ECONOMIC EFFECTS OF PURITY STANDARDS IN BIOTECH LABELING LAWS

KONSTANTINOS GIANNAKAS AND NICHOLAS KALAITZANDONAKES

Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Rhode Island, July 24-27, 2005

Konstantinos Giannakas is associate professor, Department of Agricultural Economics, University of Nebraska-Lincoln. Nicholas Kalaitzandonakes is professor, Department of Agricultural Economics, University of Missouri-Columbia. Corresponding author: Konstantinos Giannakas, Department of Agricultural Economics, University of Nebraska-Lincoln, 216 H.C. Filley Hall, Lincoln NE, 68516. Phone: (402) 472-2041; E-mail: kgiannakas@unl.edu.

ECONOMIC EFFECTS OF PURITY STANDARDS IN BIOTECH LABELING LAWS

Abstract - This paper develops a model of heterogeneous consumer preferences to analyze the market and welfare effects of reduced purity standards for non-GM labeled food. Analytical results show that purity standards affect the equilibrium prices and quantities of both the GM and non-GM products as well as the welfare of the groups involved. A change in purity standards is shown to create winners and losers among the consumers as well as among the suppliers of the GM and conventional products.

Key words: agricultural biotechnology, genetically modified products, labeling, purity standards.

Discussions of appropriate regulatory norms for foods derived through modern biotechnology date back to the early 1980s. Twenty years later, agreement among key trading countries on what such norms should be, remains elusive. Some countries, including the US and Canada, consider biotech or genetically modified (GM) foods substantially equivalent to conventional ones and regulate them similarly. Others, including the European Union (EU), Japan and Australia scrutinize and require mandatory labeling of GM foods. Mandatory labeling of GM foods has added costs to the production and trade of agricultural and food products and has restricted market access.

Not all mandatory labeling laws for biotech foods are "made equal," however, as they differ substantially in their standards. The EU requires mandatory labeling of all food ingredients, additives and flavorings in processed foods, animal feeds and feed additives as well as highly processed foods such as refined oils, sugars, and starches that contain more than 0.9% biotech material. Japan and South Korea have more liberal laws mandating labeling for food products that contain over 5% and 2% of GM food ingredients, respectively. Unlike the EU, mandatory labeling rules in Korea and Japan have affected only a small part of the market as they explicitly exclude animal feeds, highly processed foods and oils from labeling requirements.

Setting such labeling standards has never been a straightforward process either. Consider the EU, for instance. After seeing its food and feed biotech labeling and traceability law take effect in April of 2004, European regulators have sought to put the last piece of their regulatory framework in place by establishing labeling standards for biotech planting seeds. Yet, the choice of standards has remained contentious. The principal point of discord is the purity thresholds of biotech material in conventional seeds. Some interest groups have been calling for lower thresholds arguing that they should be set at the level of detectability allowed by testing technology, typically 0.1%. Other groups have been advocating higher thresholds that would presumably minimize disruptions in the agri-food supply chain, typically 0.5%. The EU Commission has been attempting to find the "middle ground" – discussing purity standards between 0.3% and 0.5% – with little success.

At first glance, the differences in these purity standards seem minute and yet they have caused strong disagreements, even inside the EU Commission. This is in part, because little is known about the relative economic implications of such alternative regulatory standards. What is known, however, is that a choice of standards that result in excessive compliance costs could imply significant welfare losses that could compromise the relevance of the labeling regulation altogether.

The objective of this study is to address the issue of GM labeling standards by analyzing the market and welfare effects of reduced purity standards for non-GM food products. In analyzing the economic effects of purity standards in biotech labeling laws, this paper follows Giannakas and Fulton (2002) and explicitly accounts for heterogeneous consumer preferences towards GM and conventional products expressed in numerous stated consumer preference studies around the world. Consumer heterogeneity is a key component of our model and it is critical in understanding the coexistence of GM and conventional food when labeling occurs.

The rest of the paper is organized as follows. The next section analyzes consumer purchasing decisions and welfare, and identifies the determinants of the equilibrium prices and quantities when no GM material is allowable in conventional, non-GM food. The section following examines the effects of reduced purity standards for non-GM food on equilibrium quantities and prices. The effects of increasing the allowable GM content of non-GM labeled food on supplier profits and consumer welfare are analyzed before the final section summarizes and concludes the paper.

Benchmark Case: Conventional Products are Free of GM Ingredients

Consumer Characteristics and Behavior

To capture the varying consumer aversion to GM products reflected in numerous stated consumer preference studies in Europe and elsewhere, GM and conventional (non-GM) products are treated in this paper as vertically differentiated goods. Specifically, the two products are uniformly quality ranked by consumers (i.e., if offered at the same price all consumers would prefer the non-GM product), but consumers differ in their valuation of the perceived quality differences (and, thus, they differ in their willingness to pay for such quality differences). The GM and conventional products considered in this study share the same observable physical characteristics (e.g., appearance, taste etc.) while differing in the presence (or absence) of credence GM ingredients.

Assuming that a consumer spends a small fraction of total expenditure on the goods in question, her utility function can be written as:

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

$$U_{ngm} = U - p_{ngm} - \mu\alpha \quad \text{if a unit of non-GM product is consumed} \qquad (1)$$

where U_{gm} is the utility associated with purchasing one unit of the GM product, and U_{ngm} is the utility associated with purchasing one unit of the non-GM version of the product. The price of the GM product is p_{gm}, and the price of its non-GM counterpart is p_{ngm}. The parameter U is a per unit base level of utility while the parameters λ and μ are utility discount factors associated with the consumption of the GM and the non-GM products, respectively. The characteristic α differs according to consumer and captures heterogeneous consumer preferences for the two products.

For simplicity of exposition, the characteristic α takes values between zero and one and consumers are assumed to be uniformly distributed between the polar values of α.[1] In this

[1] The implications of relaxing this assumption to allow a concentration of consumers at the ends of the spectrum (i.e., zero and one) are straightforward and are discussed throughout the text.

context, the terms $\lambda\alpha$ and $\mu\alpha$ give the discount in utility from consuming the GM product and the non-GM product, respectively.[2] To capture the expressed consumer aversion to GM products, λ is assumed greater than μ with the difference $(\lambda-\mu)\alpha$ reflecting the divergence in consumer valuation of the perceived quality differences between the two products. Put in a different way, the difference $(\lambda-\mu)\alpha$ captures the level of aversion to GM products of the consumer with differentiating attribute α. Finally, to allow for positive market shares of the two vertically differentiated products, we assume that the GM product is priced below its conventional counterpart, i.e., $p_{gm} \leq p_{ngm}$ (see below).

The consumption choice of an individual consumer is determined by the relationship between the utilities derived from the GM and the non-GM products. More specifically, the consumer with differentiating attribute given by:

$$\alpha_{gm} : U - p_{gm} - \lambda\alpha_{gm} = U - p_{ngm} - \mu\alpha_{gm} \Rightarrow \alpha_{gm} = \frac{p_{ngm} - p_{gm}}{\lambda - \mu} \qquad (2)$$

is indifferent between consuming a unit of GM and non-GM product – the utility associated with the consumption of these products is the same. Consumers with relatively low aversion to genetic modification (i.e., consumers with $\alpha \in [0, \alpha_{gm})$) prefer the GM product, while consumers with high aversion to GM products (i.e., consumers with $\alpha \in (\alpha_{gm}, 1]$) consume the non-GM product.

When consumers are uniformly distributed between the polar values of α, α_{gm} also determines the share of the GM product in total consumption, x_{gm}. The consumption share of the non-GM product, x_{ngm}, is given by $1-\alpha_{gm}$. Normalizing the mass of consumers at unity, x_{gm} and

[2] In this setting, U-$\lambda\alpha$ and U-$\mu\alpha$ represent the consumer willingness-to-pay (*wtp*) for a unit of the GM and the conventional product, respectively. Subtracting the relevant equilibrium prices from these *wtp* values provides an estimate of the consumer surplus associated with the consumption of these products.

x_{ngm} give the consumer demands for the GM and the non-GM products, respectively. In what follows, the terms "consumption share" and "demand" will be used interchangeably to denote x_{gm} and/or x_{ngm}. Mathematically, x_{gm} and x_{ngm} can be written as:

$$x_{gm} = \frac{p_{ngm} - p_{gm}}{\lambda - \mu} \quad (3)$$

$$x_{ngm} = \frac{\lambda - \mu - p_{ngm} + p_{gm}}{\lambda - \mu} \quad (4)$$

From equations (3) and (4) follows that the demand for the GM (non-GM) product falls with an increase in its price and/or an increase (decrease) in consumer aversion to GM products, and rises as the price of the non-GM (GM) product increases. Obviously, if p_{gm} were greater than p_{ngm}, the GM product would be driven out of the market (i.e., $x_{gm} = 0$ and $x_{ngm} = 1$), while if the price premium of the non-GM product, p_{ngm} - p_{gm}, exceeded the level of aversion to GM products, λ-μ, for all consumers ($\forall\alpha$), then the GM product would dominate the market (i.e., $x_{gm} = 1$ and $x_{ngm} = 0$).

