national organic standards, organic agriculture.

The Market and Welfare Effects of GMP Labeling and Second Generation GMPs

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 considerable 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 United States (US) have argued the “substantive equivalence” of producer-oriented, first-generation GMPs to their conventional counterparts and have been opposing the labeling of these products, the European Union advocates mandatory labeling of GMPs based on its “precautionary principle” and the vocal consumer opposition to products of biotechnology. Consumer opposition to the first-generation GMPs has hurt the prospects of the agricultural biotechnology sector and resulted in efforts by life science companies to develop consumer-oriented, second-generation GMPs with augmented functional properties (e.g., vitamin A enhanced *Golden*Rice™).

Regarding the organic sector, the process of establishing national standards for organic food in the US generated a significant public response with the dialogue among interest groups extending over a good part of the last decade. The debate over the establishment of national organic standards ended in 2002 with the introduction of the National Organic Program (NOP). In addition to instituting uniform standards for organic-labeled food, an important feature of the NOP is that it explicitly links the markets for organic and GM products. In particular, one of the NOP provisions 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 type of the product (i.e., GM versus conventional) 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 products provides the only option available to consumers exhibiting a preference for GM-free food – the NOP has made the organic label equivalent to a "GM-free" label.

An objective of this paper is to systematically analyze the effect of a change in the labeling regime for products of biotechnology on the markets for GM, conventional, and organic food products in the presence of the newly introduced NOP. In analyzing the ramifications of the introduction of labels for GMPs, the paper compares and contrasts consumer purchasing decisions and welfare under (i) no labeling and (ii) mandatory labeling of GMPs. The study builds on previous work by Giannakas and Giannakas and Fulton that examine the market and welfare effects of different regulatory and labeling regimes in markets for organic and GM products, respectively.[1] While these studies have examined the two markets in isolation, this paper explicitly considers the demand links between the 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, conventional, and first-generation GM products, the paper also examines the market and consumer welfare effects of the introduction of consumer-oriented, second-generation GMPs. To our knowledge, the implications of the introduction of consumer-oriented GMPs have not been examined previously.

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 accounts for 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 in 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

[1] On issues pertaining to GM labeling see also Caswell, Crespi and Marette, Runge and Jackson, Fulton and Giannakas, and Lapan and Moschini.

introduction of labels for GMPs. The ramifications of the introduction of consumer-oriented, second-generation GMPs are considered before the final section summarizes and concludes the paper.

Product and Consumer Characteristics

Consider a product that is available in GM, conventional (non-GM) and organic form.[2] The product in question can be seen as having two attributes – the first of these is the set of observable physical characteristics, while the second is the process through which the good is produced (or the ingredients used in its production if the good in question is a processed food product).

The GM, conventional and organic versions of this product share the same observable physical characteristics while differing in the process through which they have been produced.[3] The three forms of the product are treated by consumers as *vertically differentiated products* – if offered at the same price all consumers exhibiting a preference for the process through which those products are produced would prefer the organic version of the product, while if only the conventional and GM versions were available and priced the same, those 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 who value the process attributes of these products, consumers differ in their willingness to pay for the perceived quality differences between the three goods.[4]

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:

$$U_{gm} = U - p_{gm} - \gamma\alpha \qquad \text{if a unit of GM product is consumed,}$$

[2] One example of a product that could be supplied in a conventional, GM and organic form is tomato sauce (made from conventional, GM or organic tomatoes). A second example could be corn chips (made from conventional, organic or GM corn).
[3] By assuming that the different versions of the product share the same observable physical characteristics, the analysis applies to most (if not all) processed food products utilizing GM, conventional or organic ingredients and to fresh agricultural produce whose observable physical characteristics are not affected by the production process.
[4] Premiums paid for organic food products vary significantly by product and region (Thompson and Kidwell, Giannakas). Highly variable is also the level of consumer aversion to GM products both between and within countries (Giannakas and Fulton).

(1) $U_c = U - p_c - \delta\alpha$ if a unit of conventional (non-GM) product is consumed, and

$U_o = U - p_o + \beta\alpha$ if a unit of organic product is consumed

where U_{gm}, U_c and U_o is the utility associated with the consumption of the GM, the conventional and the organic versions of the product, respectively. The terms p_{gm}, p_c, and p_o denote the equilibrium prices of the GM, the conventional, and the organic products, respectively. The parameter U is the per unit utility derived from the observable physical characteristics of the product. It is assumed that U exceeds the prices of the different products and is common to all consumers.[5] The terms γ and δ are non-negative utility discount factors associated with the consumption of GM and conventional products, respectively, while β is a non-negative 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.[6]

Specifically, 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 the degree of intervention in the production process, the greater is the utility discount received from the consumption of the good. On the contrary, the absence of such process interventions (e.g., organic agriculture) results in utility enhancement. Thus, 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. Thus, for a consumer with attribute α, the terms $\gamma\alpha$ and $\delta\alpha$ give the utility discount from consuming the GMP and conventional product, respectively, while the term

[5] It should be noted that if the production process affects the observable physical characteristics of the product (such as the cosmetic appearance of organic tomatoes, for instance), the utility derived from those characteristics will vary among the different goods, and the products may become horizontally differentiated.

[6] 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.

$\beta\alpha$ is the utility enhancement from consuming the organic version of the product.

To capture the consumer opposition to GM products reflected in various opinion polls, we assume that $\gamma > \delta$ with the difference $\gamma - \delta$ reflecting the level of aversion to GMPs of consumers with different values of α. 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 certified and labeled as such). 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 presence or absence of genetic modification is 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 is GM, consumer utility is now:[7]

(2)

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

$$U_o = U - p_o + \beta\alpha \quad \text{if a unit of certified organic product is consumed}$$

where U_{nl} is the expected utility associated with the unit consumption of 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

[7] Assuming that consumers have rational expectations, the probability that the non-labeled product is GM reflects 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.

