Market and Welfare Effects of GMO Introduction in Small Open Economies

Alejandro Plastina and Konstantinos Giannakas
University of Nebraska-Lincoln

This paper develops a model of heterogeneous producers and consumers to analyze the market and welfare effects of the introduction of GM products in small open developing economies. Analytical results show that while the agronomic benefits associated with the introduction of the first-generation, producer-oriented GM products are certainly important, their presence does not guarantee welfare gains to small developing countries. The introduction of GM products is shown to create winners and losers among the consumers and producers of the small open economies.

Key words: agricultural biotechnology, developing countries, labeling, genetically modified products, small open economies.

"Agricultural biotechnology holds great promise for Africa and other areas of the world where circumstances such as poverty and poor growing conditions make farming difficult…. To deny desperate, hungry people the means to control their futures by presuming to know what is best for them is not only paternalistic but morally wrong."

> *Hassan Adamu*
> *Nigerian Minister of Agriculture[1]*

The advent of "Gene Revolution" has sparked a significant research effort aimed at identifying the market and welfare effects of the introduction of genetically modified (GM) crops into the food system. Due to the producer orientation of the first generation of GM products, particular emphasis has been placed on the agronomic benefits of the new technology and the potential for a productivity boost in developing countries.

The studies on the economic effects of agricultural biotechnology for the developing world have been generally based either on world trade equilibrium (WTE) models or on partial equilibrium models, sometimes modified to incorporate peasant production through production surplus models. The latter approach has shed light on the potential for productivity improvements in small developing countries, by using a country-specific setting with the production sector being the only explicitly modeled sector of the economy (Qaim, 1998, 1999; Qaim & Zilberman, 2003; Brookes & Barfoot, 2003; Wambugu & Kiome, 2001). Consumer behavior and the

conduct of the life science sector are, generally, implicit and superficially treated in this literature.

On the other hand, research based on WTE models has mainly focused on the effects of the introduction of GM products on developed countries or large developing countries with direct influence on the world prices of the GM crops under study (see Qaim & Traxler, 2005; Moschini, Lapan, & Sobolevsky, 2000; and Sobolevsky, Moschini, & Lapan, 2005, for analyses of the soybean complex; Anderson & Yao, 2003; and Huang, Hu, van Meijl, & van Tongeren, 2004, for China; Stone, Matysek, & Dolling, 2002, for Australia; Anderson & Jackson, 2003, for the US and the European Union [EU]; Meijl & Tongeren, 2004, for the EU; and Anderson, Damania, & Jackson, 2004, for the political economy of GM adoption in the US and the EU). While these studies provide several useful simulated aggregate welfare effects for different regions of the world, the insights on the economic effects of GM crops on small open economies are very limited as small countries are customarily being incorporated in the "Rest of the World."

Studies on the effects of GMO introduction in small developing countries include working papers by Anderson and Jackson (2004) that focus on the empirical estimation of the economic effects of adopting GM crops in Sub-Saharan Africa, and by Anderson, Jackson, and Nielsen (2004) that analyze the potential economic effects of adopting GM crops in Asia. While these two studies provide useful insights on the changes in *aggregate* economic welfare due to the adoption of GM technologies in developing countries of Africa and Asia, "[n]ational measures of welfare changes hide the distributional implications within countries of GM adoption and trade policy responses, … and thus fail to provide

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1. *Cited in Pinstrup-Andersen and Shioler (2001, p.5).*

insights into the political economy of GM policy choices" (Anderson, Jackson, & Nielsen, 2004).

In this context, these studies cannot provide insights on, say, the decisions of African nations (like Zimbabwe, Lesotho, Malawi, Mozambique, Swaziland, and Zambia) to reject US humanitarian aid in the form of GM corn in 2002 and 2003, while having about 25% of their population at risk of starvation (US Agency for International Development, 2002); or on the situation in Egypt where "after eight years of potato research …, the government decided not to commercialize the Bt potatoes" in 2001 (Eicher, Maredia, & Sithole-Niang, 2005).

The only study that considers the effect of introducing the GM technology in a small open economy on producer, consumer, and GM seed supplier welfare is Gouse, Pray, and Schimmelpfennig (2004). The authors find that Bt cotton adoption in South Africa has benefited producers, consumers, and GM seed suppliers. It is important to note, however, that the cotton market in South Africa is characterized by the lack of a labeling regime to segregate Bt from conventional cotton as well as by a lack of consumer (the cotton gins) aversion to the GM product.

The objective of this study is to analyze the market and welfare effects of the introduction of first-generation GM products into the food system of small open developing economies under alternative labeling regimes and consumer aversion to GM products. To analyze the system-wide effects of GMO introduction in small open economies, we develop a consistent theoretical framework that builds upon the partial equilibrium model developed by Fulton and Giannakas (2004) in their study of the economic effects of GMO introduction in a closed economy. Similar to Fulton and Giannakas, our analytical framework accounts for differences in consumer aversion to GM products, heterogeneous agronomic characteristics across producers, and imperfect competition between GM seed suppliers. Unlike the closed economy case studied by Fulton and Giannakas, consumer and producer prices in the small open economies are determined in the relevant world markets (and not by the domestic supply and demand schedules). An important ramification of that is that domestic production decisions are independent of domestic consumer preferences.

In addition to explicitly accounting for the structure of input suppliers, the labeling regimes in the domestic and the world markets, and producer and consumer heterogeneity, an important characteristic of our model is that it can provide estimates of the distributional effects of GMO introduction in small open economies with sig-

nificantly less information than that required by the WTE models. It should be pointed out that while our methodological framework can be used to analyze the effects of GMO introduction both in exporting and importing countries, our study focuses on the market and welfare effects of GMOs on small economies that are exporters of conventional products prior to the introduction of GMOs. The extension of our analysis to small importing countries is straightforward and is available from the authors upon request.

The rest of the paper is structured as follows. The general framework of analysis is developed first, followed by three sections focusing on different scenarios on the labeling regime governing the world market of the products in question. In particular, Section II analyzes the case where GM and conventional products are labeled in the world market, Section III examines the case of no labeling in the world market, and Section IV explores the case where different labeling regimes coexist in the world market. Within these cases, different scenarios on the domestic labeling regime are analyzed and compared to a base scenario in which GM products are not present in order to determine the market and welfare impacts of GMO introduction in the small open developing country. The article concludes with a discussion of the results and their implications.

Section I: The Model

Our model considers three groups of economic agents: seed suppliers, producers, and consumers. Producers buy seed from seed suppliers, produce a food product, and sell it to (domestic and foreign) consumers. The decisions of each economic agent under different labeling regimes are considered sequentially. For simplicity of exposition, fixed proportions between the seed, the agricultural product, and the final consumer product are assumed throughout the paper.

Product Characteristics and Consumer Preferences

To capture the consumer aversion to GM products expressed in numerous consumer preference studies around the world (see Lusk, Jamal, Kurlander, Roucan, & Taulman, 2005), GM and conventional products are modeled in this paper as *vertically differentiated* goods – i.e., if offered at the same price all consumers would buy the conventional form of the product.[2] While the GM and conventional products are uniformly quality ranked by consumers, consumers differ in their valuation of the perceived quality differences between these

products and, thus, they differ in their willingness-to-pay for them. Let r ($r \in [0, R]$) be the attribute that differentiates consumers. Assuming that consumers buy a unit of the product and that this purchase represents a small share of their budget, their utility function can be written as[3]

$U_c = U - p_c - \mu r$ if a unit of conventional product is consumed

$U_{gm} = U - p_{gm} - \lambda r$ if a unit of GM product is consumed

$U_{nl} = U - p_{nl} - (\psi\gamma + \mu)r$ if a unit of non-labeled product is consumed

$U_s = U - p_s$ if a unit of a substitute product is consumed (1)

where U_{gm} and U_c are the utilities associated with the unit consumption of labeled GM and conventional products, respectively; U_s is the utility associated with the consumption of a substitute product, and; U_{nl} is the utility associated with the consumption of the product when the GM and conventional products are marketed together as a non-labeled good. The parameter U represents a per-unit base level of utility that is constant across consumers; p_c, p_{gm}, p_{nl}, and p_s represent the prices of conventional, GM, non-labeled and substitute products, respectively, and; λ and μ are non-negative utility discount factors associated with the consumption of GM and conventional products, respectively.

To allow for positive market shares of these products our analysis focuses on the case where $p_s > p_c > p_{nl} > p_{gm}$ while, to capture the expressed consumer aversion to GM products, it is assumed that $\gamma = \lambda - \mu > 0$; the greater γr is, the greater the aversion to GM products of the consumer with differentiating attribute r. It is impor-

tant to note that since genetic modification is a credence process attribute, in the absence of labeling, consumers cannot determine whether a product is GM or not, and U_{nl} is an expected utility; a weighted average of U_{gm} and U_c, i.e., $U_{nl} = \psi U_{gm} + (1-\psi) U_c$ with ψ and $1-\psi$ being the perceived probabilities that the non-labeled product is GM and conventional, respectively. Under rational expectations, ψ and $1-\psi$ are given by the shares of the GM and conventional products in the total supply of the non-labeled product (Giannakas & Fulton, 2002).

Consumer Decisions and Welfare under a Domestic and World Labeling Regime. Consider first the case where GM and conventional products are required to be labeled as such in both the domestic and the world markets for these products.[4] Note that, when all internationally traded products are required to be labeled, the small open economy will have incentives to label its produce as GM or conventional because failure to do so would result in lost access to its export markets.