Figure 1 graphs the U_{gm} and U_{ngm} utility curves and depicts the consumption decisions under a labeling regime when the non-GM product is free of GM ingredients and both products enjoy positive shares of the market.[3] Aggregate consumer welfare is given by the area underneath the effective utility curve shown by the kinked dashed line in Figure 1 and equals

$$CW = \int_0^{\alpha_{gm}} U_{gm} d\alpha + \int_{\alpha_{gm}}^1 U_{ngm} d\alpha .$$

[3] When the assumption of a uniform consumer distribution is relaxed, the consumption shares of the two products depend on the skewness of the (continuous) distribution – i.e., the more skewed the distribution of consumers towards 1, the greater the consumption share of (consumer demand for) the non-GM product.

Equilibrium Prices and Quantities

Given the potential effect of the purity requirements on the segregation and identity preservation costs along a supply channel, we are interested in expressing the equilibrium conditions in the markets of the GM and conventional products in terms of the relevant costs of production. Figure 2 graphs the inverse demand curves for the GM and the non-GM products (shown as D_{gm} and D_{ngm}, respectively) and depicts the equilibrium conditions in the two markets in the familiar supply and demand framework of analysis. The inverse demand curves for the two products are derived from equations (3) and (4) and are given by:

$$p_{gm} = p_{ngm} - (\lambda - \mu)x_{gm} \tag{5}$$

$$p_{ngm} = \lambda - \mu + p_{gm} - (\lambda - \mu)x_{ngm} \tag{6}$$

In the case of constant marginal retail costs depicted in Figure 2, the equilibrium prices and quantities can be expressed as:

$$p_{gm} = \frac{\theta\lfloor\theta(\lambda - \mu) + c_{ngm}\rfloor + (1+\theta)c_{gm}}{1+2\theta} \tag{7}$$

$$p_{ngm} = \frac{(1+\theta)\lfloor\theta(\lambda - \mu) + c_{ngm}\rfloor + \theta c_{gm}}{1+2\theta} \tag{8}$$

$$x_{gm} = \frac{\theta(\lambda - \mu) + (c_{ngm} - c_{gm})}{(1+2\theta)(\lambda - \mu)} \tag{9}$$

$$x_{ngm} = \frac{(1+\theta)(\lambda - \mu) - (c_{ngm} - c_{gm})}{(1+2\theta)(\lambda - \mu)} \tag{10}$$

where θ is the conjectural variations elasticity capturing the degree of market power in the retail market for the two products,[4] and c_{gm} and c_{ngm} are the marginal costs faced by the retailers of the

[4] The parameter θ takes values between zero and one and captures the degree of retailers' market power – the greater is θ, the greater is the market power in the retail markets for the GM and non-GM products. A value of θ equal 1 corresponds to a monopoly while a value of θ equal to 0 reflects a perfectly competitive retail market structure.

GM and the non-GM products, respectively.[5]

Equations (7)-(10) indicate that the equilibrium prices and quantities depend on the level of consumer aversion to GM products, λ-μ, the retail costs c_{gm} and c_{ngm}, and the degree of market power in retailing, θ. The greater is λ-μ, and/or the greater are the c_{gm} and c_{ngm}, and/or the greater is θ, the greater are the consumer prices of the two products (i.e., $\frac{\partial p_{gm}}{\partial \lambda} > 0$, $\frac{\partial p_{gm}}{\partial \mu} < 0$, $\frac{\partial p_{gm}}{\partial c_{gm}} > 0$, $\frac{\partial p_{gm}}{\partial c_{ngm}} > 0$, $\frac{\partial p_{gm}}{\partial \theta} > 0$ and $\frac{\partial p_{ngm}}{\partial \lambda} > 0$, $\frac{\partial p_{ngm}}{\partial \mu} < 0$, $\frac{\partial p_{ngm}}{\partial c_{gm}} > 0$, $\frac{\partial p_{ngm}}{\partial c_{ngm}} > 0$, $\frac{\partial p_{ngm}}{\partial \theta} > 0$). Similarly, the greater is the consumer aversion to GM products, λ-μ, and/or the smaller is the cost difference between the two products, $c_{ngm} - c_{gm}$, the smaller is the market share of the GM product, and the greater is the market share of its conventional counterpart (i.e., $\frac{\partial x_{gm}}{\partial \lambda} < 0$, $\frac{\partial x_{gm}}{\partial \mu} > 0$, $\frac{\partial x_{gm}}{\partial c_{gm}} < 0$, $\frac{\partial x_{gm}}{\partial c_{ngm}} > 0$ and $\frac{\partial x_{ngm}}{\partial \lambda} > 0$, $\frac{\partial x_{ngm}}{\partial \mu} < 0$, $\frac{\partial x_{ngm}}{\partial c_{gm}} > 0$, $\frac{\partial x_{ngm}}{\partial c_{ngm}} < 0$).

Regarding the effect of market power on x_{gm} and x_{ngm}, it depends on the level of consumer aversion to GM products, λ-μ, relative to the cost difference $c_{ngm} - c_{gm}$. In particular, when λ-μ is greater (less) than double the cost differential $c_{ngm} - c_{gm}$, an increase in market power will increase the prices of both the GM and the non-GM product but it will increase the price of the non-GM product by more (less). The greater (smaller) increase in p_{ngm} results then in reduced (increased) demand for the non-GM product and increased (reduced) demand for its GM counterpart, i.e., $\lambda - \mu \geq (<) 2\left[c_{ngm} - c_{gm}\right] \Rightarrow \frac{\partial p_{gm}}{\partial \theta} \leq (>) \frac{\partial p_{ngm}}{\partial \theta} \Rightarrow \frac{\partial x_{gm}}{\partial \theta} \geq (<) 0$ and $\frac{\partial x_{ngm}}{\partial \theta} \leq (>) 0$.

---

[5] The retail costs of the two products reflect (i) the production, processing, and marketing costs along the two supply channels, (ii) the costs associated with the segregation and labeling of the two products (with the majority of these costs being incurred in the high quality, non-GM supply chain), and (iii) the market power at previous stages of the supply chain (i.e., the market power of agricultural input suppliers, food manufacturers, wholesalers etc.). The greater are the production, processing and/or marketing costs, and/or the greater are the labeling and segregation costs, and/or the greater is the market power upstream a supply channel, the greater are the retail costs of a product.

Market Effects of Reduced Purity Standards for Non-GM Food

Consider now the case where the non-GM labeled food is allowed to contain a certain amount of GM ingredients. This reduction in the purity standards for non-GM food affects the costs incurred in the non-GM supply channel as well as the utility associated with the consumption of the non-GM product. In particular, a reduction in the purity standards reduces the cost of segregating and identity preserving the non-GM product and thus, it reduces c_{ngm}. In addition, a reduction in purity standards increases the utility discount factor associated with the consumption of the non-GM good, μ, as the latter (i.e., the non-GM product) is now allowed to contain a certain percentage of GM ingredients.

The **cost effect** of a reduction in purity standards is given by:

$$\tau = c_{ngm} - c_{ngm}^{'} \tag{11}$$

where $c_{ngm}^{'}$ is the retail cost of the non-GM product *ex post* (i.e., after the reduction in the purity standards). The greater is the proportion of GM material allowed in the conventional product (i.e., the lower are the purity standards), the lower are the costs associated with the segregation and identity preservation of this product, the lower is $c_{ngm}^{'}$, and the greater is τ.

The **utility effect** of a reduction in purity standards is given by:

$$\sigma = \mu' - \mu \tag{12}$$

where μ' is the utility discount factor associated with the consumption of the non-GM product under reduced purity standards. The greater is the GM content of the conventional product, the greater is μ', and the greater is σ.

