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# Market and Welfare Effects of Trade Disruptions from Unapproved Biotech Crops

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## **Abstract**

Genetically modified (GM) crops have been largely adopted in major exporting countries thereby representing a dominant share of a few key agricultural commodities that are traded in international markets. Regulatory reviews and approvals for the cultivation and marketing of GM crops, however, are country-specific and significant discrepancies in the amount of time required to review and approve new GM crops between importing and exporting countries has led to “asynchronous approvals”. Trade disruptions created by asynchronous approvals of GM crops are expected and can quickly deteriorate into effective trade bans because perfect segregation between approved and unapproved GM crops is difficult. The issues we examine in this paper are the potential market and welfare impacts from trade disruptions that might be caused by asynchronous regulatory approvals of new GM crops. We develop a trade model consisting of two composite importing countries and one exporting country. We first derive a baseline equilibrium where no unapproved events exists. When then derive a second equilibrium so that the market and welfare impacts of asynchronous approval on consumers and producers in each composite country can be analyze and discussed. We found that asynchronous approvals tend to increase prices, reduce consumer surplus and increase profits of producers of identity preserved commodities in all countries. However, we found that the aggregate quantities consumed and the profits of commodity producers are depend on the relative size of the export market in the countries where event are not approved.

## **Market and Welfare Effects of Trade Disruptions from Unapproved Biotech Crops**

Modern biotechnology methods have been used to enhance the performance and quality of crops for more than 30 years. Unlike most other crop genetic improvement methods, however, modern biotechnology and biotech crops are strictly regulated for food and environmental safety. All biotech or genetically modified (GM) crops are submitted to a battery of tests and regulatory scrutiny before they can be approved for commercialization. A number of GM crops have passed the regulatory hurdle and have been commercialized over the last twelve years. Indeed, since 1996, over one billion cumulative acres of GM soybeans, corn, cotton, canola, sugar beets, and other crops have been grown around the world (James 2007). Economists have estimated the social benefits from GM crops to be in the billions of dollars, with the benefits shared among the biotechnology innovators, agricultural producers, and consumers in both exporting and importing countries (Falk-Zepeda et al. 2004; Lapan and Moschini 2004; Konduru et al. 2008; Sobolevsky et al. 2005).

Because of their extensive adoption in major exporting countries, GM crops represent a dominant share of a few key agricultural commodities that are broadly traded in international markets. The trade of GM crops, however, has not always been uneventful. There are six documented cases where unapproved GM crops found their way into the food and feed supply chain: Starlink, Bt 10 corn, Prodigene corn, Liberty Link rice 601 and 604, and Event 32 corn. In some of these instances trade disruptions have followed (Schmitz et al. 2004, 2005; Carter and Smith 2005; Lin et al. 2003)

More recently, concerns about trade disruptions from unapproved GM crops have increased as the GM crop pipeline moving towards or awaiting regulatory approval has expanded while the speed of regulatory approvals across different countries has become less synchronized (Krueger and Buanec 2008; EC DG AGRI 2007; Backus et al.2008). To fully appreciate the problem one must be mindful of certain nuisances in the regulatory process of new GM crops.

Regulatory reviews and approvals for the cultivation and marketing of GM crops are country-specific. Hence, at some point in the R&D cycle, biotech crop developers must decide in which countries they must seek regulatory approval for their products. In this context, they must take into account not only the countries where the cultivation of the new biotech crops could take place (requiring regulatory approval for cultivation) but also where the consumption of such crops might ultimately occur (requiring regulatory approval for marketing and/or use). Given the large and expanding agricultural commodity trade flows across the globe, these considerations become complex as biotech developers must balance their desire for broad regulatory approval with practical budget constraints (Kalaitzandonakes, Alston and Bradford 2006).

Currently, nineteen countries have well-developed systems that handle submissions seeking regulatory approval for the cultivation and marketing of new GM crops while a number of others are in the process of developing theirs. There are, however, significant differences in the procedures of regulatory approval of GM crops used in different countries including the amount required to complete them (Kalaitzandonakes et al. 2006).

At one extreme the US, Canada, Japan and some other countries have continued to review and approve new biotech crops, at variable but similar speeds. At the other extreme,

the European Union (EU) has been slow and unpredictable in reviewing and approving new biotech crops. Indeed, the EU stopped considering petitions for regulatory approvals in 2001 and began reviewing regulatory dossiers in 2004 again, only after mandatory labeling laws and full traceability of foods and feeds along the EU supply chain were both implemented. This de facto moratorium on regulatory approvals of new GM crops prompted the filing of a WTO complaint by the US, Argentina and Canada in 2003. Yet even today when the EU has continued to review and approve new GM crops for marketing, the review process has, on average, taken almost twice as long as in the US (EC DG AGRI 2007; FEFAC 2007).

Significant discrepancies in the amount of time required to review and approve new GM crops has led to “asynchronous approvals.” Under such conditions, new GM crops can be cultivated and marketed for food and feed in some countries but not in others. This asynchronicity becomes a particularly difficult problem for broadly traded commodities as perfect segregation of approved from unapproved GM crops is difficult within the global agricultural commodity system. Identity preservation (IP) systems and analytical GMO testing can be used but segregation is less than perfect and subject to measurement uncertainty and added costs. Under these conditions trade disruptions are expected and can quickly deteriorate into effective trade bans.