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

is indifferent between consuming a unit of non-labeled product and a unit of 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 product 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 products, 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:

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

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

Equations (4) and (5) show that if $p_o \le p_{nl}$ all consumers will buy the organic product (i.e., $x_o = 1$ and $x_{nl} = 0$). In other words, for any positive quantity of non-labeled product to be demanded (i.e., for x_{nl} to be positive), p_{nl} should be less than p_o. The greater is the price difference $p_o - p_{nl}$, the greater is x_{nl}.

The price difference between the two products is determined by the cost structure and market power in the different supply channels. In general, the greater are the costs and/or the greater is the market power in a supply channel, the greater is the price faced by consumers. In this context, there are at least three 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). Second, the labeling of organic foods implies increased segregation costs incurred by organic producers in keeping their produce separate from conventional and GM produce. Third, 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.

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), 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.[8] Consumer utility 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.

Note that the GM and conventional products are not necessarily priced the same. Given the vertical differentiation of the three products and their uniform quality ranking by consumers, for any positive quantity of GM-labeled product to be demanded, p_{gm} should be less than p_c. Similarly, for any positive quantity of conventional product to be demanded, p_c should be less than p_o.[9]

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 organic product, $x_o^{'}$, is given by $1 - \alpha_T$ where α_T corresponds to the consumer who is indifferent between the conventional and organic products (i.e., $\alpha_T : U_c = U_o \Rightarrow \alpha_T = \frac{p_o - p_c}{\beta + \delta}$). Thus,

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

[8] 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.

[9] As pointed out by Giannakas and Fulton, there are at least 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 by 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. 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).

Finally, 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 in the three supply channels, the cost savings associated with the GM technology, the market power in the GM product supply chain (which determines the extent to which production costs savings are transferred to the consumer), and the structure of the organic and conventional supply channels.

Equation (8) indicates that when the price of the GM version of the product is sufficiently lower than the price of its conventional and organic counterparts and/or when the price difference between the organic and conventional products 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 curves (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:

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

Equations (9) and (10) indicate that the consumer demand for GM (organic) product increases with an increase in $p_o - p_{gm}$ and falls (increases) with an increase in the preference parameters γ and β.

Market and Welfare Effects of GMP Labeling

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 GM, 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 $p_{gm} < p_{nl} < p_c < p_o$ and the prices and preference parameters are such that the conventional product enjoys positive share of the market under mandatory labeling of GMPs (i.e., the utility curve U_c lies above U_{gm} and U_o over some values of α).

In this case, the introduction of labels increases consumer welfare by the shaded area ΔCW in Figure 3 while reducing the consumer demand for the organic product. Consumers with relatively low aversion to interventions in the production process (i.e., consumers with $\alpha \in [0, \alpha_{gm}))$ realize an increase in their welfare under labeling of GMPs 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, consumers with $\alpha \in (\alpha_{nl}, \alpha_T)$ find it optimal to switch their consumption from the organic to the cheaper conventional product.[10]

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 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 is the consumer demand for conventional and organic food products.

Comparative statics results can easily be derived from Figure 3. For instance, an increase in p_{gm} will reduce ΔCW and will increase the demand for conventional product. Similarly, an increase in the marketing and segregation costs associated with labeling of GMPs will increase the prices of conventional and GM products which will shift the U_c and U_{gm} curves downward and will reduce the consumer benefits from the introduction of labels.

As mentioned previously (see footnote 10), the price effect of increased segregation costs will be more profound in the conventional product supply chain (i.e., the downward shift of U_c will exceed that of U_{gm}). This negative externality that the existence of GMP imposes on the conventional product 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 conventional product, and the greater is the demand for 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 that 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 when entry into the retail market of the organic product is free.

[10] Note that, for simplicity of exposition, Figure 3 is drawn on the assumption of free entry into the retail market of the organic product. When this assumption is relaxed, the reduced demand for the organic product caused by the introduction of labels reduces p_o and results in welfare gains for consumers of the organic product (i.e., consumers with $\alpha \in [\alpha_T, 1]$).

The reasoning behind this (counterintuitive) increase in the demand for 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 the conventional 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 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 organic product under labeling of GMPs. In this context, an expectation of high marketing and segregation costs might help rationalize the support of prominent organizations of organic producers for the establishment of mandatory labeling of GMPs.

Table 1 provides a numerical example that illustrates the market and consumer welfare effects of the introduction of labels for GMPs. Two different labeling scenarios, namely, low and high segregation costs are compared to the benchmark case of no labeling when the share of the GMP to the non labeled product is 50% (ψ=0.5). All parameter values are set arbitrarily and under no labeling they result in market shares for the organic and the non labeled product of 30% and 70% , respectively. Under labeling with low segregation costs and price premiums for the organic product of 100% and 54% over the GM and the conventional product, respectively, the market share of the organic product falls by 10% (to 20%) compared to the no labeling case while the GM and the conventional product each captures 40% of the market. In this case, consumer welfare increases compared to the no labeling case by 5.43%. Under labeling with high segregation costs and price premiums for the organic product of 68% and 28% over the GM and conventional product, respectively, the market share of the organic product increases by 30% (to 50%) compared to the no labeling case while the GM product captures 50% of the market and the conventional product is driven out of the market. In this case, consumer welfare falls by 16.6% compared to the no labeling case.

In Figure 5, p_c is graphed against δ, the utility discount from the consumption of conventional product. The shaded area *NC* in Figure 5 shows those combinations of p_c and δ that result in the conventional product being priced out of the market, 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 γ and β. In general, the likelihood that there will be no demand for conventional product increases with a reduction in p_{gm}, p_o and γ, 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 organic product in the GM labeling regime. The combinations of p_o and β that result in increased x_o under labeling of GMPs 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 in 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.

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

While the previous analysis applies to the producer-oriented, first-generation 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 enhancing vitamin A in rice, for instance), the US argument on the "substantive equivalence" between GMPs and conventional products that has sustained the current no-labeling of products of biotechnology breaks down. 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,[11] and the organic product. If the new generation of GMPs manages to possess attributes valued by consumers, the consumer utility function becomes:

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

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

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

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., enhanced 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 GM product, γ, is not affected by the introduction of the new-GMP since it reflects consumer attitudes towards genetic engineering – the process through which (first- and second-generation) GMPs are produced. For simplicity and without loss of generality, the value placed on the new product attribute is assumed to be constant across consumers. Obviously, if this value 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 new-GMP.