Under a labeling regime, products are segregated and domestic consumers have the choice between the GM, the conventional, and the substitute products. The consumer choice is then determined by the utilities associated with the consumption of these products given by U_c, U_{gm}, and U_s in Equation 1. Figure 1 graphs U_c, U_{gm}, and U_s against the differentiating attribute r and depicts the consumer decisions when the prices and preference parameters are such that all three products enjoy positive shares of the market. The consumer with differentiating attribute r_{gm}, where $r_{gm} : U_c = U_{gm} \Rightarrow r_{gm} = \frac{p_c - p_{gm}}{\gamma}$, is indifferent between consuming a unit of the conventional and a unit of the GM product as the utility associated with the consumption of these products is the same. Consumers with differentiating attribute $r < r_{gm}$ strictly prefer the GM product to the conventional and the substitute products. Similarly, the consumer with differentiating attribute r_C, where $r_c : U_c = U_s \Rightarrow r_c = \frac{p_s - p_c}{\mu}$, is indifferent between consuming a unit of the conventional and a unit of the substitute products. Consumers with differentiat-

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2. *The only case of consumers stating their willingness to purchase a GM product when offered at the same price with its non-GM counterpart was reported by Li, Curtis, McCluskey, and Wahl (2002) in their study of consumer preferences for soybean oil in Beijing, China. It is important to note, however, that 99% of the respondents reported little or no knowledge about biotechnology.*

3. *Note that if consumers were spending a significant part of their income on the product in question, the differentiating attribute r could be used to capture consumer differences in disposable income (rather than tastes).*

4. *It is important to note that, even though our analysis assumes that both the GM and conventional products have to be labeled, the results are more general and apply to the cases where only the GM or only the conventional products have to be labeled. Specifically, when only GM products are labeled, unlabeled products will be correctly perceived as conventional. Similarly, if conventional products are required to be labeled as such, unlabeled products will be correctly perceived as being GM.*
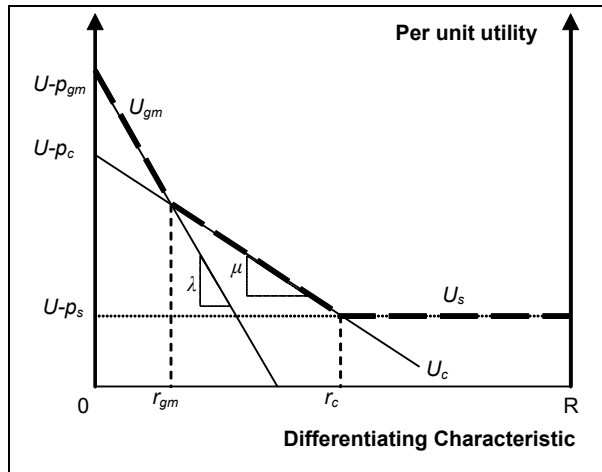
Figure 1. Consumer decisions and welfare under a domestic and world labeling regime.

Figure 2. Consumer decisions and welfare in the absence of GM products and under no-labeling regimes in the domestic and world markets.

ing attribute $r < r_C$ strictly prefer the conventional product to the substitute product, while consumers with differentiating attribute $r > r_C$ strictly prefer the substitute product to the conventional and GM products (see Figure 1). Assuming consumers are uniformly distributed with respect to r, r_{gm} gives the demand for the GM product, x_{gm}^D, i.e.,

$$x_{gm}^D = r_{gm} = \frac{p_c - p_{gm}}{\gamma} \tag{2}$$

while the consumer demand for the conventional product, x_c^D, is given by

$$x_c^D = r_C - r_{gm} = \frac{\gamma p_s - \lambda p_c + \mu p_{gm}}{\mu \gamma} \tag{3}$$

Aggregate consumer surplus is given by the area under the effective utility curve shown by the upper envelope (dashed line) in Figure 1 and equals $W_l^C = \frac{(p_s - p_c)^2}{2\mu} + \frac{(p_c - p_{gm})^2}{2\gamma} + \Omega$, where Ω is the area below the U_s curve (for the derivation of W_l^C see Appendix 1).

Consumer Decisions and Welfare in the Absence of GM Products. When there is no GM product available in the small open economy (either as a labeled GM or as a non-labeled product), then, irrespectively of the world labeling regime, domestic consumers have the choice between the conventional and the substitute products.
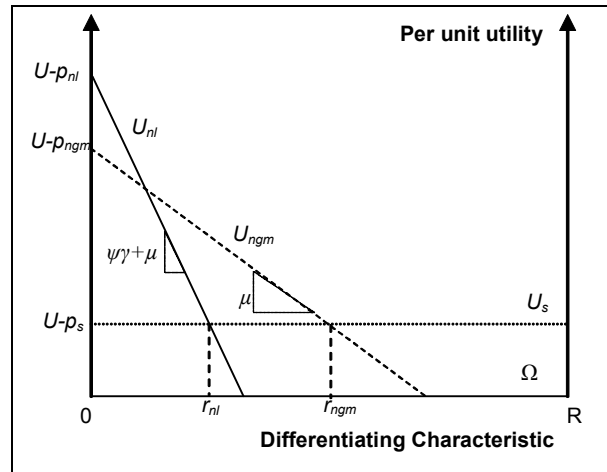
Figure 2 illustrates this case. Note that U_{ngm} is identical to the utility curve U_c in Figure 1 with the subscript changed to reflect the fact that no GM product is available in the domestic market. The price of the conventional product is relabeled as p_{ngm} and the domestic demand for conventional product is given by

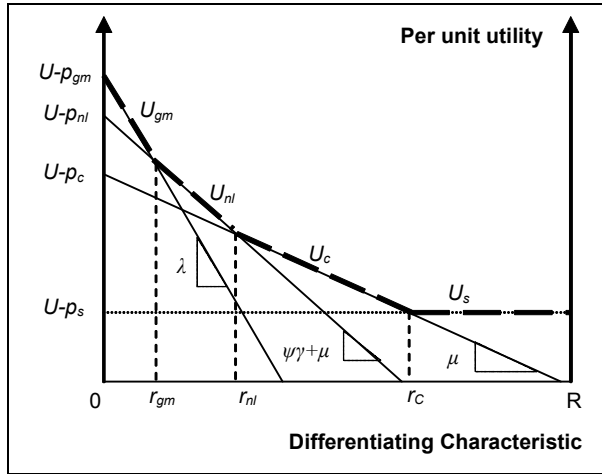$$x_{ngm}^D = r_{ngm} = \frac{p_s - p_{ngm}}{\mu} \tag{4}$$

Consumer welfare is given by the area below the upper envelope formed by the U_{ngm} and U_s curves in Figure 2

and equals $W_{ngm}^C = \frac{(p_s - p_{ngm})^2}{2\mu} + \Omega$.

Consumer Decisions and Welfare under No Labeling in the Domestic and World Markets. Consider now the domestic consumer choice problem when the GM and conventional products are marketed together as a non-labeled good. Note that in the absence of a labeling regime in the world market, the small exporting country has no incentive to segregate and label its produce as such a strategy would result in segregation and labeling costs and no benefits (as the price-taking small open economy would keep receiving the world price of the non-labeled product for both its GM and conventional products).

Figure 2 depicts the consumer decisions in the absence of a labeling regime. The consumer who is indifferent between the non-labeled and the substitute products is determined by the intersection of the U_{nl} and

Figure 3. Consumer decisions and welfare under non-uniform labeling regimes in the world market and no domestic labeling.

U_s curves in Figure 2, and is denoted by r_{nl}. The domestic demand for the non-labeled product, x_{nl}^D, is then given by

$$x_{nl}^D = r_{nl} = \frac{p_s - p_{nl}}{\psi\gamma + \mu} \tag{5}$$

and consumer welfare is given by the area below the upper envelope of the U_{nl} and U_s curves in Figure 2 or by the expression $W_{nl}^C = \frac{(p_s - p_{nl})^2}{2(\psi\gamma + \mu)} + \Omega$.

Consumer Decisions and Welfare under Non-Uniform Labeling Regimes in the World Market. Finally, consider the case where some countries require labeling of their GM and conventional products while others do not. It should be noted that this case is a more accurate depiction of the *status quo* in the world market where countries like the EU, Australia, and Japan have instituted mandatory labeling policies while the US, Canada, and Argentina have adopted a no-labeling regime.