What are the potential market and welfare impacts from trade disruptions that might be caused by asynchronous regulatory approvals of new GM crops? This is the key question we examine in this paper. A handful of empirical studies have tackled this issue in the context of specific market disruptions from specific unapproved GM crop in some market. Schmitz et al. (2004, 2005) examined the price impacts caused by the trade

disruptions from Starlink corn using a partial equilibrium model while Carter and Smith (2005) examined the same issue through a time series analysis.

Brookes and Barfoot (2008) used industry case studies to examine the price impacts of trade disruptions in the EU rice market caused by the discovery of Liberty Link Rice in the US as well as similar interruptions in the supply of certain food ingredients. DG AGRI of the EU Commission (2007) used partial equilibrium analysis to examine the price impacts of both actual trade disruptions (in the case of the EU corn gluten feed market) and potential ones (in the case of the EU soybean meal and oil markets). Hence, both Brookes and Barfoot (2008) and DG AGRI (2007) were primarily interested in the price impacts on EU consumer food products caused by trade disruptions associated with the presence of unapproved GM crops in the market.

For the current paper, we are interested in the impacts the trade disruptions have on the prices paid by the consumers and on consumer consumption levels. We are also interested in how producer profits are affected and in the end what are the net welfare effects from all relevant changes. We begin our analysis by setting up a relevant trade model and deriving the baseline equilibrium conditions when no unapproved GM crops exist. Then we introduce regulatory asynchronicity and relevant trade disruptions and analyze the market and welfare impacts.

### **Market and Welfare Effects of Trade Disruptions from Unapproved Biotech Crops**

In setting up the model we develop for the analysis in this paper, we assume that there are two separate supply chains – one that moves identity preserved (IP) crops which are strictly segregated and analytically tested to exclude all GM crops. Identity preservation

procedures and GMO testing imply added costs. There is also a commodity supply chain that moves crops that are not identity preserved (NIP).

We assume consumers to be heterogeneous in their preferences towards NIP and IP products. Because we assume heterogeneous consumer preferences, we also assume separate markets for IP and NIP products. There is also a market for a product, S, that substitutes for the commodity NIP.

We assume that there are two importing countries and one exporting one. The trade flows between the exporting and importing countries represent net exports and imports. Hence, while an importing country might have a production and export sector, its demand deficit and net import position fully describes it in the model. The same principle applies for the exporting country. Because of this set up, the exporting country is where producers are and the importing countries where the consumers are<sup>1</sup>.

When an importing country has not approved a given GM crop for marketing, the particular GM crop cannot be legally traded in the market of this country. This implies that when the unapproved GM crop is produced in an exporting country, unless specific segregation and testing efforts are expended to exclude the GM crop from the commodity supply chain, it may likely be present. IP crops therefore ensure that the unapproved GM crop is absent from any given shipment. NIP commodities, however cannot. This implies trade restrictions on NIP commodities from the exporting country to the importing country that has not approved the particular GM crop. Because of measurement uncertainty and segregation, testing and rejection costs, these implied trade restrictions typically amount to effective export bans of the NIP commodities to the importing country.

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<sup>1</sup> Relaxing this assumption and including producers and consumers in all countries complicates the set up but does not change the essential results I will present here.



Based on these assumptions, we can now begin to analyze the pricing strategies of producers in the exporting country and the buying decisions of consumers in the importing countries. In this context, we first establish equilibrium prices and quantities under a benchmark case where there are no trade restrictions. Then, in the next section we build on this framework to analyze the effects of unapproved GM crops on trade and on the welfare of producers and consumers.

*Consumer choice and market demand*

For our analysis, we follow Giannakas and Fulton (2002) and Fulton and Giannakas (2004) to model IP and NIP products as vertically differentiated goods. In this type of model, consumers rank the two products uniformly (i.e., all consumers prefer the IP product if offered at the same price as the NIP) but they differ in their valuation of the perceived quality differences.

Each consumer determines whether to buy a single unit of either the IP or the NIP product. If consumers do not buy either of those products, they buy one unit of a substitute product S. We do not consider income effects so we assume that consumers spend only a small fraction of their total expenditures on these goods. Consumers are differentiated with respect to the characteristic  $m$  which captures the heterogeneity of their preferences relative to the IP and NIP products. Based on these assumptions, the consumer utility functions can be expressed as:

$$U_{IP}^k = U - P_{IP}^k + \mu m \tag{1}$$

if a unit of IP product is consumed

$$U_{NIP}^k = U - P_{NIP}^k + \lambda m \tag{2}$$

if a unit of NIP product is consumed

$$U_S^k = U \tag{3}$$

if a unit of substitutes product is consumed

$U_{IP}^k$ ,  $U_{NIP}^k$  and  $U_S^k$  are the utilities associated with the consumption of one unit of the IP, NIP and S products, respectively. The parameter U is a unit base level of utility.

$P_{IP}^k$  and  $P_{NIP}^k$  are the unit prices of IP and NIP products respectively, and k denotes either country A or country B. We assume that  $P_{IP}^k > P_{NIP}^k$  to allow for a positive market share of the NIP product.