The equilibrium conditions under reduced purity standards can be derived by substituting $c_{ngm}^{'}$ and μ' for c_{ngm} and μ, respectively, in equations (7)-(10) and can be written as:

$$p'_{gm} = \frac{\theta\left[\theta(\lambda - \mu') + c'_{ngm}\right] + (1+\theta)c_{gm}}{1+2\theta} \tag{13}$$

$$p'_{ngm} = \frac{(1+\theta)\left[\theta(\lambda - \mu') + c'_{ngm}\right] + \theta c_{gm}}{1+2\theta} \tag{14}$$

$$x'_{gm} = \frac{\theta(\lambda - \mu') + \left(c'_{ngm} - c_{gm}\right)}{(1+2\theta)(\lambda - \mu')} \tag{15}$$

$$x'_{ngm} = \frac{(1+\theta)(\lambda - \mu') - \left(c'_{ngm} - c_{gm}\right)}{(1+2\theta)(\lambda - \mu')} \tag{16}$$

The Effect of Reduced Purity Standards on Equilibrium Prices and Quantities

Comparing equations (7) and (8) with equations (13) and (14) shows that the cost and utility effects of reduced purity standards cause the prices of both the GM and the non-GM products to fall.[6] Because of its asymmetric effect on the cost of the two products (i.e., the reduction in purity standards reduces c_{ngm} while leaving c_{gm} unaffected), while the reduction in the purity standards reduces both p_{ngm} and p_{gm}, it reduces p_{ngm} by relatively more, i.e.,

$$p_{ngm} - p'_{ngm} = \frac{(1+\theta)(\theta\sigma + \tau)}{1+2\theta} > \frac{\theta(\theta\sigma + \tau)}{1+2\theta} = p_{gm} - p'_{gm} \tag{17}$$

Similarly, comparing the equilibrium market shares before and after the reduction in the purity standards for the non-GM product shows that the effect of reduced purity standards on the equilibrium quantities of the GM and non-GM products depends on the relative magnitude of the cost and utility effects (τ and σ, respectively), the relative retail costs of the two products prior to the reduction in purity standards (determined by the degree of market power upstream the two supply channels and the relative costs of production, processing, marketing, segregation and

---

[6] Strictly speaking, the reduction in the purity standards reduces p_{gm} when θ is greater than zero. When θ equals zero, p_{gm} is not affected by the purity of the non-GM product.

labeling of GM and conventional products), and the level of consumer aversion to GM products, λ-μ. In general, the greater is τ and/or the smaller is σ and/or the smaller is $c_{ngm} - c_{gm}$ and/or the greater is λ-μ, the greater is the likelihood that a reduction in purity standards will increase the market share of the non-GM product and will reduce the market share of its GM counterpart. In particular, comparing equations (9) and (10) with equations (15) and (16) shows that when the ratio $\frac{\tau}{\sigma}$ is greater (less) than the ratio of the cost differential $c_{ngm} - c_{gm}$ over the consumer aversion to GM products, λ-μ, the reduction in purity standards increases (decreases) the consumption share of the non-GM product and reduces (increases) the consumption share of its GM counterpart, i.e.,

$$\frac{\tau}{\sigma} \geq (<) \frac{c_{ngm} - c_{gm}}{\lambda - \mu} \Leftrightarrow x_{ngm}^{'} \geq (<) x_{ngm} \text{ and } x_{gm}^{'} \leq (>) x_{gm} \quad (18)$$

Graphically, the reduction in the purity standards for the non-GM product causes a downward shift of the marginal cost curve in the non-GM market (cost effect) and a reduction in the absolute value of the slopes of the demand curves in both the GM and the non-GM product markets (utility effect). Figures 3, 4 and 5 show the equilibrium quantities and prices in the two markets under the three scenarios depicted in equation (18). The solid and dashed lines show the demand and supply relationships before and after the reduction in the purity standards, respectively. The dotted and hatched areas in these Figures depict the relevant gains and losses by retailers, respectively, as the purity standards for the non-GM product fall.

The market effects of reduced purity standards can also be shown in the consumer utility space depicted in Figure 1. In this setting, the reduced price of the GM product causes an upward shift of the U_{gm} utility curve, while the reduced price of the non-GM product and the increased μ increase the intercept and the (absolute value of the) slope of the U_{ngm} utility curve causing the rightward rotation depicted in Figure 6. Figure 6 illustrates the case in which $\frac{\tau}{\sigma} < \frac{c_{ngm} - c_{gm}}{\lambda - \mu}$ and reduced purity standards increase the consumption share of the GM product. Figures 7 and 8 illustrate the other two scenarios depicted in equation (18).

Our results on the market effects of reduced purity standards are summarized below.

RESULT 1: *A reduction in the purity standards for non-GM labeled food reduces the prices of both the conventional (non-GM) and the GM products.*

RESULT 2: *The effect of a reduction in the purity standards for non-GM labeled food on the equilibrium quantities of the GM and conventional products depends on the relative magnitude of the cost and utility effects of reduced purity standards, the level of consumer aversion to GM products, and the retail costs of the two products. The smaller (greater) the cost reduction in the non-GM supply channel and/or the greater (smaller) the reduction in the utility associated with the consumption of the non-GM product and/or the smaller (greater) the consumer aversion to GM products and/or the greater (smaller) the difference between the costs faced by the retailers of the two products prior to the reduction in purity standards, the greater is the likelihood that a reduction in purity standards will reduce (increase) the demand for conventional product and will increase (reduce) the demand for its GM counterpart.*

Welfare Effects of Reduced Purity Standards for Non-GM Food

The Effect of Reduced Purity Standards on Supplier Profits

As mentioned previously, the gains and losses of suppliers of GM and conventional products due to reduced purity standards are depicted by the dotted and hatched areas in Figures 3-5. Mathematically, the profits of GM and conventional product suppliers prior to the reduction in purity standards are given by:

$$\pi_{gm} = \left(p_{gm} - c_{gm}\right)x_{gm} = \frac{\theta\left[\theta(\lambda - \mu) + \left(c_{ngm} - c_{gm}\right)\right]^2}{(1 + 2\theta)^2 (\lambda - \mu)} \tag{19}$$

$$\pi_{ngm} = \left(p_{ngm} - c_{ngm}\right)x_{ngm} = \frac{\theta\left[(1+\theta)(\lambda-\mu) - \left(c_{ngm} - c_{gm}\right)\right]^2}{(1+2\theta)^2(\lambda-\mu)} \tag{20}$$

while the profits of these same suppliers after the reduction in purity standards are:

$$\pi'_{gm} = \frac{\theta\left[\theta\left(\lambda-\mu'\right) + \left(c'_{ngm} - c_{gm}\right)\right]^2}{(1+2\theta)^2\left(\lambda-\mu'\right)} = \frac{\theta\left[\theta(\lambda-\mu) + \left(c_{ngm} - c_{gm}\right) - (\theta\sigma+\tau)\right]^2}{(1+2\theta)^2(\lambda-\mu-\sigma)} \tag{21}$$

$$\pi'_{ngm} = \frac{\theta\left[(1+\theta)\left(\lambda-\mu'\right) - \left(c'_{ngm} - c_{gm}\right)\right]^2}{(1+2\theta)^2\left(\lambda-\mu'\right)} = \frac{\theta\left\{(1+\theta)(\lambda-\mu) - \left(c_{ngm} - c_{gm}\right) - \left[(1+\theta)\sigma - \tau\right]\right\}^2}{(1+2\theta)^2(\lambda-\mu-\sigma)} \tag{22}$$

Comparing the profits of the product suppliers before and after the reduction in purity standards shows that the effect of such reduction on supplier profits depends on the relative magnitude of the cost and utility effects, the level of consumer aversion to GM products, the market power present in the retail markets of the two products, and the initial cost difference c_{ngm} - c_{gm} (i.e., the cost difference prior to the reduction in purity standards).

In particular, comparing equations (19) and (21) shows that when the $\frac{\tau}{\sigma}$ ratio is greater (smaller) than a critical value $\left(\frac{\tau}{\sigma}\right)^+ = \frac{\left[\theta(\lambda-\mu) + \left(c_{ngm} - c_{gm}\right)\right]\left[(\lambda-\mu) + \sqrt{(\lambda-\mu)(\lambda-\mu-\sigma)}\right]}{(\lambda-\mu)\sigma} - \theta$, the profits of GM product suppliers fall (increase) with a reduction in purity standards, i.e.,

$$\frac{\tau}{\sigma} \geq (<) \left(\frac{\tau}{\sigma}\right)^+ \Leftrightarrow \pi'_{gm} \leq (>) \pi_{gm} \tag{23}$$

The reasoning is as follows. The greater are the cost savings in the non-GM supply chain and/or the smaller is the utility effect from reduced purity standards and/or the greater is the consumer aversion to GM products and/or the smaller is the initial cost difference c_{ngm} - c_{gm}, the lower is the demand for the GM product under reduced purity standards. The lower is the demand for the

GM product and/or the lower is the market power in the retail market of this product, the lower the profits that can be earned by this product's suppliers.