If the small open economy under consideration has a mandatory labeling regime in place, the domestic consumer problem is the same as that faced under labeling in both the domestic and the world markets. The reason is that the domestic mandatory labeling regime results in all GM and conventional products traded domestically being labeled as such (see Appendix 3). The consumer decisions and welfare are then those presented in the

above section entitled *"Consumer Decisions and Welfare under a Domestic and World Labeling Regime."*

If, on the other hand, the domestic country does not require labeling of GM and conventional products under non-uniform world labeling standards, domestic consumers have access to all four products depicted in Equation 1 – i.e., labeled GM and conventional products (produced in the countries with mandatory labeling regimes), non-labeled products (produced domestically), and substitute products (see Appendix 3). In this case, consumers with differentiating attribute $r < r_{gm}$, where r_{gm}: $U_{gm} = U_{nl}$, prefer the labeled GM product; consumers with $r_{gm} < r < r_{nl}$, where r_{nl}: $U_{nl} = U_c$, prefer the non-labeled product, and; consumers with $r_{nl} < r < r_c$, where r_c: $U_c = U_s$, prefer the labeled conventional product (see Figure 3). The demands for the GM, non-labeled, and conventional products are, respectively,

$$x_{gm}^D = \frac{p_{nl} - p_{gm}}{(1 - \psi)\gamma} \tag{6}$$

$$x_{nl}^D = \frac{1}{\psi\gamma} p_c + \frac{1}{\gamma(1 - \psi)} p_{gm} - \frac{1}{\psi\gamma(1 - \psi)} p_{nl} \tag{7}$$

$$x_c^D = \frac{1}{\mu} p_s + \frac{1}{\psi\gamma} p_{nl} - \left[\frac{\lambda\psi + \mu(1 - \psi)}{\mu\psi\gamma}\right] p_c. \tag{8}$$

Consumer welfare is given by the area below the bold dashed line in Figure 3 and equals

$$W^C = \frac{(p_{nl} - p_{gm})^2}{2\gamma(1 - \psi)} + \frac{(p_c - p_{nl})^2}{2\psi\gamma} + \frac{(p_s - p_c)^2}{2\mu} + \Omega.$$

The Producer Problem

Following Fulton and Giannakas (2004), farmers are assumed to differ in the returns they receive from the production of GM and conventional crops due to differences in the location and quality of their land, education, experience, management skills, technology adopted, etc. Let a be the attribute that differentiates producers with $a \in [0, A]$. The producer with differentiating attribute a has the following net returns function
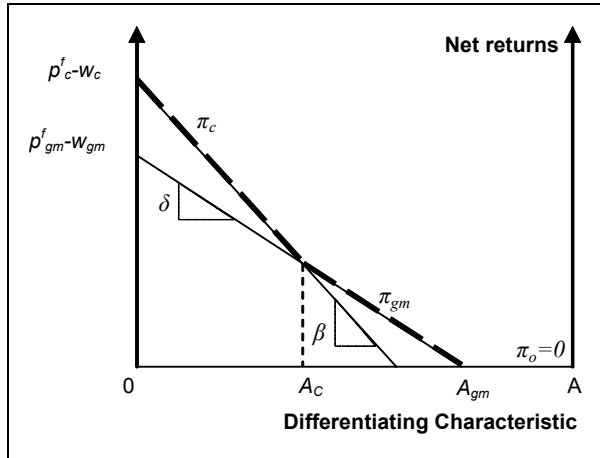
Figure 4. Producer decisions and welfare under a domestic labeling regime.

Figure 5. Producer decisions and welfare in the absence of GM products and under a domestic no-labeling regime.

$\pi_c = p_c^f - (w_c + \beta a)$ if a unit of conventional product is produced

$\pi_{gm} = p_{gm}^f - (w_{gm} + \delta a)$ if a unit of GM product is produced

$\pi_o = p_o^f - w_o$ if a unit of the alternative product is produced (9)

where p_c^f, p_{gm}^f, and p_o^f are the farm prices of conventional, GM, and alternative crops, respectively; w_c, w_{gm}, and w_o are the prices of conventional, GM, and alternative seed and chemical packages, respectively, and; β and δ are strictly positive cost-enhancement factors associated with the production of conventional and GM products, respectively. To capture the producer orientation of the first generation of GM products, we assume that $\phi = \beta - \delta > 0$; the greater ϕ is, the greater the agronomic benefits of the GM technology. To save on notation, we set $\pi_o = p_o^f - w_o = 0$.

Producer Decisions and Welfare under a Labeling Regime. Under a domestic labeling regime, producers choose whether to produce a unit of conventional, GM, or alternative product. The producer with differentiating attribute A_C, where $A_C : \pi_c = \pi_{gm}$, is indifferent between growing a unit of the conventional and a unit of the GM crop as the net returns from the production of the two crops are the same. Similarly, the producer with A_{gm}, where $A_{gm} : \pi_{gm} = \pi_o$, is indifferent between growing a
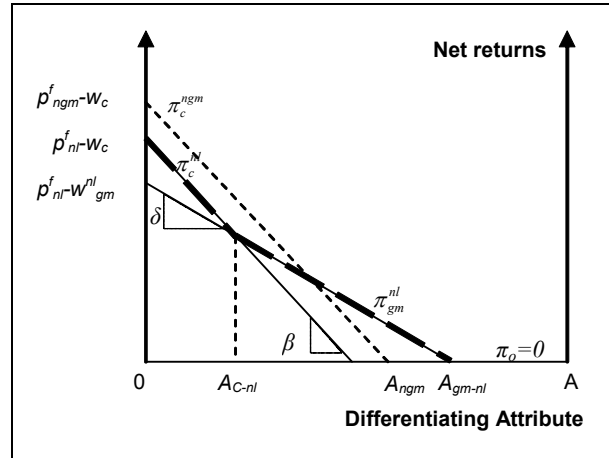
unit of the GM and a unit of the alternative crop (see Figure 4). Assuming that producers are uniformly distributed with respect to a, the domestic supplies of the conventional product, x_c^S, and the GM product, x_{gm}^S, are, respectively,

$$x_c^S = A_C = \frac{(p_c^f - p_{gm}^f) - (w_c - w_{gm})}{\phi} \qquad (10)$$

$$x_{gm}^S = A_{gm} - A_C = \frac{\beta(p_{gm}^f - w_{gm}) - \delta(p_c^f - w_c)}{\delta\phi} \qquad (11)$$

Aggregate producer welfare is given by the area under the effective net returns curve shown by the dashed kinked curve in Figure 4 and equals

$$W_l^P = \frac{\left(p_{gm}^f - w_{gm}\right)^2}{2\delta} + \frac{\left[\left(p_c^f - p_{gm}^f\right) + \left(w_{gm} - w_c\right)\right]^2}{2\phi}$$

(for the derivation of the expression for W_l^P see Appendix 2).

Producer Decisions and Welfare in the Absence of GM Products. Figure 5 illustrates the producer decisions when the GM product is not supplied in the domestic market. The curve π_c^{ngm} is identical to the net returns curve π_c in Figure 4 with the superscript "*ngm*" added to reflect the fact that the GM product is not produced domestically. The producer with differentiating attribute $A_{ngm} : \pi_c^{ngm} = \pi_o$ determines the supply of conventional product as

$$x_{ngm}^{S} = A_{ngm} = \frac{p_{ngm}^{f} - w_{c}}{\beta} \tag{12}$$

Producer welfare is given by the area under the π_c^{ngm} curve in Figure 5 and equals $W_{ngm}^{P} = \frac{\left(p_{ngm}^{f} - w_{c}\right)^{2}}{2\beta}$.

Producer Decisions and Welfare under a No-Labeling Regime. In the absence of a domestic labeling regime, the GM and conventional products are marketed together at a farm price of p_{nl}^{f}. The per unit net returns associated with the production of the GM product are then $\pi_{gm}^{nl} = p_{nl}^{f} - (w_{gm}^{nl} + \delta a)$ where w_{gm}^{nl} is the price of the GM seed and chemical package in the "No Labeling" case. As shown in Figure 5, the total supply of the non-labeled product in the small open economy is

$$x_{Total}^{S\,nl} = A_{gm-nl} = \frac{p_{nl}^{f} - w_{gm}^{nl}}{\delta} \tag{13}$$

which, under the empirically relevant case of partial adoption of the GM technology,[5] is composed of the supply of conventional product, $x_{c}^{S\,nl}$, and the supply of the GM product, $x_{gm}^{S\,nl}$, where

$$x_{c}^{S\,nl} = A_{C-nl} = \frac{w_{gm}^{nl} - w_{c}}{\phi} \tag{14}$$

$$x_{gm}^{S\,nl} = A_{gm-nl} - A_{C-nl} = \frac{p_{nl}^{f}}{\delta} + \frac{w_{c}}{\phi} - \frac{\beta w_{gm}^{nl}}{\delta \phi} \tag{15}$$

Producer welfare is given by the area under the bold dashed kinked curve in Figure 5, and equals $W_{nl}^{P} = \frac{\left(p_{nl}^{f} - w_{gm}^{nl}\right)^{2}}{2\delta} + \frac{\left(w_{gm}^{nl} - w_{c}\right)^{2}}{2\phi}$.

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5. *With the probable exception of the case of GM soybeans in Argentina, in all developing countries the GM technology has been only partially adopted; 40% of Argentina's maize is insect-resistant, 12-30% of Brazil's soybeans are biotech varieties, 50% of Paraguay's soybean crop is biotech, and 68% of China's cotton is Bt (Runge & Ryan, 2004). The adoption rates of Bt cotton in India and Mexico are 7% and 50%, respectively (Qaim, 2005). The adoption rates of GM corn, cotton and soybeans in South Africa are 29%, 92%, and 59%, respectively (US Department of Agriculture [USDA], 2006).*

Seed Suppliers

GM seed suppliers may be located in the developing country or outside of it. In the first case, any profits earned by these suppliers are a direct argument in the domestic social welfare function, while in the second case they are obviously not.