The parameters  $\mu$  and  $\lambda$  are utility enhancement factors associated with the consumption of IP and NIP products, respectively. The parameter  $\lambda < \mu$  since all consumers prefer the IP product if offered at the same price. Consumers are assumed to be uniformly distributed between the polar values of the preference parameter  $m$ ,  $m \in (0,1)$ . A  $m$  value of zero corresponds to consumers who are indifferent between the IP and NIP while a  $m$  value of one corresponds to consumers for which the perceived difference between the two products is strongest. Combining the value of the preference parameter and the utility discount factors,  $m(\mu - \lambda)$  denotes the degree of aversion to the NIP product for a consumer with differentiating attribute  $m$ .

A consumer's choice is determined by the relationship between the utilities derived from IP, NIP and S products – net of price. The consumer with characteristic  $m_{NIP}^k$  is indifferent between consuming a unit of IP and NIP product and derives the same utility from the consumption of either product when:

$$U_{IP}^k = U_{NIP}^k \Leftrightarrow U - P_{IP}^k + \mu m_{NIP}^k = U - P_{NIP}^k + \lambda m_{NIP}^k$$

Solving this equation for  $m_{NIP}^k$  yields

$$m_{NIP}^k = \frac{P_{IP}^k - P_{NIP}^k}{\mu - \lambda} \quad (4)$$

Along the same lines, a consumer with characteristic  $m_S$  is indifferent between the NIP product and S-type product when the following conditions hold:

$$U_{NIP}^k = U_S^k \Leftrightarrow U - P_{NIP}^k + \lambda m_{IP}^k = U$$

Solving this equation for  $m_S^k$  yields

$$m_S^k = \frac{P_{NIP}^k}{\lambda} \quad (5)$$

These consumer choices can be illustrated for more clarity. As indicated in figure 1, consumers for whom  $m \in (m_{NIP}^k, 1)$  buy the IP product. Consumers for whom  $m \in (m_S^k, m_{NIP}^k)$  buy the NIP commodity. And consumers for whom  $m \in (0, m_S^k)$  consume the S product. Since we have assumed that the consumers are uniformly distributed with respect to  $m$  and that the consumption of each individual is restricted to one unit of either product, the demand for the IP product is given by  $1 - m_{NIP}^k$ ; the demand for the NIP commodity by  $m_{NIP}^k - m_S^k$ , the demand for the S products by  $m_S^k$ . Based on the value of the parameters derived in equation (4) and (5) we derive the demand for each product as a function of the prices and utility discount factors as follows:

$$\begin{aligned}
x_{IP}^k &= \frac{\mu - \lambda - P_{IP}^k + P_{NIP}^k}{\mu - \lambda} \\
x_{NIP}^k &= \frac{\lambda P_{IP}^k - \mu P_{NIP}^k}{\lambda(\mu - \lambda)} \\
x_S^k &= \frac{P_{NIP}^k}{\lambda}
\end{aligned} \tag{6}$$

Conditions in (6) conform to basic economic theory since the demand for the IP commodity and the NIP commodity increase as the prices decrease and vice versa. However, the demand for the IP product also decreases as the price of the NIP commodity increases. The same logic applies for the demand of the NIP commodity which indicates that the two goods are substitutes. Since the NIP commodity substitutes also for the substitute product, an increase in the price of the NIP commodity will contribute to an increase both in the demand for the substitute product and in the demand of the NIP commodity. Condition (6) also indicates that if  $P_{NIP}^k$  is greater than  $P_{IP}^k$ , the NIP commodity will be driven out of the market and the market share of the NIP commodity will become zero. Figure 1 provides a graphical representation of the utility curves derived and the quantities demanded for all three types of products.

#### *Equilibrium prices and quantities*

The two importing countries are denoted here by  $A$  and  $B$ . As we indicated earlier, the relative market size of the two importing countries is an important consideration in this analysis. We incorporate such consideration in the model by specifying the ratio of the market size in country  $A$  relative to that in country  $B$  as  $\beta$ . This implies that the number of consumers in country  $B$  is  $\beta$  times greater than in country  $A$ . Assuming that the aggregate

preferences of consumers in both importing countries are the same we can then relate consumption in the two importing countries by the following conditions:

$$\begin{aligned}
 x_I^B &= \beta x_{IP}^A \\
 x_{NIP}^B &= \beta x_{NIP}^A \\
 x_S^B &= \beta x_S^A
 \end{aligned} \tag{7}$$

Aggregating the demand in the two importing countries we obtain

$$\begin{aligned}
 x_I &= x_{IP}^A + x_{IP}^B \\
 x_{NI} &= x_{NIP}^A + x_{NIP}^B \\
 x_S &= x_S^A + x_S^B
 \end{aligned} \tag{8}$$

Since we are interested in the aggregate quantities consumed across the two countries, and to simplify the notation, from this point forward we drop the superscripts indexing each country.