Similarly, a comparison of equations (20) and (22) reveals that the smaller are the cost savings in the non-GM supply chain and/or the greater is the utility effect from reduced purity standards and/or the smaller is the consumer aversion to GM products and/or the greater is the initial cost difference $c_{ngm} - c_{gm}$, and/or the lower is the market power in the retail market of the non-GM product, the greater is the likelihood that a reduction in purity standards will result in losses for the non-GM product suppliers. In particular, when the $\frac{\tau}{\sigma}$ ratio is smaller (greater) than a critical value given by $\left(\frac{\tau}{\sigma}\right)^{++} = (1+\theta) - \frac{\left[(1+\theta)(\lambda-\mu) - (c_{ngm} - c_{gm})\right]\left[(\lambda-\mu) + \sqrt{(\lambda-\mu)(\lambda-\mu-\sigma)}\right]}{(\lambda-\mu)\sigma}$, the profits of non-GM product suppliers fall (increase) with a reduction in purity standards, i.e.,

$$\frac{\tau}{\sigma} \leq (>) \left(\frac{\tau}{\sigma}\right)^{++} \Leftrightarrow \pi'_{ngm} \leq (>) \pi_{ngm} \qquad (24)$$

Overall, when the $\frac{\tau}{\sigma}$ ratio is relatively small (i.e., when $\frac{\tau}{\sigma}$ is less than $\left(\frac{\tau}{\sigma}\right)^{+}$), suppliers of the GM product gain while suppliers of the non-GM product lose from a reduction in the purity standards for non-GM food. For intermediate values of the $\frac{\tau}{\sigma}$ ratio (i.e., for values of $\frac{\tau}{\sigma}$ between $\left(\frac{\tau}{\sigma}\right)^{+}$ and $\left(\frac{\tau}{\sigma}\right)^{++}$), both GM and non-GM product suppliers lose from a reduction in purity standards. Finally, when the $\frac{\tau}{\sigma}$ ratio is relatively large (i.e., when $\frac{\tau}{\sigma}$ is greater than $\left(\frac{\tau}{\sigma}\right)^{++}$), suppliers of the non-GM product gain while those of the GM product lose from a reduction in the purity standards for non-GM food.

RESULT 3: *The effect of reduced purity standards for non-GM food on the suppliers of the non-GM and GM products depends on the relative magnitude of the cost and utility effects, the market power of the product suppliers, the level of consumer aversion to GM products, and the initial difference in the retail costs of the two products. The smaller (greater) the cost savings in the non-GM supply channel and/or the greater (smaller) the reduction in consumer valuation of the non-GM product and/or the smaller (greater) the consumer aversion to GM products and/or the greater (smaller) the initial cost difference* $c_{ngm} - c_{gm}$*, and/or the lower the market power in the retail markets of the two products, the greater the likelihood that reduced purity standards will result in losses for suppliers of the non-GM (GM) product*.

The Effect of Reduced Purity Standards on Consumer Welfare

In addition to illustrating the market effects of reduced purity standards in the consumer utility space, Figures 6-8 can also be used to determine the effects of reduced purity standards for the welfare of consumers. The areas marked as ***G*** and ***L*** represent the consumer welfare gains and losses, respectively, that result from a reduction in the purity standards for the non-GM product under the different scenarios depicted in equation (18).[7] The mathematical expressions for the relevant consumer welfare gains and losses are also presented in these figures.

The analysis shows that some consumers always gain while others may lose from a reduction in the purity standards for the non-GM product. Specifically, consumers with relatively low aversion to GM products that find it optimal to consume the GM product both before and after a reduction in purity standards gain due to the reduction in p_{gm} that results from reduced purity standards. Thus, reduced purity standards in the non-GM supply chain create a positive externality for consumers of the GM product by reducing p_{gm}.

[7] When the assumption of a uniform consumer distribution is relaxed, the welfare effects of reduced purity standards depend on the skewness of the distribution. For the case where $\frac{\tau}{\sigma} < \frac{c_{ngm} - c_{gm}}{\lambda - \mu}$, for instance, the more skewed the distribution of consumers towards 1, the greater the total consumer welfare losses from reduced purity standards.

The effect of reduced purity standards on consumers of the non-GM product depends on the level of their aversion to GM products. In particular, consumers with intermediate level of aversion to GM products gain because the effect of reduced p_{ngm} outweighs the effect from the increase in the utility discount factor μ, while consumers with high aversion to GM products may lose because the utility effect dominates the price effect of reduced purity standards. The greater a consumer's aversion to GM products (i.e., the greater is α), the greater the utility discount from a reduction in purity standards, and the greater the likelihood that this consumer will realize a welfare loss from a reduction in purity standards for non-GM labeled food.

Formally, consumers with differentiating attribute $\alpha \in [0, \alpha_w)$ in Figures 6-8 gain from reduced purity standards while consumers with $\alpha \in (\alpha_w, 1]$ realize a welfare loss where:

$$\alpha_w = max\left\{\frac{(1+\theta)(\theta\sigma+\tau)}{(1+2\theta)\sigma}, \frac{\theta(\theta\sigma+\tau)+\theta(\lambda-\mu)+(c_{ngm}-c_{gm})}{(1+2\theta)(\lambda-\mu)}\right\} \tag{25}$$

with $\frac{(1+\theta)(\theta\sigma+\tau)}{(1+2\theta)\sigma} \geq (<) \frac{\theta(\theta\sigma+\tau)+\theta(\lambda-\mu)+(c_{ngm}-c_{gm})}{(1+2\theta)(\lambda-\mu)} \Leftrightarrow \frac{\tau}{\sigma} \geq (<) \frac{(c_{ngm}-c_{gm})-\theta^2(\lambda-\mu')}{(\lambda-\mu)+\theta(\lambda-\mu')}$.

Note that the greater are the cost savings in the non-GM supply channel, τ, and/or the smaller is the reduction in consumer valuation of the non-GM product, σ, the greater is the share of consumers who benefit from the reduction in purity standards. When $\frac{\tau}{\sigma} > \frac{1+\theta(1-\theta)}{1+\theta}$, the price effect of reduced purity standards dominates the utility effect, the utility associated with the consumption of the non-GM product increases after the reduction in the purity standards for all consumers (i.e., $U'_{ngm} > U_{ngm}$ $\forall\alpha$), and all consumers gain from reduced purity standards. This case is depicted in Figure 9.

Our results on the effects of reduced purity standards on consumer welfare are summarized in Results 4 and 5 below, while Table 1 presents the market and welfare effects of reduced purity standards for non-GM labeled food.

RESULT 4: *Consumers of the GM product benefit from a reduction in the purity standards for non-GM labeled food due to the reduction in the price of the GM product.*

RESULT 5: *The effect of a reduction in purity standards for non-GM products on the consumers of these products depends on their aversion to GM products and the relative magnitude of the cost and utility effects of reduced standards. For given cost and utility effects, the smaller (greater) is the consumer aversion to GM products, the smaller (greater) are the welfare losses due to reduced purity standards, and the greater (smaller) is the likelihood that the reduced product prices will result in consumer welfare gains. When the cost effect is relatively large and/or when the utility effect is relatively small, a reduction in purity standards results in welfare gains for all consumers.*

Concluding Remarks

This paper develops a model of heterogeneous consumer preferences to analyze the market and welfare effects of reduced purity standards for non-GM labeled food. A reduction in the purity standards for non-GM food affects both the supply and the demand side of the market – it reduces the segregation and identity preservation costs in the conventional supply chain as well as the consumer willingness to pay for non-GM food.

The cost and utility effects of reduced purity standards are shown to reduce the prices of both the GM and non-GM products and have an effect on the market shares of these products and the welfare of the groups involved. While the reduction in the price of the GM food product causes an unambiguous increase in the welfare of consumers of the GM product, the effects of reduced purity standards on the market shares of the two products, the welfare of the non-GM product consumers, and the profits of the suppliers of GM and non-GM products are shown to be case-specific depending on the relative magnitude of the cost and utility effects of reduced purity standards; the distribution of consumer preferences and the level of aversion to GM products; the production, processing, and marketing costs along the GM and conventional supply chains; the costs associated with the segregation and labeling of the two products; and the market power present in the supply channels of the GM and conventional products.

In addition to identifying the effect of reduced purity standards on prices, quantities, and the welfare of the groups involved, a key result of the paper is that a reduction in purity standards creates winners and losers among the consumers as well as among the suppliers of the two products. The identity of these winners and losers is determined by the relative cost and utility effects of reduced purity standards. For instance, while a reduction in purity standards under a relatively low cost effect and a relatively high utility effect results in benefits for suppliers of the GM product and consumers with low and moderate aversion to GM products, and losses for suppliers of the non-GM product and consumers with relatively high aversion to GM products, the same reduction under a high cost effect and a low utility effect has the exact opposite effect for the suppliers of the two products and those consumers with relatively high aversion to GM products.

Since a reduction in purity standards creates winners and losers among the consumers and the suppliers of the two products, the regulatory decision on the purity standards of non-GM labeled food will be determined by the identity of the potential winners and losers and the relative weight placed by the regulator on the welfare of these groups. In this context, the market and welfare effects of purity standards are of interest to the government and all the participants in the two supply channels.

References

Giannakas K., M. Fulton. "Consumption Effects of Genetic Modification: What if Consumers are Right?" *Agricultural Economics* 27(2002): 97-109.