Irrespectively of their location, GM seed suppliers can take different organizational forms. They can be (a) for-profit-firms, (b) not-for-profit organizations that collaborate with national and/or international not-for-profit research institutions, and (c) joint ventures among profit and not-for-profit organizations. Examples for each case are, respectively, (a) Monsanto, Pioneer Hi-Bred, and Syngenta in South Africa where Monsanto is the sole supplier of GM soybean and cotton seeds, and all three companies supply GM maize seeds; (b) the Brazilian government-sponsored program at Cornell University for virus-resistant papaya, and; (c) the non-exclusive, royalty-free licensing agreement between the Kenya Agricultural Research Institution (KARI) and Monsanto, through which KARI can use and develop GM technology for sweet potatoes and transfer this technology to any country in Africa (Runge & Ryan, 2004; USDA, 2006). In this context, it is important for our analysis to account for the different institutional arrangements in the GM seed supply sector.

When the GM seed suppliers face a linear (derived) demand for GM seed of the form $w_{gm} = z - bY$, and have a constant marginal cost of obtaining or producing the GM seed, mc, the equilibrium price and quantity for the GM seed are, respectively (see Shy, 1995, p.102),

$$w_{gm} = z \frac{\theta}{(1+\theta)} + mc \frac{1}{(1+\theta)} \tag{16}$$

$$Y = \frac{(z - mc)}{b(1+\theta)} \tag{17}$$

where $\theta = \sum_{i=1}^{N} \frac{\partial Y}{\partial Y_i} \frac{Y_i}{Y}$ is the conjectural variation elasticity of total industry output with respect to the output of firm i ($i = 1, \dots, N$) and captures the degree of market power of the GM seed suppliers. Specifically, under perfect competition $\theta = 0$, under a monopoly $\theta = 1$, and when $0 < \theta < 1$ some degree of oligopoly power exists (Applebaum, 1982). In this context, the conjectural variation elasticity allows for an examination of the various

organizational structures of GM seed suppliers dis-cussed earlier. If, for example, there is only one for-profit GM seed supplier in the domestic market (such as Monsanto and Genética Mandiyú in the South African and Argentine Bt cotton markets, respectively [Qaim & de Janvry, 2003; USDA, 2006]), and significant barriers to entry exist, $\theta = 1$ can capture this firm's behavior. If there are N suppliers of very similar GM seeds (as in South Africa where three life science companies pro-vide seven varieties of GM maize [USDA, 2006]), then $\theta = 1/N$ may capture their behavior in a homogeneous N-firm Cournot-Nash setting. If the GM seeds are sup-plied by not-for-profit organizations, then marginal cost pricing may prevail, implying $\theta = 0$.

Supplier Decisions and Profits under a Labeling Regime. Using Equations 11, 16, and 17, the equilib-rium GM seed price and output under a domestic label-ing regime are

$$w_{gm} = \left(\frac{\beta p_{gm}^f - \delta(p_c^f - w_c)}{\beta} \right) \frac{\theta}{(1+\theta)} + mc \frac{1}{(1+\theta)} \tag{18}$$

$$Y = x_{gm}^S = \left(\frac{\beta(p_{gm}^f - mc) - \delta(p_c^f - w_c)}{\delta\phi} \right) \frac{1}{(1+\theta)} \tag{19}$$

Aggregate GM seed suppliers' profits are then

$$W_l^R = \frac{\theta\left[\beta(p_{gm}^f - mc) - \delta(p_c^f - w_c) \right]^2}{\beta\delta\phi(1+\theta)^2} \tag{20}$$

Supplier Decisions and Profits under a No-Labeling Regime. In the absence of labels, using Equations 15, 16, and 17, the equilibrium price and quantity of the GM seed are

$$w_{gm}^{nl} = \left(\frac{\phi p_{nl}^f + \delta w_c}{\beta} \right) \frac{\theta}{(1+\theta)} + mc \frac{1}{(1+\theta)} \tag{21}$$

$$Y = x_{gm}^{S\,nl} = \left(\frac{\phi p_{nl}^f + \delta w_c - \beta mc}{\delta\phi} \right) \frac{1}{(1+\theta)} \tag{22}$$

Aggregate GM seed suppliers' profits are then

$$W_{nl}^R = \frac{\theta\left[\phi p_{nl}^f + \delta w_c - \beta mc \right]^2}{\beta\delta\phi(1+\theta)^2} \tag{23}$$

Equilibrium Consumer and Producer Prices

The prices received by agricultural producers of the small open economy are given by the prices paid by consumers (which equal the world prices of the relevant products) minus an internal marketing margin, *IM*. The *IM* accounts for things like transportation, packaging, market power along the supply chain, etc. Hence, the price equilibrium conditions in each scenario conform to the general relationship $p = p^f + IM$.

Domestic and World Labeling . When there is a label-ing regime in the domestic and the world markets, the GM and conventional products are marketed separately and the domestic consumer prices of these products are, respectively,

$$p_c = p_c^f + IM_c \tag{24}$$

$$p_{gm} = p_{gm}^f + IM_{gm}. \tag{25}$$

To capture the fact that most segregation and labeling costs are incurred in the conventional supply channel, we assume that $IM_c > IM_{gm}$.[6]

No-GM Products. In the absence of GM products, the domestic consumer price of the conventional product is

$$p_{ngm} = p_{ngm}^f + IM_{ngm}. \tag{26}$$

No Labeling in the Domestic and World Markets . The consumer price in the absence of labeling in the domes-tic and the world markets is

$$p_{nl} = p_{nl}^f + IM_{nl}. \tag{27}$$

Non-Uniform World Labeling Regimes. When the small open economy has a mandatory labeling regime, the GM and conventional products are segregated and domestic consumer prices are given by Equations 24

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6. *Huang et al. (2004, p. 46) report that segregation costs may raise unit cost for the EU, Canada, and the US, on average, by up to 28% for oilseeds and 22% for corn.*

and 25. When the domestic country does not label its products, the pricing condition for the (domestically produced) non-labeled product is given by Equation 27. The consumer prices of labeled GM and conventional products (imported from countries that label their produce) are then the world prices of these products.

Section II: Effects of GMO Introduction under Labeling in the World Market

After analyzing the decisions of consumers, producers, and GM seed suppliers under different labeling regimes, we focus next on the market outcomes when the GM and conventional products are required to be labeled in the world market. Two scenarios are analyzed here. In the first scenario (the benchmark case), the small developing country exports the conventional product to the world market, and no production or consumption of GM products takes place domestically. In the second scenario, the GM product is produced and consumed in the small economy under a labeling regime that matches the one in the world market. The equilibrium conditions under the two scenarios are then compared to determine the market and welfare effects of the introduction of GMOs in the small exporting country.

World Labeling. No Domestic GM Production or Consumption (Base Scenario 1)

This section examines the case in which only the conventional product is supplied in the small economy, in a way that an exportable surplus exists. Since in the world market the conventional and GM products are segregated, the domestic produce is traded as conventional and receives a price premium. The domestic consumer and producer decisions in the absence of GM products from the small open economy are analyzed in the above sections entitled "*Consumer Decisions and Welfare in the Absence of GM Products*" and "*Producer Decisions and Welfare in the Absence of GM Products*," respectively.

Market Outcome. Since the country is a small exporter, it faces an infinitely elastic external demand at the world price of the conventional product p_c^*. The external equilibrium condition is

$$p_{ngm} = p_c^* \tag{28}$$

which, when combined with Equations 4, 12, and 26, determines the equilibrium quantity consumed in the

domestic market, the equilibrium quantity produced, and the equilibrium quantity exported as

$$x_{ngm\ Eq.}^D = \frac{p_s - p_c^*}{\mu} \tag{29}$$

$$x_{ngm\ Eq.}^S = \frac{p_c^* - IM_{ngm} - w_c}{\beta} \tag{30}$$

$$Exports_{ngm\ Eq.} = p_c^* \frac{(\mu+\beta)}{\mu\beta} - \frac{\beta p_s + \mu(IM_{ngm} + w_c)}{\mu\beta} > 0 \tag{31}$$

Welfare Analysis. Aggregate consumer welfare is a decreasing function of p_c^* and the utility discount factor μ:

$$W_{ngm}^C = \frac{(p_s - p_c^*)^2}{2\mu} + \Omega \tag{32}$$

while aggregate producer welfare is an increasing function of p_c^*, and a decreasing function of the internal marketing margin, the cost of the conventional seed, and the cost-enhancement factor β:

$$W_{ngm}^P = \frac{(p_c^* - IM_{ngm} - w_c)^2}{2\beta} \tag{33}$$

Since there is no domestic supply of GM seeds in this case, aggregate domestic welfare is given by the summation of domestic consumer and producer welfare. An increase in the world price of the conventional product generates an increase in aggregate welfare, with producer gains outweighing consumer losses. Increases in the cost of conventional seeds and/or in the internal marketing margin reduce aggregate welfare by reducing producer welfare. Finally, an increase in the price of the substitute in consumption induces more people to consume the conventional product and increases the aggregate welfare generated by this sector of the economy.

World Labeling. Domestic GM Production and Consumption under Domestic Labeling.

Consider now the case where the small open economy produces both GM and conventional products under a domestic labeling regime that matches the labeling regime in the world market. Under this scenario, the

small open economy could be an importer or an exporter of the GM product. Since the results are very similar for the two cases, our analysis will focus on the case where the small country is an importer of the GM product and an exporter of its conventional counterpart.[7]

The fact that the country imports the GM product and exports the conventional product imposes the following external market conditions:

$$p_c = p_c^* \tag{34}$$

$$p_{gm} = p_{gm}^*. \tag{35}$$

Market Outcome. Equations 2, 34, and 35 determine the equilibrium quantity of the GM product consumed domestically as

$$x_{gm\ Eq.}^D = \frac{p_c^* - p_{gm}^*}{\gamma}. \tag{36}$$

The domestic demand for the GM product increases with an increase in the world price of the conventional product, and falls with an increase in either the world price of, or the consumer aversion to, the GM product.