In order to derive the equilibrium conditions in our trade model, we assume that because of arbitrage, the prices for each product in the two importing countries are equal. In other words, it is not possible to make a profit by purchasing the commodity in one of the importing countries at a discount and reselling it in the other importing country at a premium. In reality, transport and transaction costs would likely differ across different destinations for an export country but explicitly incorporating such differences would not change the analysis in any way. By combining the system of equations in (6) and (8) we derive the inverse aggregate demand curves for each of the products:

$$\begin{aligned}
 P_{NIP} &= \frac{\lambda[P_{IP}(1+\beta) - (\mu-\lambda)x_{NIP}]}{\mu(1+\beta)} \\
 P_{IP} &= P_{NIP} + \frac{(\mu-\lambda)(1+\beta-x_{IP})}{(1+\beta)}
 \end{aligned} \tag{9}$$

Equation (9) implies that the prices of the two products are positively related and move in the same direction. Based on those inverse demand curves, we can also derive the marginal revenue curves which are illustrated in Figure 2 for each type of exporter. The inverse demand curve and the marginal revenue curve for each product have the same intercept which can be obtained by setting  $x_{NIP}$  and  $x_{IP}$  equal to 0 in the system of equations in (9). The intercept for the demand and the marginal revenue curve for the NIP type and the IP type product are therefore  $\lambda P_{IP} / \mu$  and  $P_{NIP} + (\mu - \lambda)$

The slope of the marginal revenue curve is equal to  $(1 + \theta)^2$  time the slope of the demand curve, where the parameters  $\theta$  represent conjectural variations elasticities capturing the degree of market power of the exporters (Tirole, 1988). Using equation (9) again we derive the slope of the marginal revenue curve for the IP and NIP products which are, respectively,

$$\frac{-(\mu - \lambda)(1 + \theta)}{(1 + \beta)}$$

and  $\frac{\lambda(\mu - \lambda)(1 + \theta)}{\mu(1 + \beta)}$

In oligopolistic models, a conjecture refers to the expectations that a firm has about the reaction of other firms. In our model the conjectural variation elasticities  $\theta$  indicates that a given firm believes that increasing the quantities it produces by one unit will induce all other firms to increase the aggregate quantity they produce by  $\theta$  units. Hence a value of 0 for the parameter  $\theta$  implies that the firm believes that the quantity it chooses will not affect the quantities chosen by other firms. The slope and intercept equations derived

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<sup>2</sup> For the sake of simplicity, I assume that conjectural variations elasticities are the same for both IP and NIP products but the results in this paper are qualitatively the same if conjectural variations elasticities are different for each product type.

above also indicate that a value of 0 for the parameter  $\theta$  means that the marginal revenue curve and the demand curve coincide as in the case of perfect competition. A value of 1 for the parameter  $\theta$  implies that the firm believes it is the only firm in the market since a one unit increase on its part will lead to the same unit increase in the aggregate. The slope equations also indicate that a value of 1 for the parameter  $\theta$  means that the slope of the marginal revenue curve is twice as large in absolute value as the slope of the demand curve, as in the case of a monopoly market structure defined by a linear demand.

Revenue maximization by the exporter implies that the marginal cost equals marginal revenue. Based on the slope and intercept of the marginal revenue curve derived earlier, the following must hold:

$$MR_{NIP} = \lambda P_{IP} / \mu - \frac{\lambda(\mu - \lambda)(1 + \theta)}{\mu(1 + \beta)} x_{NIP} = C_{NIP}$$

$$MR_{IP} = P_{NIP} + (\mu - \lambda) - \frac{-(\mu - \lambda)(1 + \theta)}{(1 + \beta)} x_{IP} = C_{IP}$$

where  $C_{IP}$  and  $C_{NIP}$  are the marginal costs faced by the exporters of the IP and NIP products. Solving the two equations, we obtain the quantities that maximize revenue for each product type

$$\begin{aligned} x_{IP} &= \frac{(1 + \beta)(C_{IP} - P_{NIP} + \lambda - \mu)}{(1 + \theta)(\lambda - \mu)} \\ x_{NIP} &= \frac{(1 + \beta)(P_{IP}\lambda - C_{NIP}\mu)}{(1 + \theta)\lambda(\mu - \lambda)} \end{aligned} \tag{10}$$

Substituting those expressions for the values obtain in system (9) and solving simultaneously for the prices, we derive the equilibrium prices expressed uniquely as a function of the exogenous parameters of the model:

$$P_{IP} = \frac{-C_{IP}(1+\theta)\mu - C_{NIP}\mu\theta + \mu(1+\theta)(\lambda - \mu)}{\lambda\theta^2 - \mu(1+\theta)^2} \quad (11)$$

$$P_{NIP} = \frac{\lambda\theta(\lambda\theta - C_{IP}) - (C_{NIP} + C_{NIP}\theta + \lambda\theta^2)\mu}{\lambda\theta^2 - \mu(1+\theta)^2} \quad (12)$$

Substituting those expressions for the values obtained in (10) we can also derive the equilibrium quantities expressed uniquely as a function of the exogenous parameters of the model:

$$x_{IP} = \frac{(1+\beta)[C_{IP}\theta\lambda - C_{IP}(1+\theta)\mu - (C_{NIP} - (1+\theta)(\lambda - \mu))\mu]}{\lambda(\lambda - \mu)[\lambda\theta^2 - \mu(1+\theta)^2]} \quad (13)$$

$$x_{NIP} = \frac{(1+\beta)\mu[C_{IP}\lambda + C_{NIP}\theta\lambda - C_{NIP}\mu(1+\theta) + \lambda\theta(\mu - \lambda)]}{\lambda(\lambda - \mu)[\lambda\theta^2 - \mu(1+\theta)^2]} \quad (14)$$