It is important to note that the introduction of the consumer-oriented, second-generation GMP alters the nature of the relationship between the (new) products of biotechnology and their conventional

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[11] Due to the "substantive equivalence" between the first-generation GMP and the conventional product, these two offerings are marketed together as a non-labeled product.

and organic counterparts. In particular, for certain values of the preference parameters, β, γ, δ, and V, the inclusion of the new product attribute that confers value to consumers results in the new-GMP being horizontally (rather than vertically) differentiated with respect to its conventional and organic counterparts. In this case, unlike the first-generation GMP that is uniformly quality ranked by consumers relative to the conventional and organic products, the new-GMP is not uniformly quality ranked either with the conventional products or with its organic counterparts.[12]

The market and welfare effects of the introduction of the second-generation GMP are shown to 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 GM supply channel and the segregation costs required in keeping the new-GMP separate from the conventional and first-generation GM products), the level of consumer aversion to genetic engineering, γ-δ, and the share of the first-generation GMP in 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 $\alpha \in [0, \alpha_{gm}^{N})$) who switch their consumption from the non-labeled product 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 product, $x_{o}^{''}$, are given by:

[12] It can be shown that, when only the new-GMP and conventional product are available and 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-GMP 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 the new-GMP and organic product 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 in 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 GMP and conventional product) are driven out of the market – 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 product. 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 is given by:

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

Equations (15) and (16) show that the demand for 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. Obviously, when $V \geq \beta + \gamma - \left(p_o - p_{gm}^N\right)$ the utility curve U_{gm}^N lies above the U_o curve for all consumers (i.e., $\forall \alpha$) and the new-GMP dominates the market (i.e., $\bar{x}_{gm}^N = 1$).

Figure 8 graphs V against the preference parameter γ and summarizes the different possibilities regarding the market effects of the introduction of new-GMPs. In particular, Figure 8 is divided into four areas. In *Area I*, the value consumers place on the new product attribute of the consumer-oriented GMP is sufficiently low so that there is no demand for the new product (i.e., the U_{gm}^N curve lies underneath the curves U_{nl} or/and U_o for all consumers and $x_{gm}^N = 0$). In *Area II*, medium values of V and relatively high consumer aversion to GM products result in positive consumption shares of all three products (this case is depicted in Figure 7). In *Area III*, high values of V and medium values of γ drive the non-labeled products (i.e., first-generation GMP and conventional product) out of the market, while, very high values of V combined with low values of γ in *Area IV* result in all consumers buying the new-GMP.

Table 2 provides a numerical example that illustrates the market and consumer welfare effects of the introduction of new-GMPs as the value consumers place on the new product attribute, V, and the price of the new-GMP, p_{gm}^N, vary. Without loss of generality, all parameter values are arbitrarily set and under the benchmark case of no labeling (ψ=0.5) they result in market shares for the organic and non labeled product of 30% and 70%, respectively. As illustrated in Table 2, when the value consumers place on the new product attribute, V, is 6.24% of the U value, and the price of the new-GMP is 62.5% of the organic product price, the new-GMP does not enter the market and the market shares of the organic and the non labeled product as well as consumer welfare are unaffected (Area I in Figure 8). As the value of V increases, *ceteris paribus*, all three products enjoy positive market shares when the V value is 12.48% of the U value

(Area II in Figure 8), the non labeled product is driven out of the market when the *V* value is 19.35% of the *U* value (Area III in Figure 8), while both the non labeled and the organic product are driven out of the market when the *V* value is 43.69% of the *U* value (Area IV in Figure 8). The greater is the value of *V*, ceteris paribus, the greater is the gain in consumer welfare from the introduction of the new-GMP.

When the price of the new-GMP decreases, *ceteris paribus*, both the market share of the new-GMP and consumer welfare increase. Thus, when p_{gm}^{N} is 68.75% of the price of the organic product, p_o , and the *V* value is 12.48% of the *U* value, the new-GMP does not enter the market (Area I in Figure 8). As the value of p_{gm}^{N} decreases, *ceteris paribus*, all three products enjoy positive market shares when p_{gm}^{N} is 62.5% of p_o (Area II in Figure 8), the non labeled product is driven out of the market when p_{gm}^{N} is 55.62% of p_o and p_{gm}^{N} drops below p_{nl} (Area III in Figure 8), while both the non labeled and the organic product are driven out of the market when p_{gm}^{N} is 31.25% of p_o (Area IV in Figure 8).

Before concluding the paper, it should be noted that, irrespective of its market effects, the introduction of the new-GMP has an unambiguous positive effect on aggregate consumer welfare. In particular, when $V \geq p_{gm}^{N} - p_{nl}$ and entry into the retail sector is free, the introduction of consumer-oriented, second-generation GMPs increases the welfare of consumers with relatively low aversion to production process interventions. Interestingly, the consumers who benefit from the introduction of the new-GMP are exactly those who find it optimal to consume the new product. In the absence of free entry into the retail market of these products, the reduced demand for non-labeled products due to the introduction of new-GMPs reduces the consumer prices of both the organic and non-labeled products and results in welfare gains for all consumers.

Summary and Concluding Remarks

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 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.

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 marketing and segregation costs under mandatory labeling of GMPs, the distribution of consumer preferences and the level of aversion to genetic modification, the production share of the GM product in the no-labeling case, and the structure of the different supply channels.

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 consumer-oriented, second-generation GM products both for consumer welfare and the market acceptance and growth of agricultural biotechnology. The introduction of 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 relative price of the new-GMP, the level of consumer aversion to genetic engineering, the preference for organic food, the production share of the first-generation GMPs under the no-labeling regime, and the conditions of entry into the retail market of the organic and non-labeled products.

Finally, the analysis shows that when the value consumers place on the new product is sufficiently high, the introduction of new-GMPs can drive the first-generation GMPs and their conventional counterparts out of the market and reduce 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 jeopardize the prospects of the fast-growing organic agriculture.