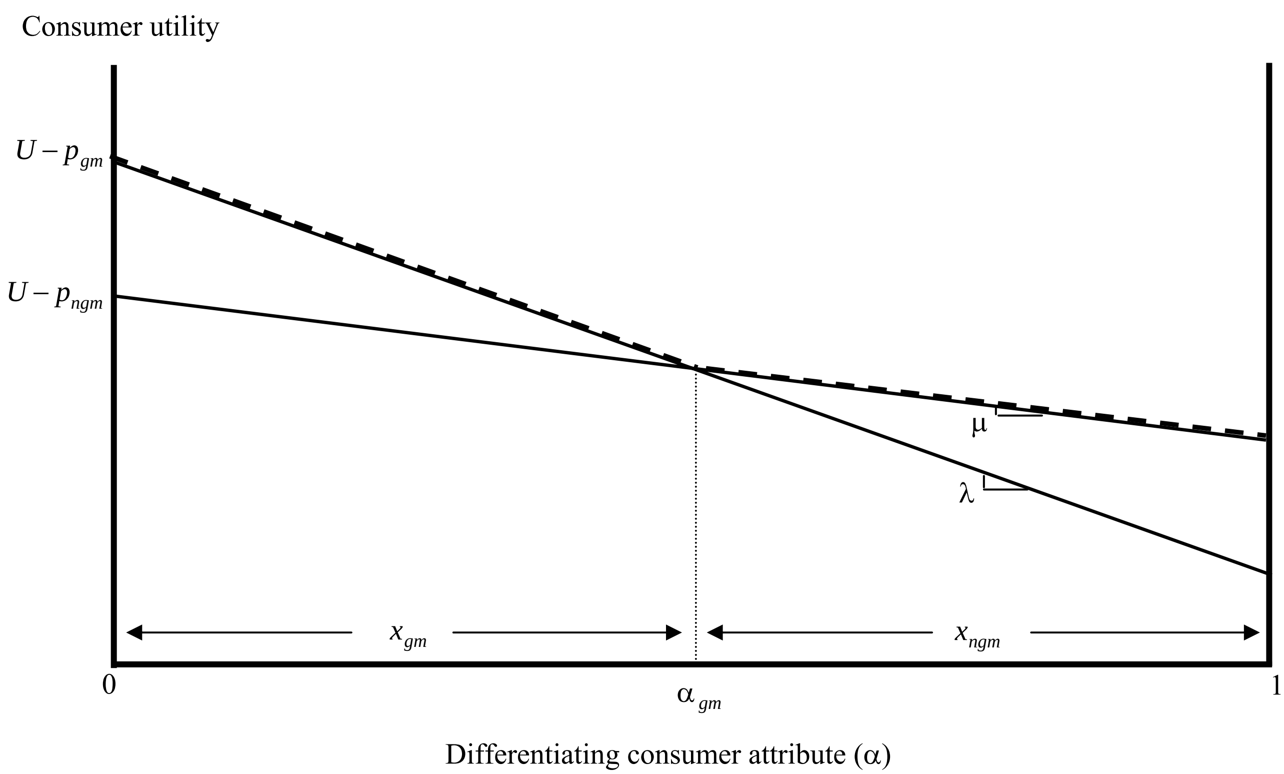


Figure 1. Consumption decisions when conventional products are free of GM ingredients.

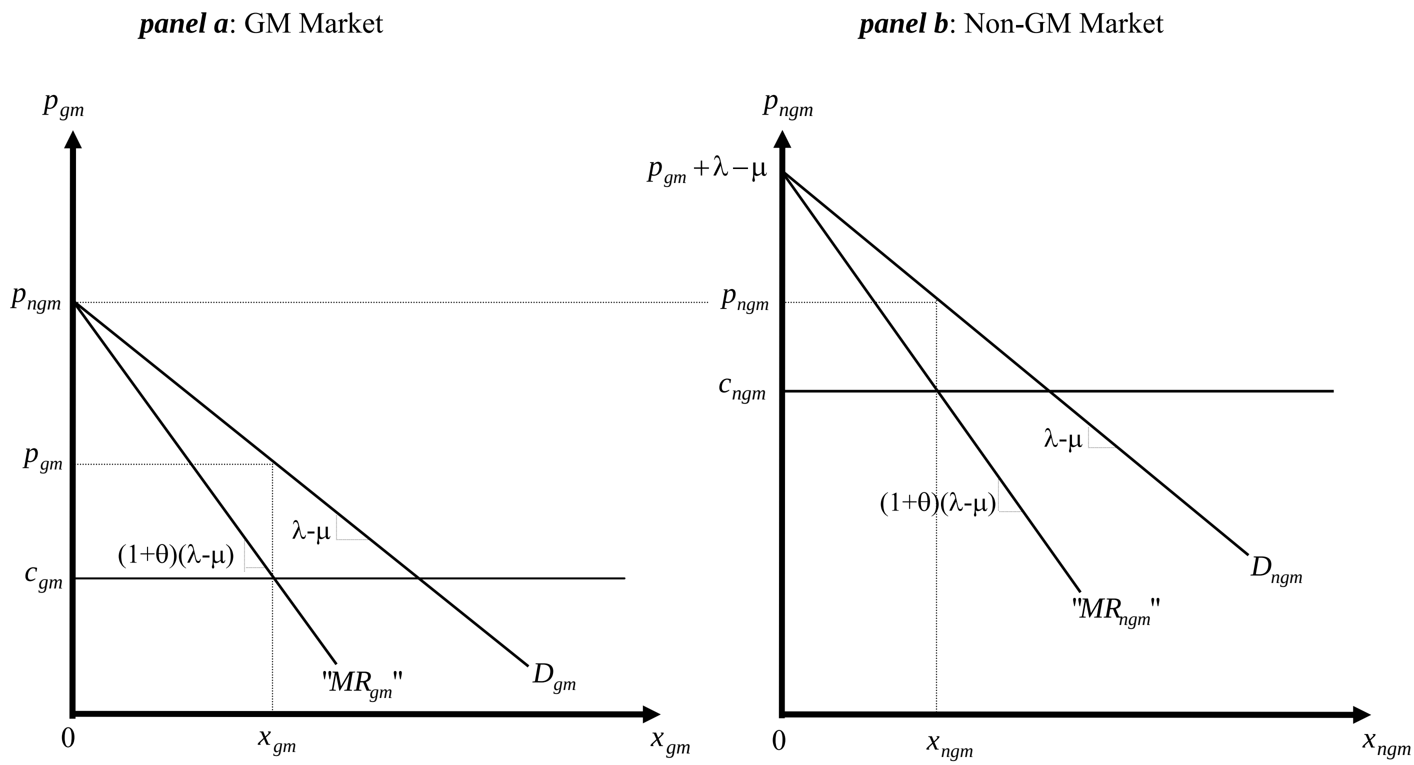


Figure 2. Equilibrium conditions when conventional products are free of GM ingredients.

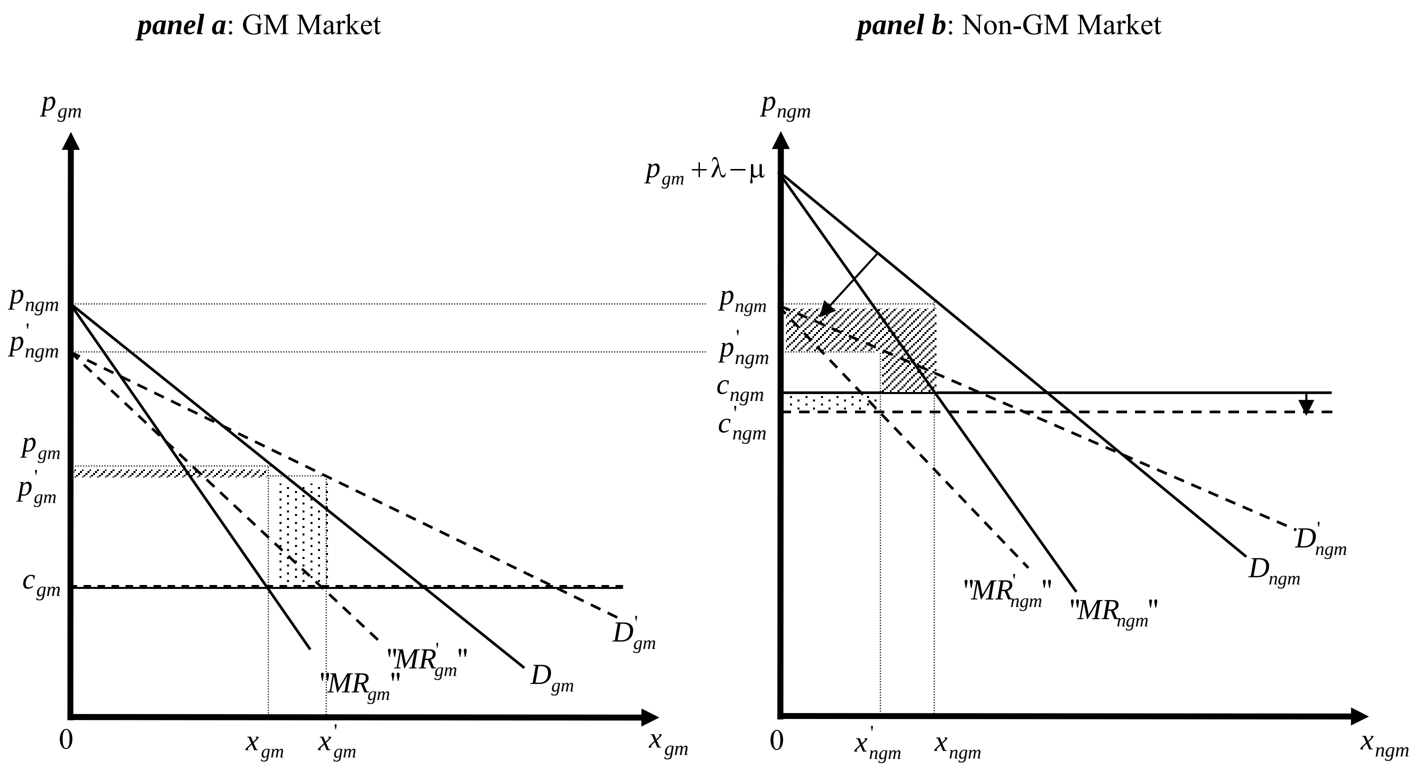


Figure 3. Market effects of reduced purity standards when $\frac{\tau}{\sigma} < \frac{c_{ngm} - c_{gm}}{\lambda - \mu}$.