Finally, the profit equations can be readily obtained from the price and quantities in (11) through (14) as follows:

$$\Pi_{IP} = (P_{IP} - C_{IP})x_{IP} = \frac{-(1+\beta)\theta[C_{IP}\lambda\theta - C_{IP}(1+\theta)\mu + (C_{NIP} - (1+\theta)(\lambda - \mu))\mu]^2}{(\lambda - \mu)[\lambda\theta^2 - (1+\theta)^2\mu]^2} \quad (15)$$

$$\Pi_{NIP} = (P_{NIP} - C_{NIP})x_{NIP} = \frac{-(1+\beta)\theta\mu[C_{IP}\lambda + C_{NIP}\theta\lambda - C_{NIP}(1+\theta)\mu + \lambda\theta(\mu - \lambda)]^2}{\lambda(\lambda - \mu)[\lambda\theta^2 - (1+\theta)^2\mu]^2} \quad (16)$$

### **Impact of trade restrictions on unapproved biotech crops**

As we explained in the previous section, when an importing country has not approved a given GM crop for consumption, the particular GM crop cannot be legally traded in the market of this country. Because of measurement uncertainty and large segregation, testing and rejection costs, we assume here that the implied trade restrictions will amount to an effective export bans of the NIP commodities to the importing country that has not



approved it. Here we assume that regulatory authorities in importing country *A* have approved all GM crops that are currently commercially available but that regulatory authorities in importing country *B* have not yet approved one of these GM crops. Based on all these, we assume that the exporting country can ship NIP and IP products to the importing country *A* but only IP products to importing country *B*. The substitute product *S* can also be consumed in both importing countries. Based on these assumptions, the aggregate demand curves for both importing countries are expressed as follows:

$$\begin{aligned}
x_I &= x_{IP}^A + x_{IP}^B \\
x_{NI} &= x_{NIP}^A + 0 = x_{NIP}^A \\
x_S &= x_S^A + x_S^B
\end{aligned} \tag{17}$$

Following similar procedures as in the previous section, we can derive the inverse demand functions, which are specified as:

$$\begin{aligned}
P_{NIP} &= \frac{\lambda}{\mu} [P_{IP} - (\mu - \lambda)x_{NIP}] \\
P_{IP} &= \frac{P_{NIP} + (x_{IP} - \beta - 1)(\lambda - \mu)\mu}{\mu + \beta(-\lambda + \mu)}
\end{aligned} \tag{18}$$

As in the case of the baseline, the prices of the two products are positively related and move in the same direction. Following the steps as in the baseline, we can now obtain the equilibrium prices and quantities for this scenario:

$$P_{IP}'' = \frac{-\theta(C_{NIP} - (1 + \beta)(1 + \theta)(\lambda - \mu))\mu + C_{IP}(1 + \theta)(\lambda\beta - (1 + \beta)\mu)}{(\theta^2 + \beta(1 + \theta^2)\lambda - (1 + \beta)(1 + \theta)^2\mu)} \tag{19}$$

$$P_{NIP}'' = \frac{C_{IP}\theta\lambda(\beta\lambda - (1 + \beta)\mu) - \mu[-(1 + \beta)\lambda\theta^2(\lambda - \mu) + C_{NIP}(1 + \theta)(\mu + \beta(\mu - \lambda))]}{\mu[(\theta^2 + \beta(1 + \theta^2)\lambda - (1 + \beta)(1 + \theta)^2\mu]} \tag{20}$$

$$x_{IP}'' = \frac{(\beta\lambda - (1+\beta)\mu)(-C_{IP}(\beta + \theta + \beta\theta)\lambda + C_{IP}(1+\beta)(1+\theta)\mu - C_{NIP} - (1+\beta)(1+\theta)(\lambda - \mu))\mu}{(\lambda - \mu)\mu[(\theta^2 + \beta(1+\theta^2)\lambda - (1+\beta)(1+\theta)^2\mu]} \quad (21)$$

$$x_{NIP}'' = \frac{-\mu[-C_{NIP}(\beta + \theta + \beta\theta)\lambda + (1+\beta)\lambda\theta(\lambda - \mu) + C_{NIP}(1+\beta)(1+\theta)\mu] + C_{IP}\lambda(\mu + \beta(\mu - \lambda))}{(\lambda - \mu)\lambda[(\theta^2 + \beta(1+\theta^2)\lambda - (1+\beta)(1+\theta)^2\mu]} \quad (22)$$

### *Market Effects*

By comparing equations (10) and (11) with equations (19) and (20), we can show that the prices of both the IP and NIP commodities increase once a ban on NIP commodity exports to country *B* are imposed. That is,

$$P_{IP}'' - P_{IP} = \frac{\theta\beta(1+\theta)(\lambda - \mu)(C_{IP}\theta\lambda + (C_{NIP}(1+\theta) - \lambda(1+2\theta)\mu))^2}{(\theta^2\lambda - (1+\theta)^2\mu)[(\theta^2 + \beta(1+\theta)^2\lambda - (1+\beta)(1+\theta)^2\mu]^2} > 0$$

$$P_{NIP}'' - P_{NIP} = \frac{\theta\beta^2\lambda(\lambda - \mu)(C_{IP}\theta\lambda + (C_{NIP}(1+\theta) - \lambda(1+2\theta)\mu))^2}{\mu(\theta^2\lambda - (1+\theta)^2\mu)[(\theta^2 + \beta(1+\theta)^2\lambda - (1+\beta)(1+\theta)^2\mu]^2} > 0$$

Those inequalities can be shown to hold as long as the NIP commodity is not driven out of the market in the baseline.