Equations 3, 34, and 35 determine the equilibrium quantity of the conventional product consumed domestically as

$$x_{c\ Eq.}^D = \frac{\gamma p_s - \lambda p_c^* + \mu p_{gm}^*}{\mu \gamma} \tag{37}$$

which increases with an increase in the price of the substitute in consumption, the utility discount factor for GM products, and the world price of the GM product, and falls with an increase in its price and the utility discount factor for the conventional product.

The equilibrium domestic supply of the GM product is determined by Equations 19, 24, 25, 34, and 35 as

$$x_{gm\ Eq.}^S = \frac{\beta\left(p_{gm}^* - IM_{gm} - mc\right) - \delta\left(p_c^* - IM_c - w_c\right)}{\delta\phi(1+\theta)} \tag{38}$$

and depends positively on the difference between the world price of the GM product and the sum of its marketing margin and the marginal cost of the GM seed, and negatively on the conjectural variation elasticity, the difference between the world price of the conventional product, the sum of its marketing margin, and the price of conventional seed.

The equilibrium price of GM seeds in the domestic market when the country produces the GM product but also imports some of it is determined by Equations 18, 24, 25, 34, and 35 as

$$w_{gm\ Eq.} = \frac{\theta\left[\beta\left(p_{gm}^* - IM_{gm}\right) - \delta\left(p_c^* - IM_c - w_c\right)\right]}{\beta(1+\theta)} + \frac{mc}{(1+\theta)} \tag{39}$$

Using Equations 10, 34, 35, and 39, the equilibrium supply of the conventional product is

$$x_{c\ Eq.}^S = \frac{(\beta + \phi\theta)\left(p_c^* - IM_c - w_c\right)}{\phi\beta(1+\theta)} - \frac{\left(p_{gm}^* - IM_{gm} - mc\right)}{\phi(1+\theta)} \tag{40}$$

while, using Equations 36 and 38 the quantity of the GM product imported in equilibrium is given by

$$Imports_{gm\ Eq.} = p_c^*\left[\frac{1}{\gamma} + \frac{1}{\phi(1+\theta)}\right] - p_{gm}^*\left[\frac{1}{\gamma} + \frac{\beta}{\phi\delta(1+\theta)}\right] + \frac{\beta\left(IM_{gm} + mc\right)}{\phi\delta(1+\theta)} - \frac{\left(IM_c + w_c\right)}{\phi(1+\theta)}. \tag{41}$$

Note that GM imports increase with the price of the conventional product, the marginal cost of GM seed, and the marketing margin of the GM product, and fall with the world price of the GM product, the price of the conventional seed, and the marketing margin of the conventional product.[8]

Using Equations 37 and 40, the equilibrium quantity of conventional product exported to the world market is given by

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7. *The results for the case where the introduction of the GM technology in the small country results in it being an exporter of the GM product are available from the authors upon request.*

$$Exports_{gm \, Eq.} = p_c^* \left[\frac{\beta + \theta\phi}{\phi\beta(1+\theta)} + \frac{\lambda}{\mu\gamma} \right]$$

$$- p_{gm}^* \left[\frac{1}{\gamma} + \frac{1}{\phi(1+\theta)} \right] - \frac{p_s}{\mu} + \frac{(IM_{gm} + mc)}{\phi(1+\theta)}$$

$$- \frac{(\beta + \theta\phi)(IM_c + w_c)}{\phi\beta(1+\theta)}. \tag{42}$$

The exports of the conventional product increase with the world price of the product, the marginal cost of GM seeds, and the marketing margin of the GM product, and they fall with the cost of the conventional seed, the marketing margin of the conventional product, the world price of the GM product, and the price of the substitute product.[9]

Welfare Effects. The welfare of consumers and producers, and the profits of GM seed suppliers are, respectively,

$$W_l^C = \frac{(p_s - p_c^*)^2}{2\mu} + \frac{(p_c^* - p_{gm}^*)^2}{2\gamma} + \Omega \tag{43}$$

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8. *The higher the price of the conventional product, the lower its demand, and the higher the demand for the GM product. The higher the price of the GM product, the lower its domestic demand, and the higher its domestic production. The higher the marketing margin of the GM product, the lower its farm price, and the lower its supply. The higher the production cost and the marketing margin of the conventional product, the higher the supply of its GM counterpart.*

9. *A higher world price of the conventional product reduces its domestic consumption and increases its domestic production and exports. An increase in either the marginal cost of GM seeds or the marketing margin for the GM product reduces domestic GM production and some producers shift their production to the conventional product. An increase in the world price of the GM product increases the domestic consumption of conventional product, and some producers shift their production to GM products, negatively affecting the exports of conventional product. An increase in either the price of conventional seed or the marketing margin for the conventional product reduces the net returns of conventional producers, increasing the relative profitability of the GM product. An increase in the price of the substitute in consumption increases the consumption of the conventional product, reducing its exports.*

$$W_l^P = \frac{\beta(p_{gm}^* - IM_{gm} - mc)^2}{2\phi\delta(1+\theta)^2}$$

$$+ \frac{[\beta + \theta\phi(2+\theta)](p_c^* - IM_c - w_c)^2}{2\phi\beta(1+\theta)^2}$$

$$- \frac{(p_{gm}^* - IM_{gm} - mc)(p_c^* - IM_c - w_c)}{\phi(1+\theta)^2} \tag{44}$$

$$W_l^R = \frac{\theta[\beta(p_{gm}^* - IM_{gm} - mc) - \delta(p_c^* - IM_c - w_c)]^2}{\phi\delta\beta(1+\theta)^2} \tag{45}$$

Comparing Equation 43 with 32, we get:

$$\Delta W^C = \frac{(p_c^* - p_{gm}^*)^2}{2\gamma} > 0 \tag{46}$$

The change in consumer welfare is strictly positive, indicating that domestic consumers benefit from the introduction of GM products under a labeling regime. Consumer welfare increases because a new product is being offered at a lower price without altering the price of the existing (conventional and substitute) products. The striped shaded area in Figure 6 depicts the increase in domestic consumer welfare caused by the introduction of the GM product. The change in consumer welfare *increases* with the difference in the world prices of the GM and conventional products, and it *decreases* with the consumer aversion to GM products.

To analyze the change in producer welfare caused by the introduction of GM products in the small open economy, it is assumed that $IM_c = IM_{ngm} + k_c$, where k_c represents the marginal costs of segregating the conventional from the GM product under a domestic labeling regime.

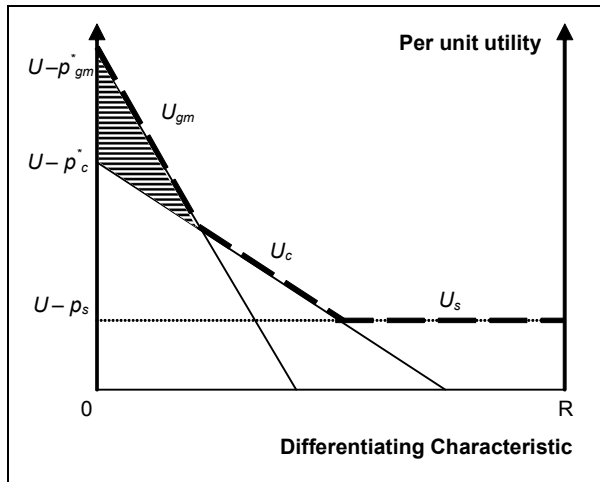By comparing Equation 44 with 33 we get the change in producer welfare as

Figure 6. Increase in consumer welfare due to GMO introduction under domestic and world labeling regimes.
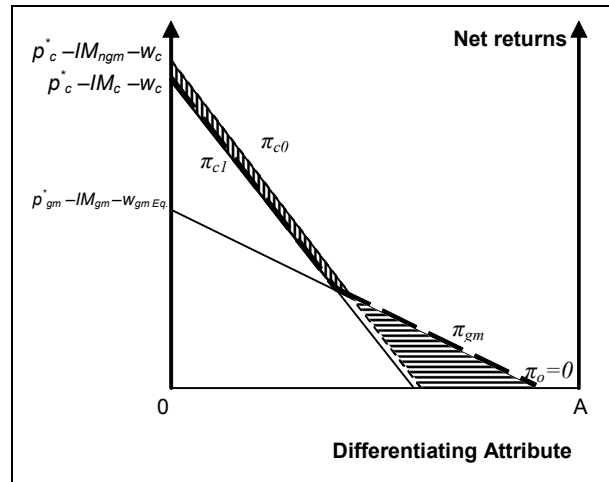

Figure 7. Change in producer welfare due to GMO introduction under domestic and world labeling regimes.