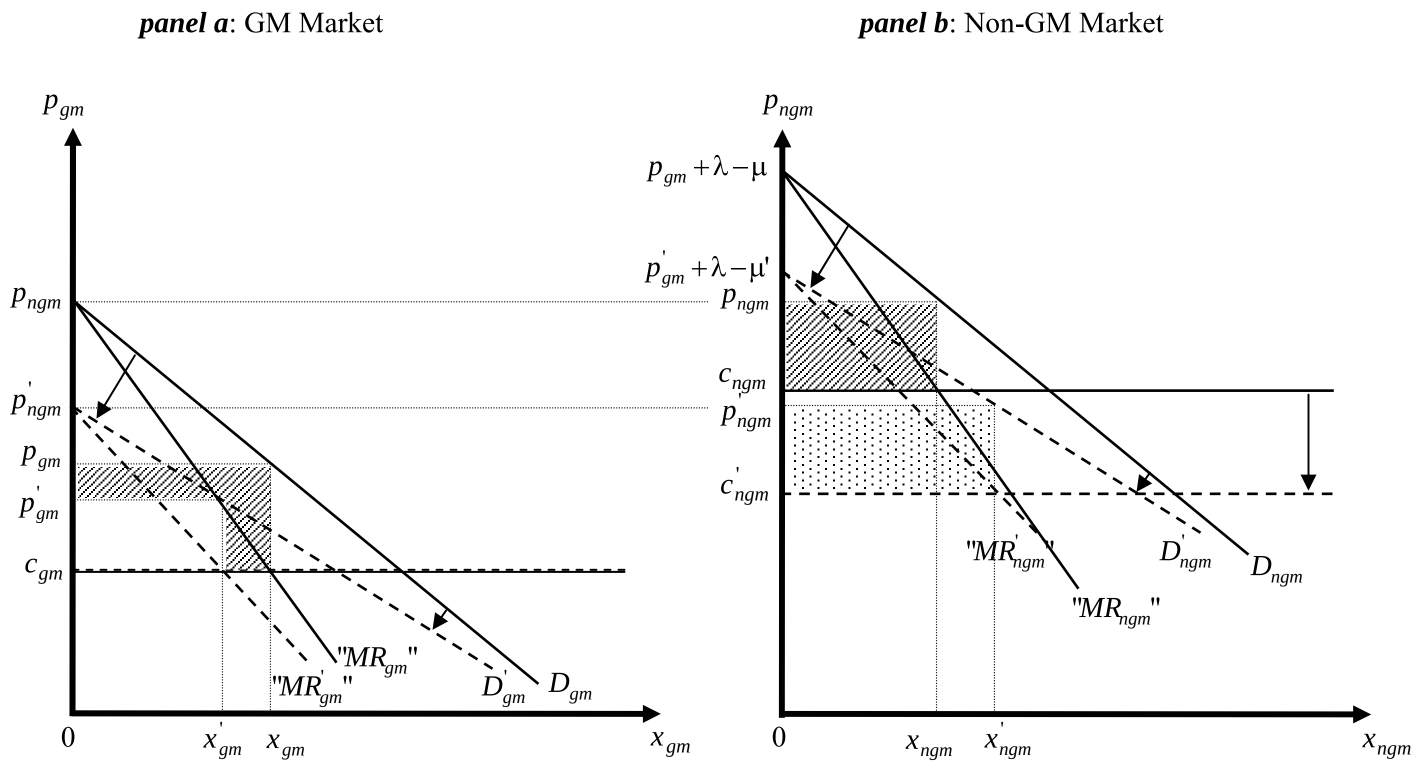


Figure 4. Market effects of reduced purity standards when $\frac{\tau}{\sigma} > \frac{c_{ngm} - c_{gm}}{\lambda - \mu}$.