The disappearance of NIP commodity in country *B* creates the equivalent of a shift to the right of the demand for the IP product in this country. As a result, consumer prices for the IP product in country *B* would tend to increase. However, because of arbitrage the price of the IP product would also increase in country *A*. The mechanism of price transmission attenuates the rise in price in country *B* but implies that consumers in country *A* now also pay higher price for the IP product.

While the increase in the price of IP products is intuitively expected, the increase in the price of the NIP products is somewhat more surprising. However, as the conditions in (18) establish, the prices of IP and NIP products would tend to move in the same direction

due to their substitutability. The implication here is that the price increase for the IP product that started in country *B* spills over to country *A* and eventually also results in higher NIP commodity prices even though their consumption occurs only in country *A*. Hence, even if the regulatory authorities in country *A* work diligently to provide regulatory approvals that allow trade to continue in an orderly fashion, regulatory delays in other countries can still lead to higher prices both for the IP crops and the NIP commodities.

Trade disruption in one of the importing countries also affects the total quantities consumed of each of the products. By comparing the equations (21)-(22) to equations (12)-(13), we can infer that the aggregate demand for I-type and S-type products increases, i.e.,  $(x_{IP}'' + x_S'') > (x_{IP} + x_S)$ . However, the equilibrium quantity for the IP product alone could decrease if the ratio of market size  $\beta$  is larger than a critical value<sup>3</sup>  $\beta_{IP}^x$ , or:

$$\beta > (\leq) \beta_{IP}^x \Leftrightarrow x_{IP}'' < (\geq) x_{IP}$$

Once again, this result appears less than intuitive since it could be expected that the overall quantities of the IP product would increase after the NIP commodity is banned in country *B*. However, the results have indicated that this is not necessarily the case. As we have shown above, the price of the IP product in country *A* where there are no trade restrictions would increase. As a response to this price increase, demand for the IP product tends to decrease in country *A*. If the demand for the IP product in country *B* does not increase enough to make up the difference then the overall quantity of the IP product would tend to decrease. Indeed, depending on the degree of market power in the export

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<sup>3</sup> The critical market size value can be shown to be:

$$\beta_{IP}^x = \frac{(-C_{IP}\lambda(\theta^3(\lambda - \mu)^2 + \mu^2 + 2\theta\mu^2 + 2\theta^2\mu(-\lambda + \mu)) + \mu(\theta^2(1 + \theta)\lambda(\lambda - \mu)^2 + C_{NIP}(\mu^2 2\theta\mu^2 + \theta^2(-\lambda^2 + \mu^2))))}{((1 + \theta)(\lambda - \mu)(C_{IP}\lambda(\theta^2(\lambda - \mu) - \mu - \theta\mu) + \mu(C_{NIP}\mu + C_{NIP}\theta\mu + \theta^2\lambda(-\lambda + \mu)))}$$

market to country  $B$ , exporters may reduce their supply at the same time they increase prices – as economic theory would predict. Supply declines may be exacerbated if the demand for the IP product in country  $B$  becomes more inelastic after the disappearance of the NIP commodity. As a result, the equivalent of the shift to the right for the IP product may not be enough to compensate for these quantity reductions. As the size of country  $B$  increases and the potential profit for the IP product increases in this country, it may be more profitable for exporters to restrict overall quantities.

A similar result is derived for the change in the equilibrium quantity of the NIP commodity. The equilibrium quantity for the IP product decreases when the ratio of market size  $\beta$  is more than the critical value<sup>4</sup>  $\beta_{NIP}^x$

$$\beta > (\leq) \beta_{NIP}^x \Leftrightarrow x_{NIP}'' < (\geq) x_{NIP}$$

If the market size in country  $B$  is large, then banning NIP exports in this market could contribute to a decline in the overall quantity of the NIP commodity consumed. The reasoning is similar as above. The restriction of NIP exports to country  $B$  leads to higher prices for both IP and NIP product. When the price of the IP product increases, the demand for the NIP commodity can become more inelastic. As a result, if exporters of NIP commodities exercise market power, they may find it profitable to reduce their supplies (exports) to consumers in country  $A$ .

It is also possible that the quantity of the NIP consumed may increase. This result is less intuitive especially since its price increases and it is also banned from country  $B$ . However, if the price of the IP product increases relatively more than the price of the NIP

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$\beta_{NIP}^x = (C_{IP}\lambda(\mu^2 + 2\theta\mu^2 + \theta^2(-\lambda^2 + \mu^2)) - \mu(-\theta(1+\theta)^2\lambda(\lambda-\mu)^2 + C_{NIP}(\theta^3(\lambda-\mu)^2 + \mu^2 + \theta^2(\lambda^2 - 4\lambda\mu + 3\mu^2) + \theta(\lambda^2 - 2\lambda\mu + 3\mu^2)))/((1+\theta)^2(\lambda-\mu)\mu(C_{IP}\lambda + \theta\lambda(-\lambda+\mu) + C_{NIP}(\theta\lambda - \mu - \theta\mu)))$

commodity, then some consumers that were previously buying the IP product in country A would now consume the NIP commodity.