Note: π_{c0} and π_{c1} represent, respectively, producer net returns before and after the introduction of the GM technology.

$$\Delta W_l^{\mathrm{P}} = \frac{\beta \left(p_{gm}^* - IM_{gm} - mc \right)^2}{2\phi\delta \left(1+\theta \right)^2}$$

$$+ \frac{\delta \left(p_c^* - IM_{ngm} - w_c \right)^2}{2\phi\beta \left(1+\theta \right)^2} - \frac{\left(p_c^* - IM_c - w_c \right)}{\phi \left(1+\theta \right)^2}$$

$$\left\{ \left(p_{gm}^* - IM_{gm} - mc \right) + \frac{\left[\beta + \theta\phi \left(2+\theta \right) \right]}{2\beta} k_c \right\}$$

$$(47)$$

The effect that the introduction of the GM product in the small economy has on producer welfare is ambiguous and it depends on the world prices of conventional and GM products, the cost of segregating the two products, the cost advantage of the GM over the conventional crop, and the market power of the GM seed suppliers. If k_c tends to zero, the change in producer welfare is strictly positive.[10] All producers of the conventional product in Base Scenario 1 will receive reduced farm prices in the above scenario entitled "*World Labeling. Domestic GM Production and Con-*

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10. *Note that a sufficient condition for Equation 47 to be positive is that* $\left[\beta \left(p_{gm}^* - IM_{gm} - mc \right) - \delta \left(p_c^* - IM_{ngm} - w_c \right) \right]^2$
$> \delta k_c \left(p_c^* - IM_{ngm} - k_c - w_c \right) \left[\beta + \theta\phi \left(2+\theta \right) - 2\beta \left(p_{gm}^* - IM_{gm} - mc \right) \right].$

sumption under Domestic Labeling" due to increased marketing margins stemming from the segregation costs. At the same time, some producers will find it optimal to grow the GM crop in the above scenario entitled "*World Labeling. Domestic GM Production and Consumption under Domestic Labeling,*" increasing their aggregate profits. These opposite effects that the introduction of GM products has on producer welfare can be seen graphically in Figure 7, where the producer welfare losses are represented by the vertically striped area and the producer welfare gains by the horizontally striped area. Obviously, the net effect of the introduction of GM products on aggregate producer welfare depends on the relative size of the two areas.

Finally, the change in GM seed suppliers' profits is non-negative ($\Delta W^R = W_l^R \geq 0$). The greater the market power of these suppliers, the greater are their profits. It follows that the effect of GMO introduction on the aggregate welfare of small open economies will depend on the relative changes in the welfare of the interest groups involved. If producer welfare is increased, then aggregate welfare change is positive; if producer welfare falls, then the aggregate welfare change can be either positive or negative.

Result 1: The introduction of GM products under a labeling regime in a small open economy that has been an exporter of conventional products benefits domestic consumers and GM seed suppliers and has an ambiguous effect on aggregate producer welfare.[11]

Section III: Effects of GMO Introduction under No Labeling in the World Market

In this section, we consider the case where there is no labeling in the world market. Since the GM and conventional products are marketed together, there is no price premium for the conventional product and the small exporting country has no incentive to segregate and label its produce. Two scenarios are considered here. A base scenario with only the conventional product being produced domestically and exported to the world market, followed by a scenario where both the GM and conventional products are produced and consumed in the small open economy.

No World Labeling. No Domestic GM Production or Consumption (Base Scenario 2).

In this scenario, only the conventional product is produced and consumed domestically. Similar to the previous cases, the small country is assumed to be an exporter of the conventional product. Hence, the domestic consumer price for the conventional product equals the world price of the non-labeled product:

$$p_{ngm} = p^*_{nl} \tag{48}$$

The domestic consumer and producer decisions in the absence of GM products from the small open economy are analyzed in the above sections entitled "*Consumer Decisions and Welfare in the Absence of GM Products*" and "*Producer Decisions and Welfare in the Absence of GM Products*," respectively.

Market Outcome. The equilibrium domestic supply of the conventional product is derived from Equations 12, 26, and 48 as

$$x^S_{ngm \ Eq.} = \frac{p^*_{nl} - IM_{ngm} - w_c}{\beta} \tag{49}$$

The domestic demand for the conventional product is (from Equations 4, 26, and 48)

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11. *Result 1 holds as long as the country remains an exporter of the conventional product after the introduction of GM products under a labeling regime, i.e., it holds no matter if the small open economy becomes an importer or an exporter of the GM product.*

$$x^D_{ngm \ Eq.} = \frac{p_s - p^*_{nl}}{\mu} \tag{50}$$

The quantity exported is, then,

$$Exports_{ngm \ Eq.} = \frac{\mu + \beta}{\beta\mu} p^*_{nl} - \frac{p_s}{\mu} - \frac{IM_{ngm} + w_c}{\beta} \tag{51}$$

and depends positively on the world price of the non-labeled product and the disutility associated with the consumption of the conventional product, and negatively on the price of the substitute in consumption, the marketing margin, the cost of conventional seed, and the cost-enhancement factor associated with the production of the conventional product.

Welfare Effects. Aggregate welfare in the economy is the sum of consumer and producer welfare, where

$$W^C_{ngm} = \frac{(p_s - p^*_{nl})^2}{2\mu} + \Omega \tag{52}$$

$$W^P_{ngm} = \frac{(p^*_{nl} - IM_{ngm} - w_c)^2}{2\beta} \tag{53}$$

Aggregate welfare depends positively on the world price of the non-labeled product and the price of the substitute product, and negatively on the marketing margin, the marginal cost of the conventional seed, the utility discount factor associated with the consumption of the conventional product, and the cost-enhancement factor associated with the production of this product.

No Labeling in the World Market. Domestic GM Production and Consumption under No Labeling.

In this scenario, some domestic producers supply GM products. Since the introduction of the producer-oriented GM product increases the domestic supply of the non-labeled product, and since the world price of the non-labeled product is exogenous to the small economy, the exportable surplus increases, assuring that the country continues to be an exporter in this second scenario. The external price condition is

$$p_{nl} = p^*_{nl}. \tag{54}$$

Consumer, producer and GM seed supplier decisions in the absence of a labeling regime are analyzed in the above sections entitled "*Consumer Decisions and Welfare under No Labeling in the Domestic and World Markets,*" "*Producer Decisions and Welfare under a No-Labeling Regime,*" and "*Supplier Decisions and Profits under a No-Labeling Regime,*" respectively.

Market Outcome. The equilibrium price and quantity of GM seed are, respectively (using Equations 21, 27, and 54 for the former, and Equations 22, 27, 54, and 55 for the latter),

$$w_{gm\,Eq.}^{nl} = \left(\phi\beta(p_{nl}^* - IM_{nl}) + \frac{\delta}{\beta} w_c \right) \frac{\theta}{(1+\theta)} + \frac{mc}{(1+\theta)} \quad (55)$$

$$x_{gm\,Eq.}^{S\,nl} = \frac{\beta\left(p_{nl}^* - IM_{nl} - mc\right) - \delta\left(p_{nl}^* - IM_{nl} - w_c\right)}{\delta\phi(1+\theta)}. \quad (56)$$

The equilibrium supply of the conventional product is (using Equations 14 and 55)

$$x_{c\,Eq.}^{S\,nl} = \frac{(p_{nl}^* - IM_{nl})}{\beta(1+\theta)} + \frac{mc}{\phi(1+\theta)} - \frac{\beta + \theta\phi}{\beta\phi(1+\theta)} w_c \quad (57)$$

and the total domestic supply of the unlabeled product is

$$x_{Total\,Eq.}^{S\,nl} = \frac{(\beta + \delta\theta)\left(p_{nl}^* - IM_{nl}\right)}{\beta\delta(1+\theta)} - \frac{mc}{\delta(1+\theta)} - \frac{\theta}{\beta(1+\theta)} w_c \quad (58)$$

The equilibrium quantity of the non-labeled product demanded domestically is (using Equations 5, 27, and 54)

$$x_{nl}^D = \frac{p_s - p_{nl}^*}{\psi\gamma + \mu} \quad (59)$$

where, under rational expectations,

$$\psi = \frac{x_{gm\,Eq}^{S\,nl}}{x_{Total\,Eq}^{S\,nl}} = \frac{\beta\left[\beta\left(p_{nl}^* - IM_{nl} - mc\right) - \delta\left(p_{nl}^* - IM_{nl} - wc\right)\right]}{\phi\left[\beta\left(p_{nl}^* - IM_{nl} - mc\right) + \delta\left(p_{nl}^* - IM_{nl} - wc\right)\right]}.$$

Welfare Effects. Consumer welfare, producer welfare, and GM seed suppliers' profits are, respectively,

$$W_{nl}^C = \frac{(p_s - p_{nl}^*)^2}{2(\psi\gamma + \mu)} + \Omega \quad (60)$$

$$W_{nl}^P = \frac{\left(p_{nl}^* - IM_{nl} - w_c\right)^2}{2\beta} + \frac{\left[\phi\left(p_{nl}^* - IM_{nl}\right) - \beta mc + \delta w_c\right]^2}{2\phi\delta\beta(1+\theta)^2} \quad (61)$$

$$W_{nl}^R = \frac{\theta\left[\phi\left(p_{nl}^* - IM_{nl}\right) - \beta mc + \delta w_c\right]^2}{\delta\beta\phi(1+\theta)^2} \quad (62)$$