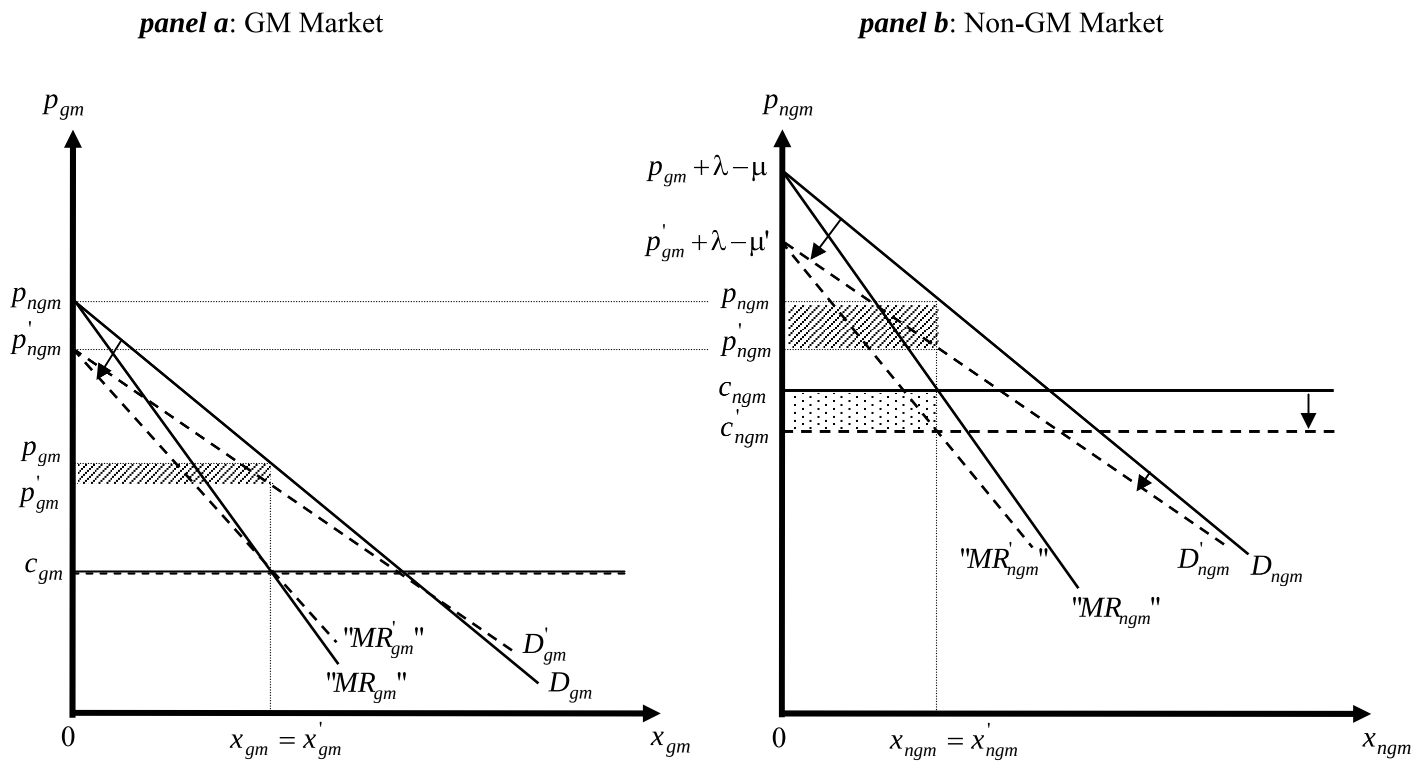
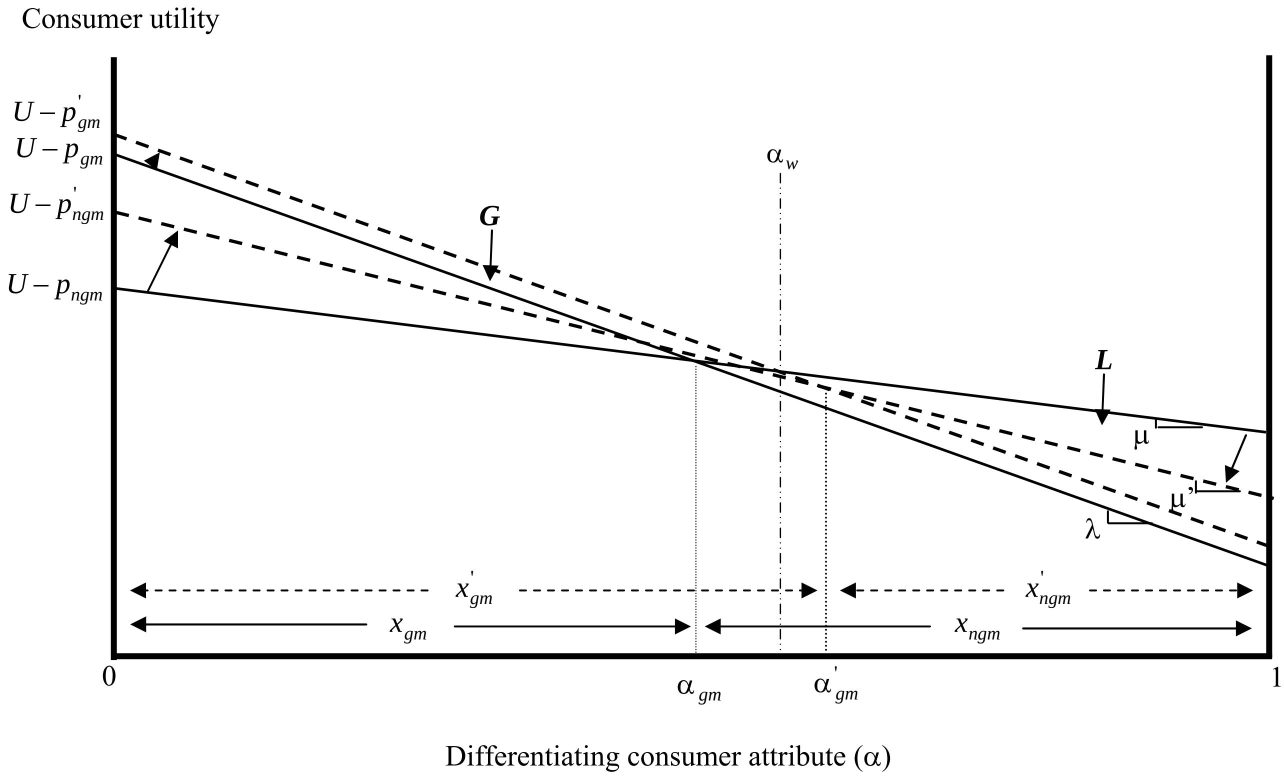
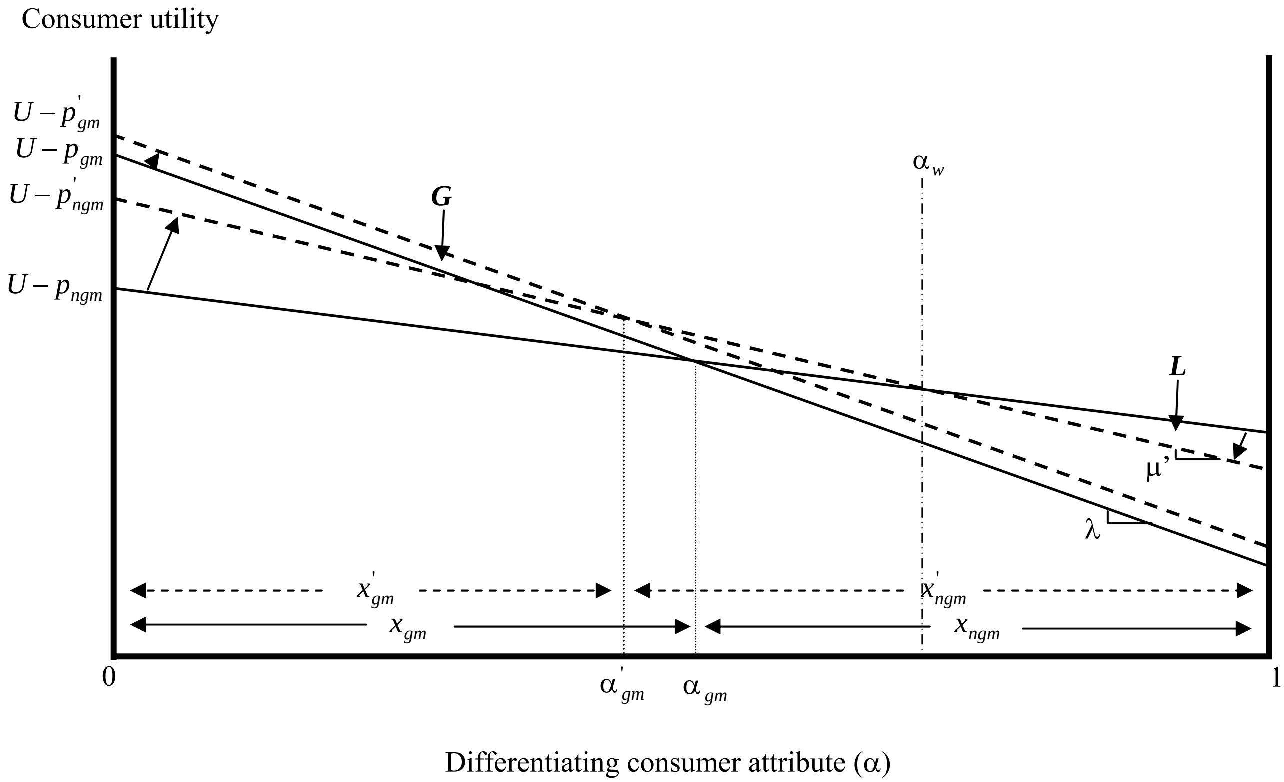


Figure 5. Market effects of reduced purity standards when $\frac{\tau}{\sigma} = \frac{c_{ngm} - c_{gm}}{\lambda - \mu}$.



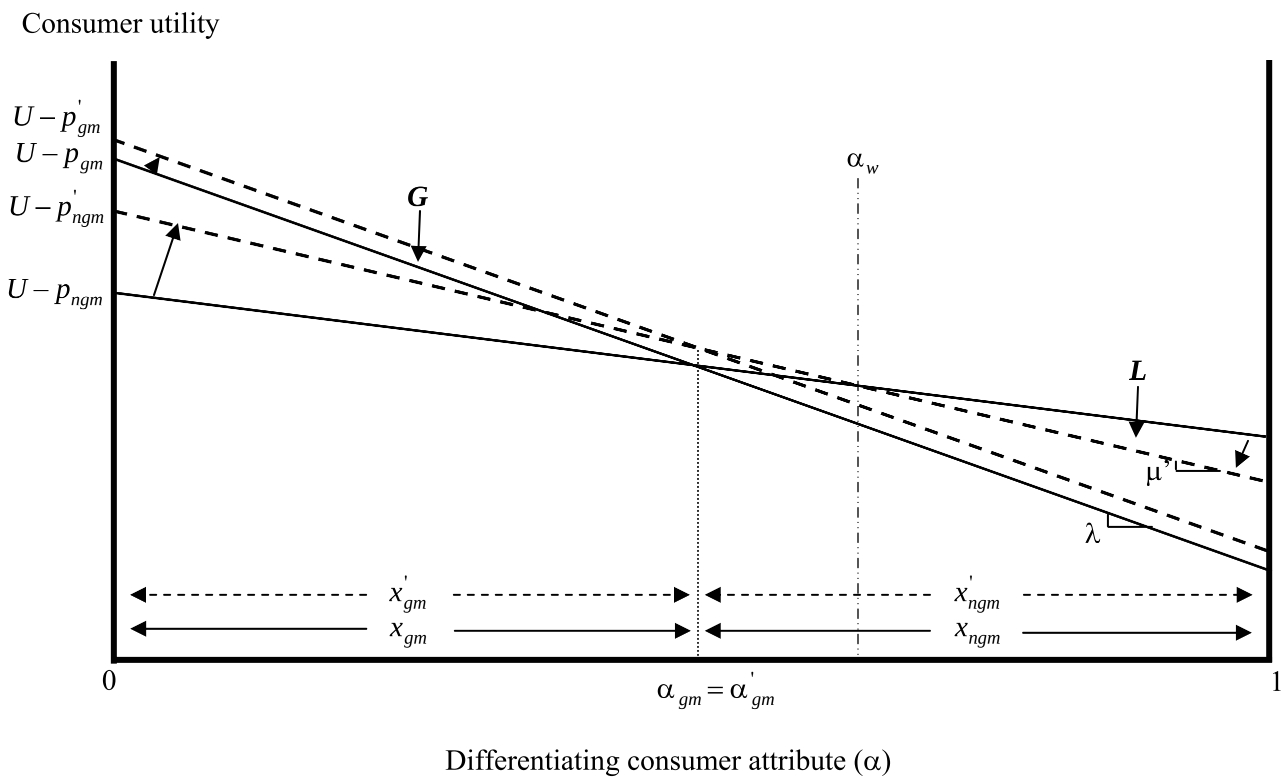
$$G = \int_0^{\alpha_{gm}} \left(U'_{gm} - U_{gm}\right) d\alpha + \int_{\alpha_{gm}}^{\alpha_w} \left(U'_{gm} - U_{ngm}\right) d\alpha \quad \text{and} \quad L = \int_{\alpha_w}^{\alpha'_{gm}} \left(U_{ngm} - U'_{gm}\right) d\alpha + \int_{\alpha'_{gm}}^{1} \left(U_{ngm} - U'_{ngm}\right) d\alpha$$

Figure 6. Consumption decisions under reduced purity standards when $\frac{\tau}{\sigma} < \frac{c_{ngm} - c_{gm}}{\lambda - \mu}$.