We can now summarize the main results on market effects as follows:

Result 1: Trade restrictions because of asynchronous approvals of a new GM crop in a given importing country will tend to increase the prices of identity-preserved (non-GMO) and NIP commodities, irrespective of the size of the importing country imposing the restrictions.

Result 2: The effect of trade restrictions on the equilibrium quantities of IP and NIP commodities depends on the relative size of the market (country) where the restrictions are imposed. For each product, if the relative size of this country is larger than some critical value, then the aggregate quantity consumed in both countries will decrease.

#### *Welfare effects - exporter profits*

Based on the prices and quantities derived above, we can now calculate the profits of IP and NIP product exporters as follows:

$$\Pi_{IP}'' = \frac{\theta(\beta\lambda - (1 + \beta)\mu)(C_{IP}(\beta + \theta + \beta\theta)\lambda - C_{IP}(1 + \beta)(1 + \theta)\mu + C_{NIP} - (1 + \beta)(1 + \theta)(\lambda - \mu))\mu^2}{\mu(\lambda - \mu)[(\theta^2 + \beta(1 + \theta)^2\lambda - (1 + \beta)(1 + \theta)^2\mu]^2} \quad (23)$$

$$\Pi_{NIP}'' = \frac{-\theta C_{IP}\lambda(\beta\lambda - (1 + \beta)\mu) + \mu(-C_{NIP}(\beta + \theta + \beta\theta)\lambda + (1 + \beta)\theta\lambda(\lambda - \mu) + C_{NIP}(1 + \beta)(1 + \theta)\mu)^2}{\lambda\mu(\lambda - \mu)[(\theta^2 + \beta(1 + \theta)^2\lambda - (1 + \beta)(1 + \theta)^2\mu]^2} \quad (24)$$

By comparing equations (15)-(16) with equations (23)-(24), it follows that the profits of IP exporters increase irrespective of the market size parameter  $\beta$ , i.e.

$$\beta > 0 \Leftrightarrow \Pi_{IP}'' > \Pi_{IP}.$$

This result appears to be consistent since the trade restrictions of the NIP commodity in country B create the equivalent of a shift in demand to the right for the IP

product. Quantities of the NIP commodity may increase or decrease but the price of the IP product would always rise in response to the restrictions. The profit of NIP-type exporter, however, can decrease if the relative size of the country  $B$  is more than a critical value<sup>5</sup>

$\beta_{NIP}^{\Pi}$  :

$$\beta > (\leq) \beta_{NIP}^{\Pi} \Leftrightarrow \Pi_{NIP}'' < (\geq) \Pi_{NIP}.$$

The producers of the NIP commodity may benefit from the price increase induced by the complementarities between the IP of the NIP commodity. However, the price increase of the NIP commodity may not be large enough to compensate for the overall drop in quantity from the export restrictions. In the case where the market of country  $B$  is large, the profits of the NIP-type exporter would tend to decrease.

We can now summarize the main results regarding the impact of the trade restrictions on the exporters' profits:

Result 3: Trade restrictions implied by the asynchronous approval of a new GM crop in an importing country will tend to increase the profits of the IP exporter, irrespective of the size of the country imposing the trade restrictions.

Result 4: Trade restriction because of the asynchronous approval of a new GM crop in an importing country will tend to decrease the profits of NIP commodity exporters if the relative size of the importing country imposing the restrictions is larger than some critical value.

### *Consumer welfare*

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<sup>5</sup>  $\beta_{NIP}^{\Pi}$  = The expression is too large to be show here butit will be provided on request.

The change in the aggregate consumer welfare due to trade restrictions from the presence of an unapproved GM crop imposed by importing country *B* can be observed from Figures 3 and 4. Before the trade restrictions were put in place, consumer welfare was represented by area under the line *abcd* in Figure 1 which corresponds to the area under the highest utility curve each consumer can reach. Figure 3 which corresponds to the market in country *A*, shows that the utility curves for both the IP and NIP commodities will shift downward after the trade restriction is put in place. The downward shift of the utility curve is entirely explained by the increase in the prices of both products. As result, welfare declines in the importing country *A* for both the consumers of IP and NIP products. The loss is represented as the area *befdc* in Figure 3. There may be situations when the quantity of the NIP commodity increases as consumers shift away from the IP product due to relevant price increases. But even in this case, the welfare of the consumers in country *A* decreases.

Figure 4, which corresponds to the market in importing country *B* shows that the utility function for the IP product shifts downward after the trade restriction is in place because of the corresponding price increase. Since the NIP commodity is effectively banned from the market, the utility function for this product disappears completely. Some of the consumers who were buying the NIP commodity may now consume the IP products but the overall welfare decreases for those consumers who were consuming either the IP or the NIP commodity. The loss of consumer welfare in the importing country *B* is represented by the area *befdc* in Figure 4.

Based on these results, we can now summarize the impacts from the effective trade ban due to the lack of regulatory approval for certain new GM crops on consumer welfare as follows:

Result 5: In an importing country where certain new GM crops are not approved, consumer welfare will tend to be reduced due to the rise in prices of the IP products and the disappearance of the NIP commodity caused by the implied trade restrictions.