Note that, since in this case the GM products are introduced in the small economy without a labeling regime, there are no segregation costs involved and $IM_{ngm} = IM_{nl}$. Comparing the welfare measures in Equations 60-62 to those under the Base Scenario 2 shows that the introduction of GM products results in a reduction in consumer welfare, an increase in producer welfare, and an increase in GM seed supplier profits, i.e.,

$$\Delta W^C = -\psi\gamma\frac{(p_s - p_{nl}^*)^2}{2\mu(\psi\gamma + \mu)} \le 0 \quad (63)$$

$$\Delta W^P = \frac{\left[\left(p_{nl}^* - IM_{nl}\right)\phi - \beta mc + \delta w_c\right]^2}{2\delta\beta\phi(1+\theta)^2} > 0 \quad (64)$$

$$\Delta W^R = W_{nl}^R \ge 0. \quad (65)$$

Obviously, the aggregate welfare effect will depend on the magnitude of the increase in producer welfare and GM seed suppliers' profits (if these suppliers are located in the small economy) relative to the reduction in consumer welfare. The horizontally striped area in Figure 8 panel (a) depicts the reduction in consumer welfare due to the likelihood of the (non-labeled) product being GM after the introduction of GM products in the domestic economy. The vertically striped area of panel (b) shows the increase in producer welfare due to the agronomic benefits of the GM technology.
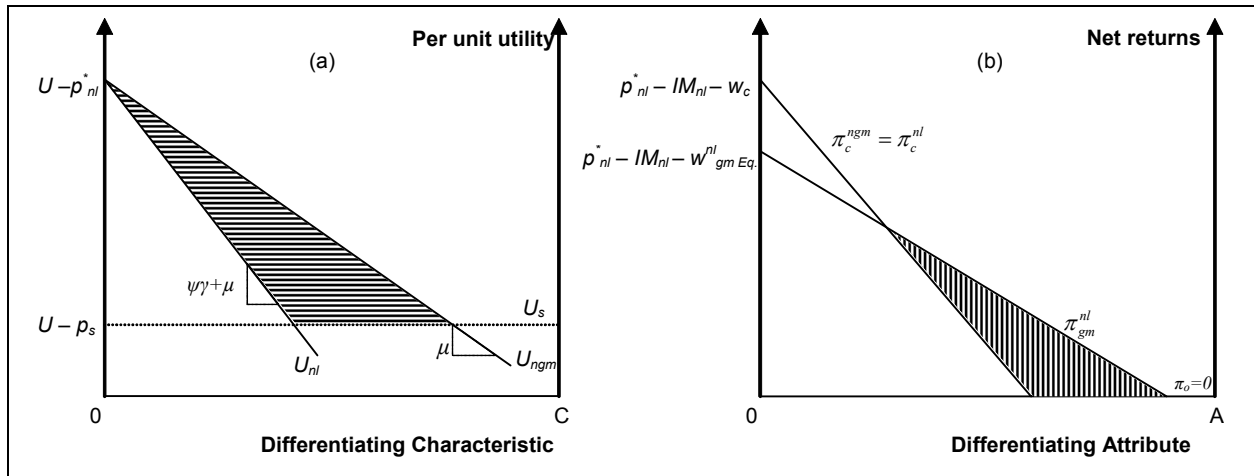
Figure 8. Welfare effects of GMO introduction in the small open economy under no-labeling in the domestic and world markets.

<u>*Result 2*</u>*:* The introduction of unlabeled GM products in a small open economy that has been an exporter of conventional products to the world market of unlabeled products has a positive effect on producer welfare and GM seed suppliers' profits, and a negative effect on consumer welfare.

Section IV: Effects of GMO Introduction under Non-Uniform Labeling Regimes in the World Market

In this section, we consider the empirically relevant case where countries with different labeling regimes trade GM and conventional products in the world market. In what follows, we will term as Market 1 the international market for labeled GM and conventional products and as Market 2 the international market for non-labeled products. The prices of labeled conventional and GM products traded in Market 1 are p^*_{C1} and p^*_{GM1}, respectively, and the price of non-labeled products traded in Market 2 is p^*_{NL2}.

Three scenarios are analyzed here. In the base scenario, only the conventional product is produced and consumed in the small open economy, and the surplus production is exported to Market 1. In the second scenario, both GM and conventional products are produced and consumed under a domestic labeling regime. The last scenario considers the case where both products are produced and consumed domestically under a no-labeling regime.

Non-uniform World Labeling. No Domestic GM Production or Consumption (Base Scenario 3).

The case in which only the conventional product is produced and consumed in the small economy is similar to the case examined in Base Scenario 1. The domestic surplus is exported to Market 1 at p^*_{C1}. All analytical results from this section apply, *mutatis mutandis* (i.e., by replacing p^*_C with p^*_{C1}), to this scenario.

Non-uniform World Labeling. Domestic GM Production and Consumption under Domestic Labeling.

The case in which the small open economy produces both GM and conventional products under a domestic labeling regime that matches the labeling regime in Market 1 is similar to the case of labeling in both the domestic and the world markets examined in the above section entitled "*World Labeling. Domestic GM Production and Consumption under Domestic Labeling*" (see Appendix 3). All analytical results from this section apply *mutatis mutandis* (i.e., by replacing p^*_C with p^*_{C1} and p^*_{gm} with p^*_{GM1}) to this scenario. The welfare effects of GMO introduction in the small open economy are then those described in *Result 1*.

Non-uniform World Labeling. Domestic GM Production and Consumption under No Labeling.

Consider finally the case where the GM product is produced and consumed in the small open economy under a no-labeling regime. The excess domestic supply is exported to Market 2 as a non-labeled product. Whereas

only non-labeled products are produced domestically, consumers may have access to labeled GM and conventional products imported from Market 1. The equilibrium prices of the three products are then

$$p_{nl} = p^*_{NL2} \tag{66}$$

$$p_{gm} = p^*_{GM1} \tag{67}$$

$$p_c = p^*_{C1}. \tag{68}$$

The relevant consumer, producer, and GM seed supplier decisions are analyzed in the above sections entitled "*Consumer Decisions and Welfare under Non-Uniform Labeling Regimes in the World Market,*" "*Producer Decisions and Welfare under a No-Labeling Regime,*" and "*Supplier Decisions and Profits under a No-Labeling Regime,*" respectively.

Market Outcome. The equilibrium domestic price and quantity of the GM seed are (using Equations 21, 27, and 66; and Equations 22, 27, and 66, respectively)

$$w^{nl}_{gm\ Eq.} = \left(\frac{\phi(p^*_{NL2} - IM_{nl}) + \delta w_c}{\beta} \right) \frac{\theta}{(1+\theta)} + \frac{mc}{(1+\theta)} \tag{69}$$

$$x^{S\ nl}_{gm\ Eq.} = \left(\frac{\phi(p^*_{NL2} - IM_{nl}) + \delta w_c - \beta mc}{\delta \phi} \right) \frac{1}{(1+\theta)} \tag{70}$$

The equilibrium quantity of the conventional product produced domestically is obtained from Equations 14, 21, 27, and 66 as

$$x^{S\ nl}_{c\ Eq.} = \frac{\theta}{\beta(1+\theta)} (p^*_{NL2} - IM_{nl})$$
$$- \frac{(\beta + \phi\theta)}{\beta\phi(1+\theta)} w_c + \frac{1}{\phi(1+\theta)} mc \tag{71}$$

The equilibrium total quantity of non-labeled product produced domestically is then

$$x^{S\ nl}_{Total\ Eq.} = \frac{\left(p^*_{NL2} - IM_{nl} - mc \right)}{\delta(1+\theta)} + \frac{\theta\left(p^*_{NL2} - IM_{nl} - w_c \right)}{\beta(1+\theta)} \tag{72}$$

The equilibrium domestic demands for GM, non-labeled, and conventional products are (from Equations 6-8 and 66-68)

$$x^D_{gmEq.} = \frac{p^*_{NL2} - p^*_{GM1}}{(1-\psi^*)\gamma} \tag{73}$$

$$x^D_{nl\ Eq.} = \frac{(1-\psi^*)p^*_{C1} + \psi^* p^*_{GM1} - p^*_{NL2}}{\psi^*\gamma(1-\psi^*)} \tag{74}$$

$$x^D_{c\ Eq.} = \frac{\psi^*\gamma(p_s - p^*_{C1}) - \mu(p^*_{C1} - p^*_{NL2})}{\mu\psi^*\gamma} \tag{75}$$

where, under rational expectations,

$$\psi^* = \frac{\beta\left[\beta\left(p^*_{NL2} - IM_{nl} - mc \right) - \delta\left(p^*_{NL2} - IM_{nl} - wc \right)\right]}{\phi\left[\beta\left(p^*_{NL2} - IM_{nl} - mc \right) + \delta\left(p^*_{NL2} - IM_{nl} - wc \right)\right]}.$$

Welfare Effects. Consumer welfare, producer welfare, and GM seed suppliers' profits are, respectively,

$$W^C = \frac{\left(p^*_{NL2} - p^*_{GM1}\right)^2}{2(1-\psi^*)\gamma} + \frac{\left(p^*_{C1} - p^*_{NL2}\right)^2}{2\psi^*\gamma} + \frac{\left(p_s - p^*_{C1}\right)^2}{2\mu} + \Omega \tag{76}$$

$$W^P = \frac{1}{2\phi}\left\{ \frac{\phi\theta\left(p^*_{NL2} - IM_{nl} - wc \right)}{\beta(1+\theta)} + \frac{(mc - w_c)}{(1+\theta)} \right\}^2$$
$$+ \frac{1}{2\delta}\left\{ \frac{(\beta+\delta\theta)\left(p^*_{NL2} - IM_{nl}\right)}{\beta(1+\theta)} - \frac{\delta\theta w_c}{\beta(1+\theta)} - \frac{mc}{(1+\theta)} \right\}^2 \tag{77}$$

$$W^R = \frac{\theta\left[\phi\left(p^*_{NL2} - IM_{nl}\right) + \delta w_c - \beta mc\right]^2}{\phi\delta\beta(1+\theta)^2}. \tag{78}$$