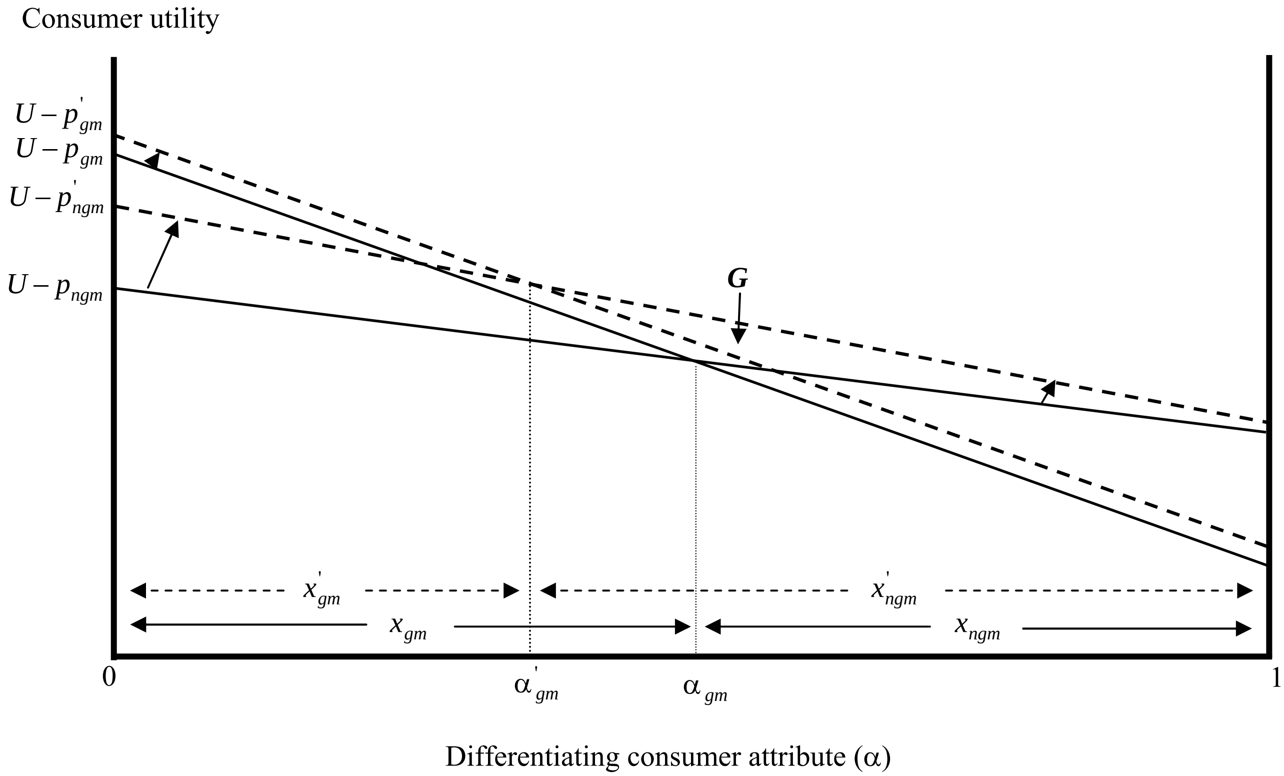
$$G = \int_{0}^{\alpha'_{gm}} \left(U'_{gm} - U_{gm}\right) d\alpha + \int_{\alpha'_{gm}}^{\alpha_{gm}} \left(U'_{ngm} - U_{gm}\right) d\alpha + \int_{\alpha_{gm}}^{\alpha_{w}} \left(U'_{ngm} - U_{ngm}\right) d\alpha \quad \text{and} \quad L = \int_{\alpha_{w}}^{1} \left(U_{ngm} - U'_{ngm}\right) d\alpha$$

Figure 7. Consumption decisions under reduced purity standards when $\frac{\tau}{\sigma} > \frac{c_{ngm} - c_{gm}}{\lambda - \mu}$.



$$G=\int_0^{\alpha_{gm}}\left(U'_{gm}-U_{gm}\right)d\alpha+\int_{\alpha_{gm}}^{\alpha_w}\left(U'_{ngm}-U_{ngm}\right)d\alpha \quad \text{and} \quad L=\int_{\alpha_w}^{1}\left(U_{ngm}-U'_{ngm}\right)d\alpha$$

Figure 8. Consumption decisions under reduced purity standards when $\frac{\tau}{\sigma}=\frac{c_{ngm}-c_{gm}}{\lambda-\mu}$.



$$G = \int_0^{\alpha'_{gm}} \left(U'_{gm} - U_{gm}\right) d\alpha + \int_{\alpha'_{gm}}^{\alpha_{gm}} \left(U'_{ngm} - U_{gm}\right) d\alpha + \int_{\alpha_{gm}}^{1} \left(U'_{ngm} - U_{ngm}\right) d\alpha$$

Figure 9. Market and welfare effects of reduced purity standards when $\frac{\tau}{\sigma} > \frac{1+\theta(1-\theta)}{1+\theta}$.

Table 1. Market and welfare effects of reduced purity thresholds for non-GM products

Ratio of the Cost over the Utility Effect of Reduced Purity Standards (τ/σ)	Prices		Quantities		Retailer Profits		Consumer Welfare		
	p_{gm}	p_{ngm}	x_{gm}	x_{ngm}	π_{gm}	π_{ngm}	CS_{gm} [1]	CS^{a}_{ngm} [2]	CS^{b}_{ngm} [3]
$\frac{\tau}{\sigma} < \left(\frac{\tau}{\sigma}\right)^{+} = \frac{\left[\theta(\lambda-\mu)+(c_{ngm}-c_{gm})\right]\left[(\lambda-\mu)+\sqrt{(\lambda-\mu)(\lambda-\mu-\sigma)}\right]}{(\lambda-\mu)\sigma} - \theta$	↓	↓	↑	↓	↑	↓	↑	↑	↓
$\left(\frac{\tau}{\sigma}\right)^{+} < \frac{\tau}{\sigma} < \frac{c_{ngm}-c_{gm}}{\lambda-\mu}$	↓	↓	↑	↓	↓	↓	↑	↑	↓
$\frac{\tau}{\sigma} = \frac{c_{ngm}-c_{gm}}{\lambda-\mu}$	↓	↓	-	-	↓	↓	↑	↑	↓
$\frac{c_{ngm}-c_{gm}}{\lambda-\mu} < \frac{\tau}{\sigma} < \left(\frac{\tau}{\sigma}\right)^{++} = (1+\theta) - \frac{\left[(1+\theta)(\lambda-\mu)-(c_{ngm}-c_{gm})\right]\left[(\lambda-\mu)+\sqrt{(\lambda-\mu)(\lambda-\mu-\sigma)}\right]}{(\lambda-\mu)\sigma}$	↓	↓	↓	↑	↓	↓	↑	↑	↓
$\left(\frac{\tau}{\sigma}\right)^{++} < \frac{\tau}{\sigma} < \frac{1+\theta(1-\theta)}{(1+\theta)}$	↓	↓	↓	↑	↓	↑	↑	↑	↓
$\frac{1+\theta(1-\theta)}{(1+\theta)} < \frac{\tau}{\sigma}$	↓	↓	↓	↑	↓	↑	↑	↑	↑

[1] CS_{gm} is the welfare of consumers that prefer the GM product prior to the reduction in purity standards (i.e., consumers with $\alpha \in [0, \alpha_{gm}]$ in Figures 1 and 6-9).

[2] CS^{a}_{ngm} is the welfare of consumers that prefer the non-GM product prior to the reduction in purity standards and have moderate aversion to GM products (i.e., consumers with $\alpha \in (\alpha_{gm}, \alpha_{w}]$ in Figures 6-8).

[3] CS^{b}_{ngm} is the welfare of consumers that prefer the non-GM product prior to the reduction in purity standards and have relatively high aversion to GM products (i.e., consumers with $\alpha \in (\alpha_{w}, 1]$ in Figures 6-8).

The colored symbols indicate parameters on which the effect of reduced purity standards changes as the ratio τ/σ increases.