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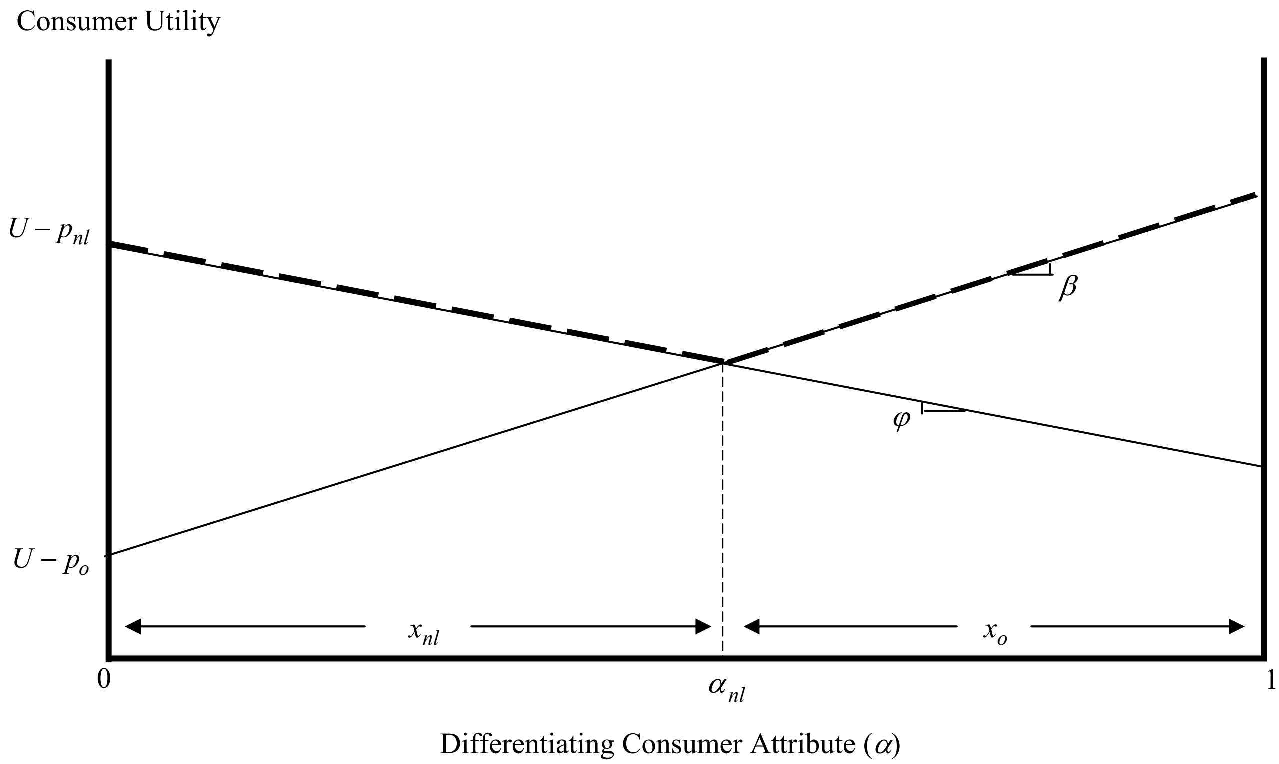

Figure 1. Consumption Decisions and Welfare under No Labeling of GM Food.

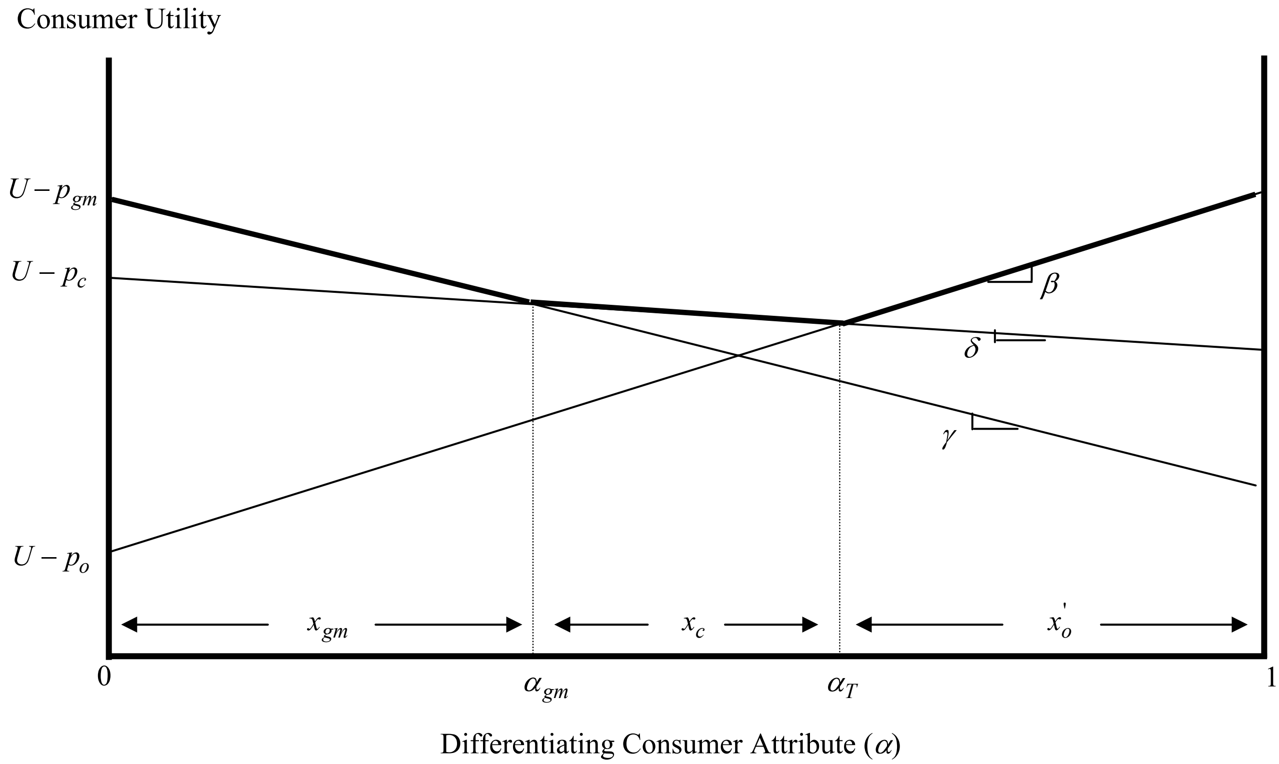

Figure 2. Consumption Decisions and Welfare under Labeling of GM Food.