Consumer welfare change from the Base Scenario 3 is strictly positive (see Figure 9) and is given by

$$\Delta W^C = \frac{\left(p^*_{NL2} - p^*_{GM1}\right)^2}{2(1-\psi^*)\gamma} + \frac{\left(p^*_{C1} - p^*_{NL2}\right)^2}{2\psi^*\gamma} > 0. \tag{79}$$
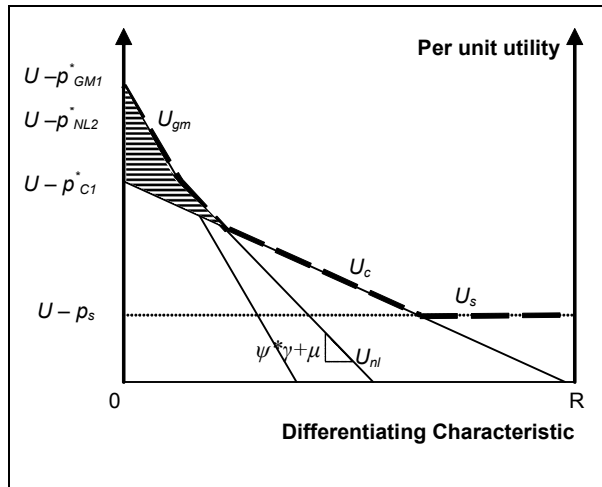
Figure 9. Change in consumer welfare due to GMO introduction under non-uniform labeling regimes in the world market and a domestic no-labeling regime.

Setting $p^*_{C1} - p^*_{NL2} = PP$ and $IM_{nl} = IM_{ngm}$, the change in producer welfare can be expressed as

$$\Delta W^P = \frac{\beta\left(p^*_{NL2} - IM_{ngm} - mc\right)^2 - \delta\left(p^*_{NL2} - IM_{ngm} - w_c\right)^2}{2\delta\beta(1+\theta)^2}$$
$$+ \frac{(w_c - mc)^2}{2\phi(1+\theta)^2} - \frac{PP}{\beta}\left(p^*_{NL2} + \frac{PP}{2} - IM_{ngm} - w_c\right)$$

(80)

and is of ambiguous sign.

Result 3: The introduction of GM products under a no-labeling regime in a small open economy that has been an exporter of conventional products to the international market for labeled products benefits consumers and GM seed suppliers and has an ambiguous effect on producer welfare.

Concluding Remarks

The focus of this study has been on the market and welfare effects of the introduction of GM crops in small open economies. The effects of the introduction of GM crops in small countries that have been exporters of conventional products have been shown to be case-specific and dependent on the a) labeling regime(s) in the world market, b) labeling regime in the domestic market, c) segregation costs and the marketing margins under the

different labeling scenarios, d) attitudes of domestic consumers towards GM products, e) price premium enjoyed by the non-GM crops in the world market, f) relative cost effectiveness of GM crops under local production conditions, and g) market power of GM seed suppliers.

An important implication of these results is that while the agronomic benefits associated with the first-generation, producer-oriented GM technology are certainly important, their presence does not guarantee a positive effect on aggregate domestic welfare. In fact, the agronomic benefits associated with the GM technology do not even assure gains in producer welfare as the introduction of GM products is shown to create winners and losers even among the producers of the small open economy.

Since the introduction of GM products creates winners and losers among the consumers and the suppliers of GM and conventional products, and since the identity of these winners and losers is shown to be affected by the domestic labeling regime, the regulatory and labeling decisions of small open economies can be expected to be affected by the incidence of (labeled and unlabeled) GM products and the relative weight placed by the regulator on the welfare of the different groups. In this context, an appropriate calibration of our model with data from small developing countries and a quantitative assessment of the effects of GMO introduction could provide policy makers and stakeholder groups with valuable insights both on the market potential of various biotechnology innovations and the likely effect of these innovations on the welfare of the interest groups involved.

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Appendix 1. Consumer surplus

Consumer surplus is measured as the area under the effective net utility curve. For the domestic and world labeling case, consumer surplus is represented by the sum of the areas A, B, and Ω in the following graph:
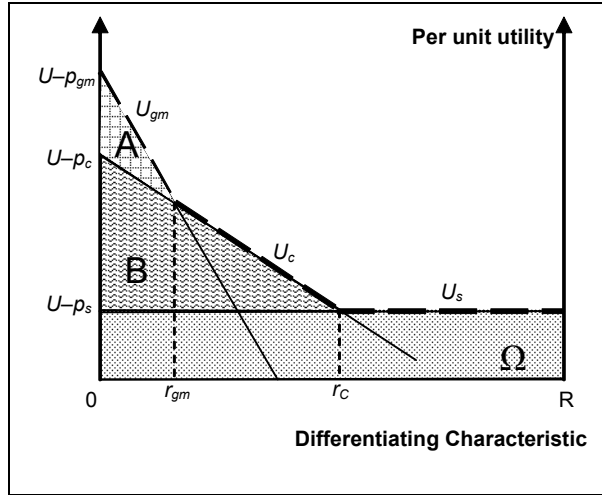
where

$$A = \int_{0}^{r_{gm}} U_{gm}dr - \int_{0}^{r_{gm}} U_c dr = \frac{(p_c - p_{gm})^2}{2\gamma}$$

(81)

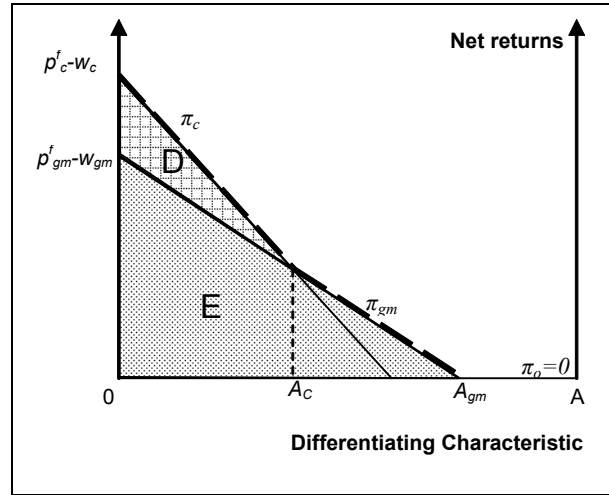$$B = \int_{0}^{r_c} U_c dr - \int_{0}^{r_c} U_s dr = \frac{(p_s - p_c)^2}{2\mu}$$

(82)

$$\Omega = \int_{0}^{R} U_s dr$$

(83)

Aggregate consumer welfare under domestic and world labeling is then

$$W_l^C = \frac{(p_s - p_c)^2}{2\mu} + \frac{(p_c - p_{gm})^2}{2\gamma} + \Omega$$

. (84)

Appendix 2. Producer welfare

Producer welfare is measured as the area under the effective net returns curve. For the domestic labeling case, producer welfare is represented by the sum of the areas D and E in the following graph:

where

$$D = \int_{0}^{A_C} \pi_c da - \int_{0}^{A_C} \pi_{gm} da = \frac{\left[\left(p_c^f - p_{gm}^f\right) + \left(w_{gm} - w_c\right)\right]^2}{2\phi}$$

(85)

$$E = \int_{0}^{A_{gm}} \pi_{gm} da = \frac{\left(p_{gm}^f - w_{gm}\right)^2}{2\delta}$$

(86)

Aggregate producer welfare under domestic labeling is then:

$$W_l^P = \frac{\left(p_{gm}^f - w_{gm}\right)^2}{2\delta} + \frac{\left[\left(p_c^f - p_{gm}^f\right) + \left(w_{gm} - w_c\right)\right]^2}{2\phi}$$

(87)

Appendix 3. Available products for domestic consumption and international trade.

		Small exporting country's labeling regime	
		GM & C labeled	**No labeling**
Uniform labeling regime in the world market	GM & C labeled	Section II: World Labeling. Domestic GM Production and Consumption under Domestic Labeling World market: GM, C Domestic market: GM, C Imports: GM Exports: C	N/A (see Section I: Consumer Decisions and Welfare under a Domestic and World Labeling Regime)
	No labeling	N/A (see Section I: Consumer Decisions and Welfare under No Labeling in the Domestic and World Markets)	Section III: No Labeling in the World Market. Domestic GM Production and Consumption under No Labeling World market: NL Domestic market: NL Imports: - Exports: NL
Non-uniform labeling regimes in the world market	Market 1: GM & C labeled Market 2: No labeling	Section IV: Non-uniform World Labeling. Domestic GM Production and Consumption under Domestic Labeling World market: GM, C, NL Domestic market: GM, C Imports: GM(M1) Exports: C(M1)	Section IV: Non-uniform World Labeling. Domestic GM Production and Consumption under No Labeling World market: GM, C, NL Domestic market: GM, C, NL Imports: GM(M1), C(M1) Exports: NL(M2)

Note: GM stands for genetically modified product, C for conventional product, and NL for non-labeled product. M1 and M2 in parentheses refer to export and import markets 1 and 2.