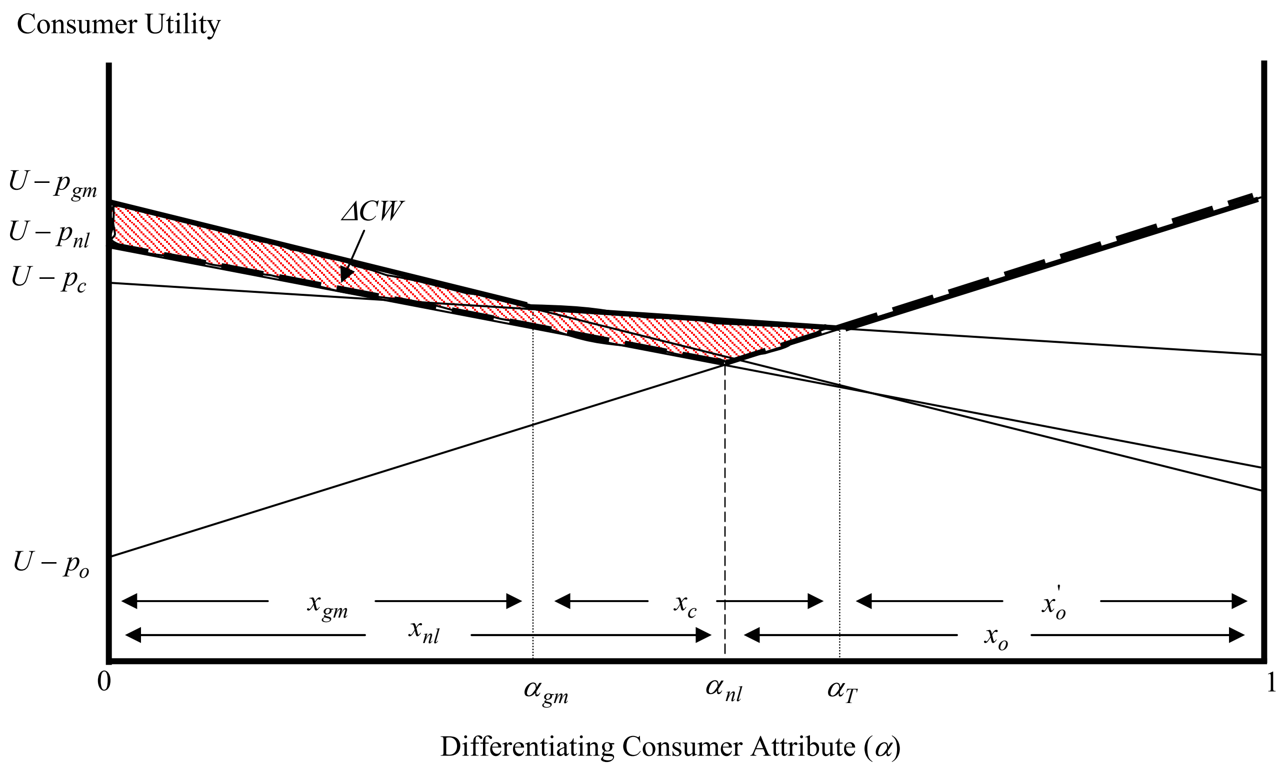

Figure 3. Market and Welfare Effects of GM Labeling.

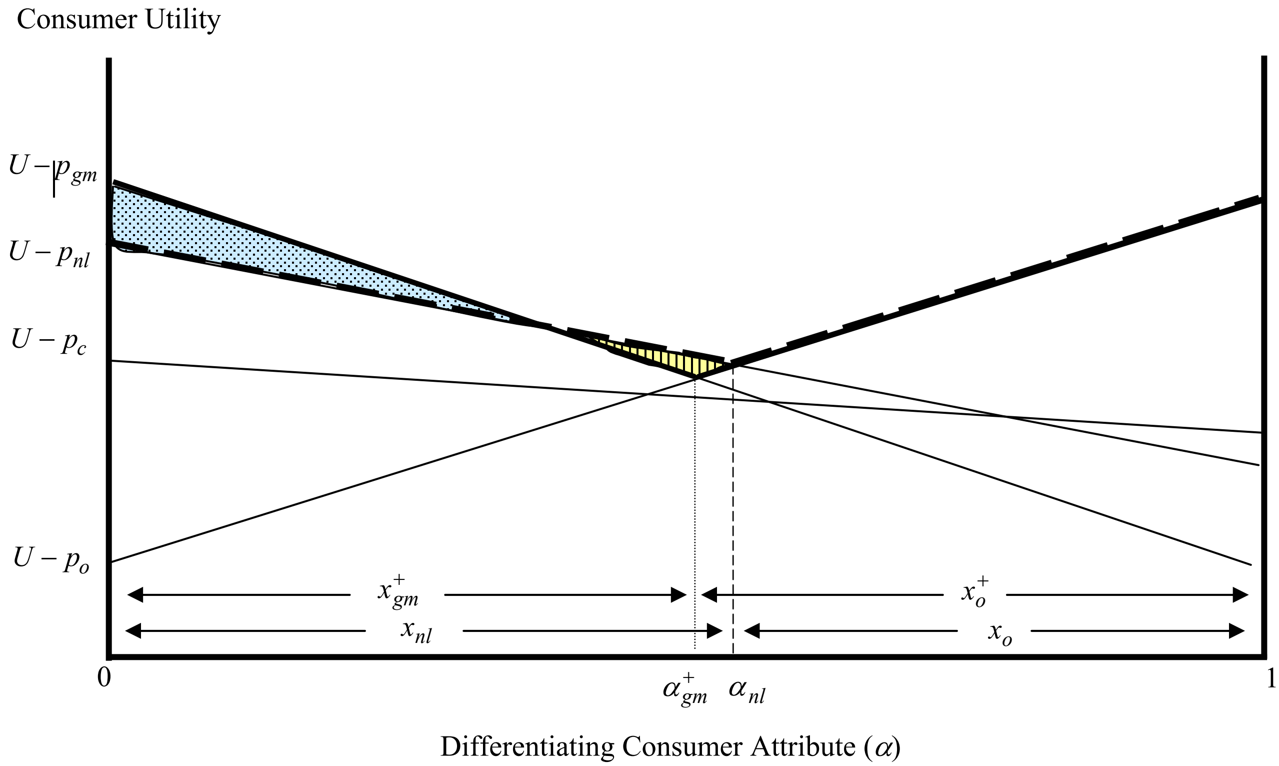

Figure 4. Market and Welfare Effects of GM Labeling (High Segregation Costs).

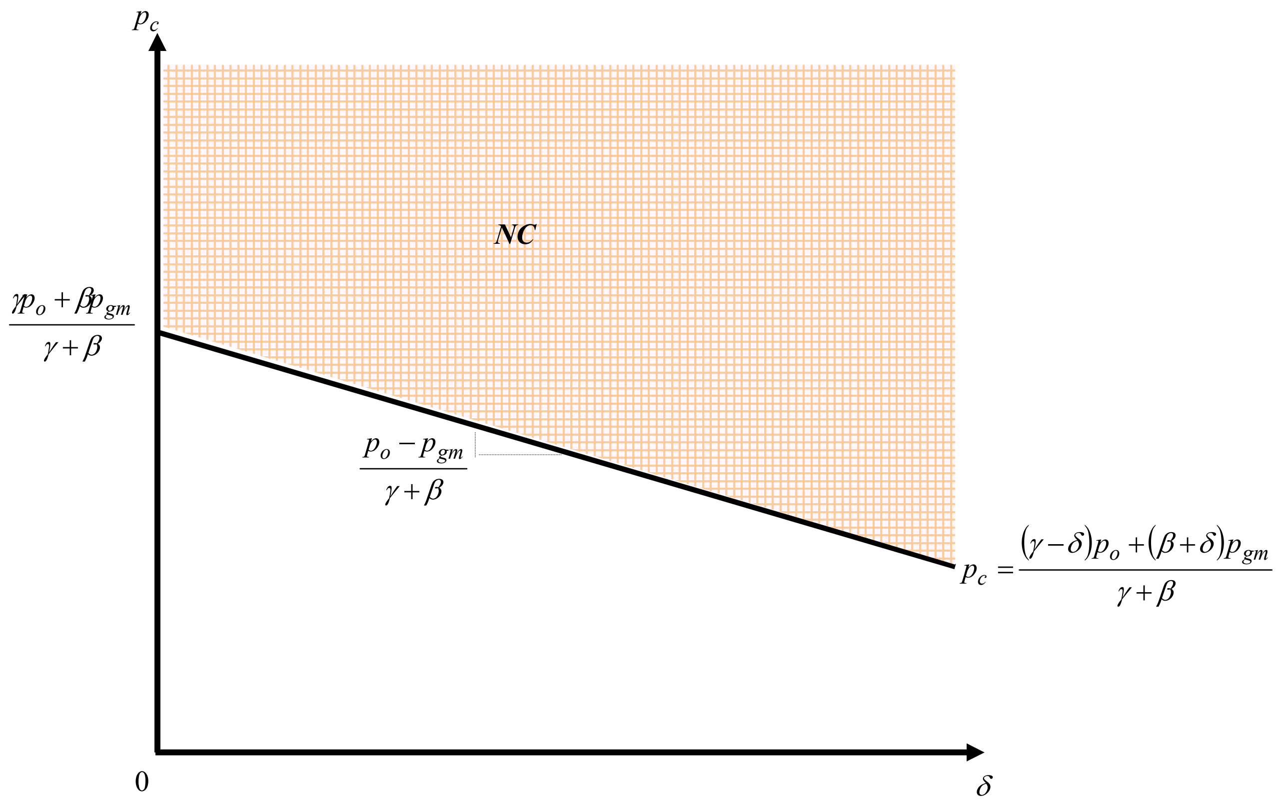

Figure 5. The Effect of GM Labeling on Conventional Products.

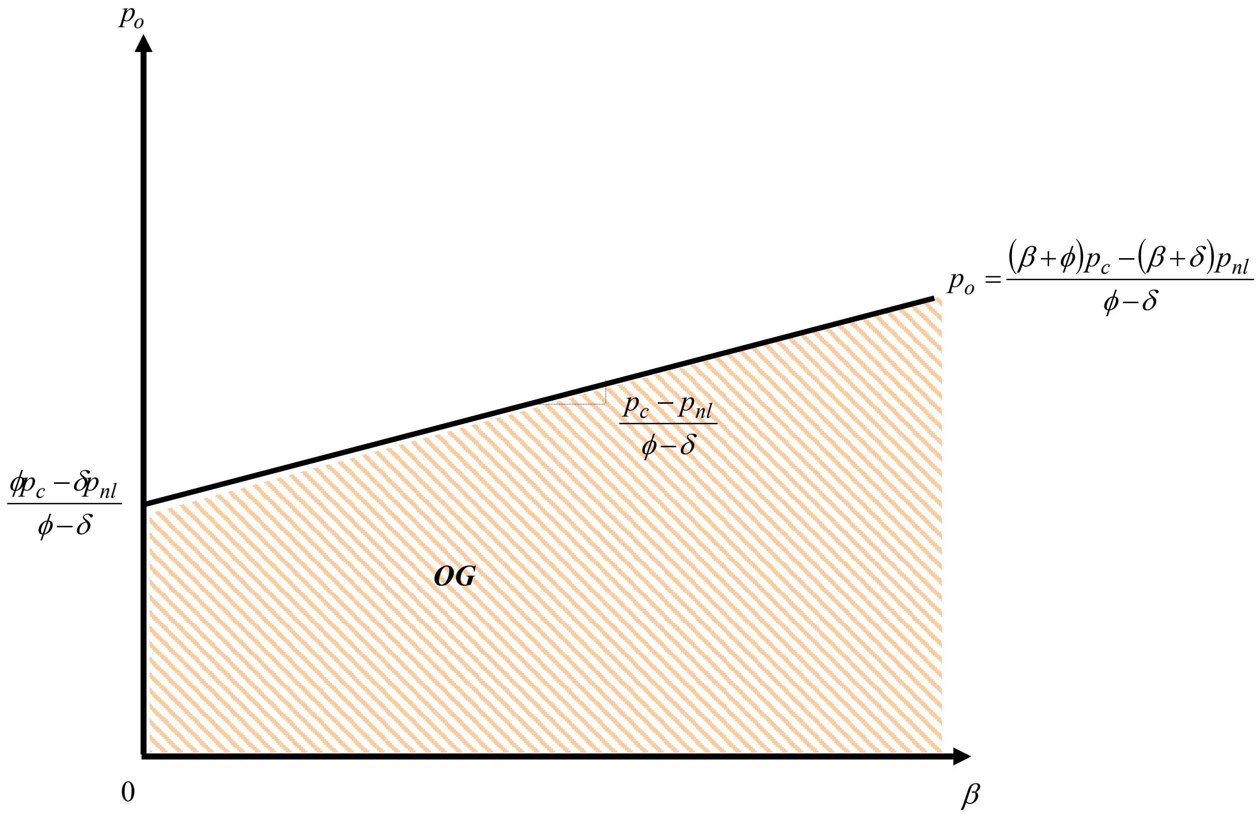

Figure 6. The Effect of GM Labeling on the Demand for Organic Products.

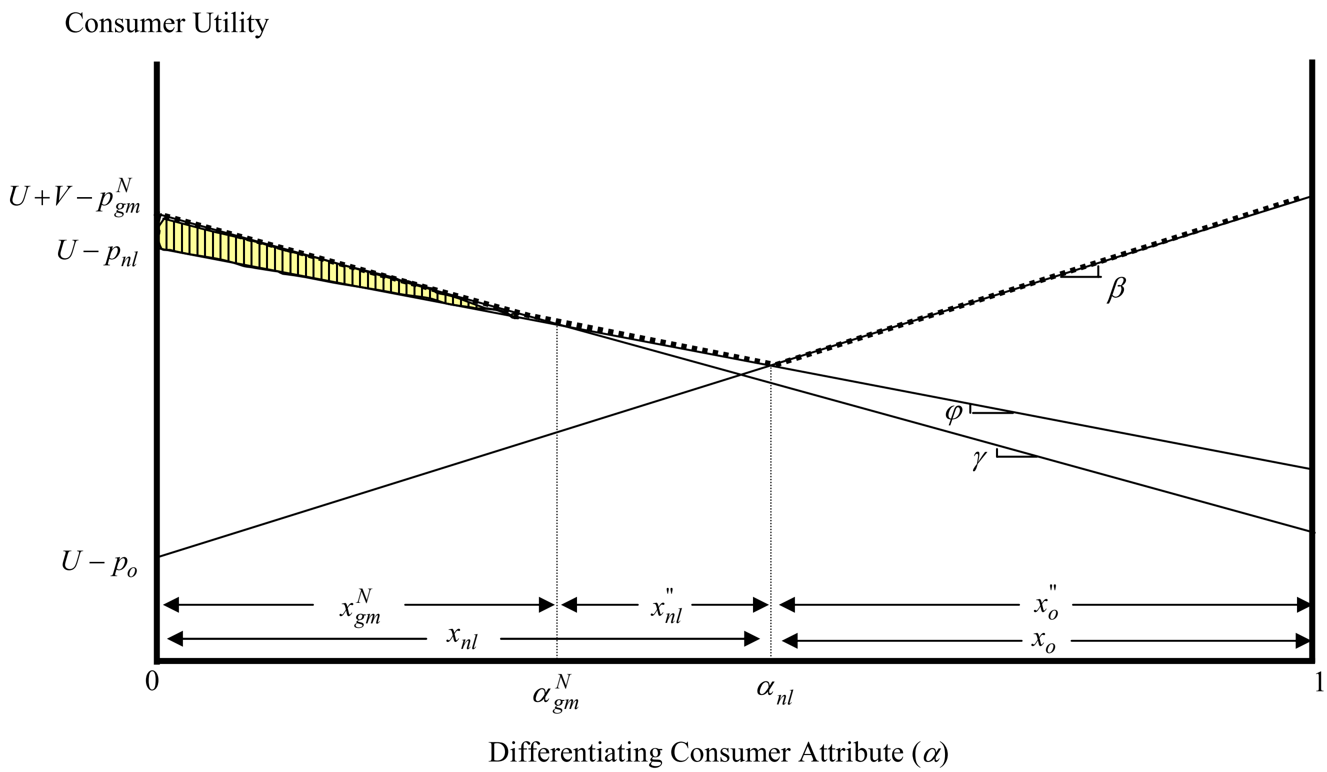

Figure 7. Market and Welfare Effects of the Introduction of New-GMPs when
$$\left(p_{gm}^{N}-p_{nl}\right)<V<\left(p_{gm}^{N}-p_{nl}\right)+\frac{(1-\psi)(\gamma-\delta)(p_{o}-p_{nl})}{\beta+\psi\gamma+(1-\psi)\delta}.$$

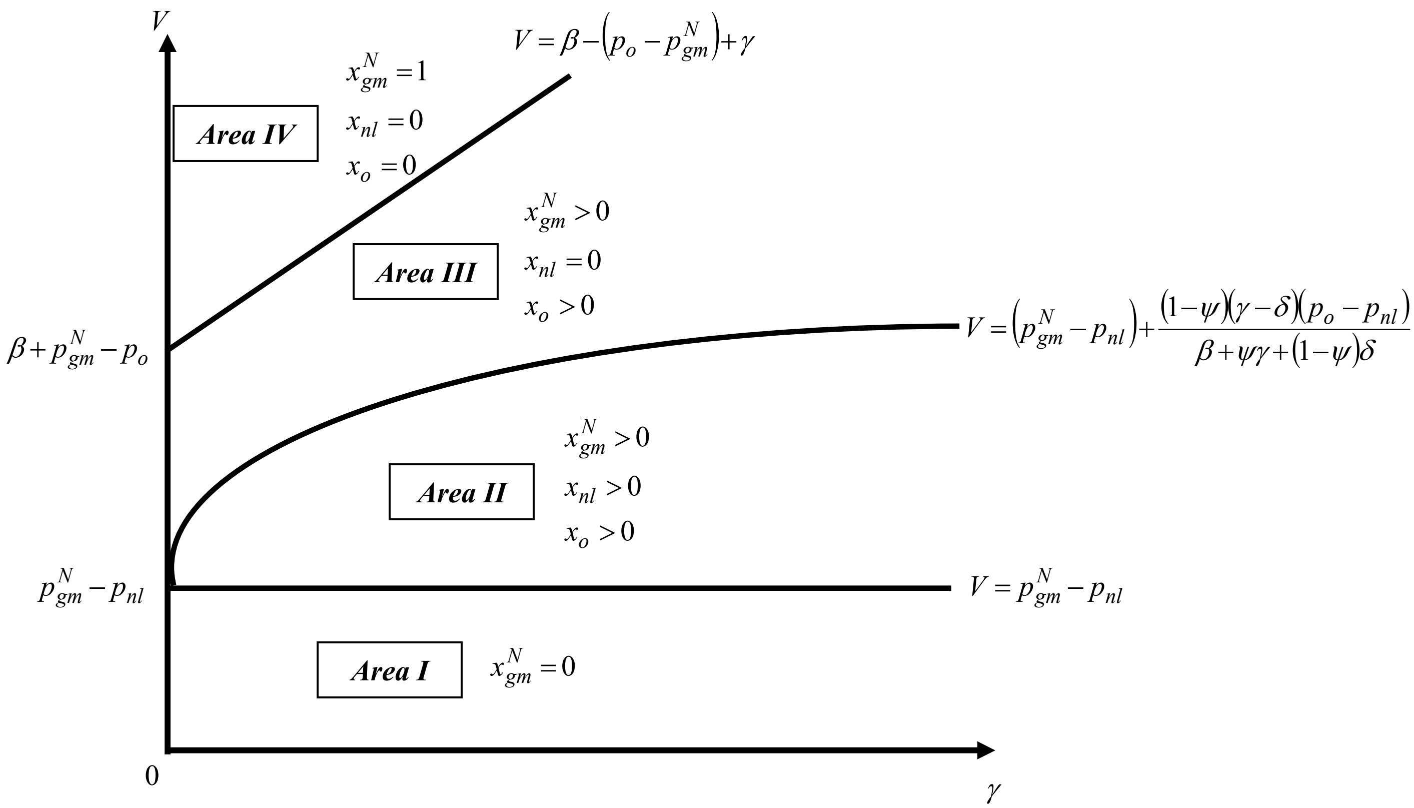

Figure 8. Market Effects of the Introduction of New-GMPs.

Table 1. Market and Consumer Welfare Effects of GMP Labeling

Scenarios	Parameter Values									Market Shares				Changes in Consumer Welfare
	U	P_{gm}	P_c	P_o	P_{nl}	γ	δ	β	φ	x_{gm}	x_c	x_o	x_{nl}	%ΔCW[a]
No Labeling (ψ=0.5) (Benchmark case)	8.01	---	---	8	4.5	4	1	2.5	2.5	---	---	0.3	0.7	
Labeling – Low Segregation Costs	8.01	4	5.2	8	---	4	1	2.5	2.5	0.4	0.4	0.2	---	5.43
Labeling – High Segregation Costs	8.01	4.75	6.25	8	---	4	1	2.5	2.5	0.5	0	0.5	---	-16.6

[a] % Changes in consumer welfare are estimated with respect to the benchmark case of No Labeling (ψ=0.5)

Table 2. Market and Consumer Welfare Effects from of the Introduction of New-GMPs

Scenarios	Parameter Values									Market Shares			Changes in Consumer Welfare
	U	V	P^N_{gm}	P_o	P_{nl}	γ	δ	β	φ	x^N_{gm}	x_o	x_{nl}	%ΔCW[a]
No Labeling (ψ=0.5) (Benchmark case)	8.01	---	---	8	4.5	4	1	2.5	2.5	---	0.3	0.7	
New GMPs: Area I (x^N_{gm}=0, x_{nl}>0, x_o>0)	8.01	0.5	5	8	4.5	4	1	2.5	2.5	0	0.3	0.7	0
New GMPs: Area II (x^N_{gm}>0, x_{nl}>0, x_o>0)	8.01	1	5	8	4.5	4	1	2.5	2.5	0.33	0.3	0.37	3.35
New GMPs: Area III (x^N_{gm}>0, x_{nl}=0, x_o>0)	8.01	1.55	5	8	4.5	4	1	2.5	2.5	0.7	0.3	0	14.8
New GMPs: Area IV (x^N_{gm}>0, x_{nl}=0, x_o=0)	8.01	3.5	5	8	4.5	4	1	2.5	2.5	1	0	0	120.7
New GMPs: Area I (x^N_{gm}=0, x_{nl}>0, x_o>0)	8.01	1	5.5	8	4.5	4	1	2.5	2.5	0	0.3	0.7	0
New GMPs: Area II (x^N_{gm}>0, x_{nl}>0, x_o>0)	8.01	1	5	8	4.5	4	1	2.5	2.5	0.33	0.3	0.37	3.35
New GMPs: Area III (x^N_{gm}>0, x_{nl}=0, x_o>0)	8.01	1	4.45	8	4.5	4	1	2.5	2.5	0.7	0.3	0	14.8
New GMPs: Area IV (x^N_{gm}>0, x_{nl}=0, x_o=0)	8.01	1	2.5	8	4.5	4	1	2.5	2.5	1	0	0	120.7

[a] % Changes in consumer welfare are estimated with respect to the benchmark case of No Labeling (ψ=0.5)