Result 6: In an importing country where all current commercial GM crops have been approved, consumer welfare will tend to be reduced due to the rise in the prices of both IP and NIP products imposed by market disruptions caused by asynchronous approvals in other importing countries.

### **Synthesis of Results and Concluding Comments**

In this paper, we have derived the market and welfare effects of trade disruptions from the presence of unapproved GM crops in international agricultural commodity markets. We have developed a stylized but general trade model which allows for heterogeneous consumer preferences; segmentation of commodity and identity preserved non-GM markets; possible market power in different markets; and consideration of market size among importing countries with asynchronous approvals and restricted trade flows.

The results of our analysis appear consistent with observed behavior of various stakeholders in exporting and importing countries lending credence to their generality. A key result from the analysis suggests that the profits of exporters of agricultural commodities would tend to suffer when trade restrictions are imposed by importing countries that are large in size because of the presence of unapproved GM crops. This



conclusion might then explain the behavior of separate stakeholder groups in agricultural exporting countries who have gone to great pains to align the introduction of new GM crops with their regulatory approvals in large importing countries.

For instance, the biotech industry (both through industry-wide actions and via individual firm decisions) has adopted voluntary restraints and has pledged to introduce new GM crops in the US only after regulatory approvals for these crops have been received in all of its major import markets. Commitment to such voluntary restraints are often referred to as “Stewardship Policy” and seek to reassure US farm producer groups and grain traders, the very groups that could see their profits suffer from potential disruptions in the US agricultural commodity trade (for instance see announcements by the Biotechnology Industry Organization (BIO) or Monsanto’s Pledge<sup>6</sup>).

Similarly, as pointed out in a recent report of the DG AGRI of the EU Commission (EC DG AGRI 2007 pp. 2), regulatory agencies in some other major exporting countries, like Argentina and Brazil, appear to manage regulatory approvals for plantings of new GM crops in order to follow relevant approvals in their key importing markets. This behavior would be consistent with the results of our analysis and with the history of active government involvement in the agricultural trade of these major agricultural exporting countries.

Our analysis further indicates that the profits of producers and exporters of IP non-GM products would tend to increase in the presence of trade restrictions on commodity trade because of the presence of unapproved GM crops. One might expect such groups

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<sup>6</sup> The full content of Monsanto’s Pledge and references to BIO’s position for instance can be found at [http://www.monsanto.com/monsanto/ag\\_products/pdf/stewardship/Monsanto\\_Commitment\\_to\\_BIO\\_PLSP\\_05-23-2007.pdf](http://www.monsanto.com/monsanto/ag_products/pdf/stewardship/Monsanto_Commitment_to_BIO_PLSP_05-23-2007.pdf)

then to position themselves against measures that would limit the chance trade restrictions on commodities from regulatory asynchronicity. Consequently, the behavior of EU organic producers that have strongly opposed the introduction of allowances for low level adventitious presence of unapproved GM crops in the agricultural supply chain would seem quite rational in the context of our analysis.

The results we derived here also indicate that consumer welfare in importing countries would tend to decrease from disruptions in commodity trade caused by asynchronous approvals of GM crops. As a result, commodity buyers, consumer groups and governments in countries that import large amounts of certain agricultural crop commodities would be expected to support orderly regulatory approvals and trade. In this context, and since the EU is the second largest importer of commodity soybeans in the world, the calls of various European soybean buyers<sup>7</sup> as well as that of the DG AGRI of the EU Commission for timely regulatory approvals and the adoption of AP thresholds for low level presence of unapproved GM crops in the EU, would therefore seem reasonable.

The results in our analysis also suggest that consumer welfare losses are not limited to importing countries where trade disruptions occur but extend to other importing countries which do not experience direct disruptions in their commodity trade. These welfare losses appear particularly acute when the importing country with regulatory asynchronicity is large in size causing equilibrium prices to increase and quantities to decline in both the IP and NIP markets. Consequently, asynchronous regulatory approvals of GM crops and their implications on trade and social welfare may not be an issue of single national concern. The recent involvement of the CODEX Alimentarius in the

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<sup>7</sup> For instance see declaration of the European Feed Manufacturers (FEFAC) on zero tolerance of unapproved events in the face of asynchronous approvals in the EU at <http://www.fefac.org/file.pdf?FileID=12138>

development of international guidelines for low level of accidental presence of GM crops would therefore seem quite appropriate.

The potential market and welfare impacts we have discussed here become particularly important when one considers key emerging trends, including: (a) the fast-expanding pipeline of novel GM crops; (b) the fast-expanding GMO acreage in major agricultural export countries; (c) the expanding number of GM crops being grown and traded; (d) the expanding share of GM crops in international commodity trade; and (e) the increasing number of countries with nascent and inexperienced regulatory programs that will be called to manage a large number of regulatory submissions for new GM crops in the coming years. These trends speak to the need for significant coordination in the international regulatory system in order to avert systemic trade disruptions and associated losses in producer profits and consumer surplus. In this context, the introduction of AP thresholds provides temporary relief to regulatory asynchronicity of new GM crops by minimizing the chance of trade disruptions. In the long run, however, harmonization in the regulatory approval process of new GM crops across countries will be necessary.

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Figure 1: Utility curves and consumer surplus when there are no unapproved crops.

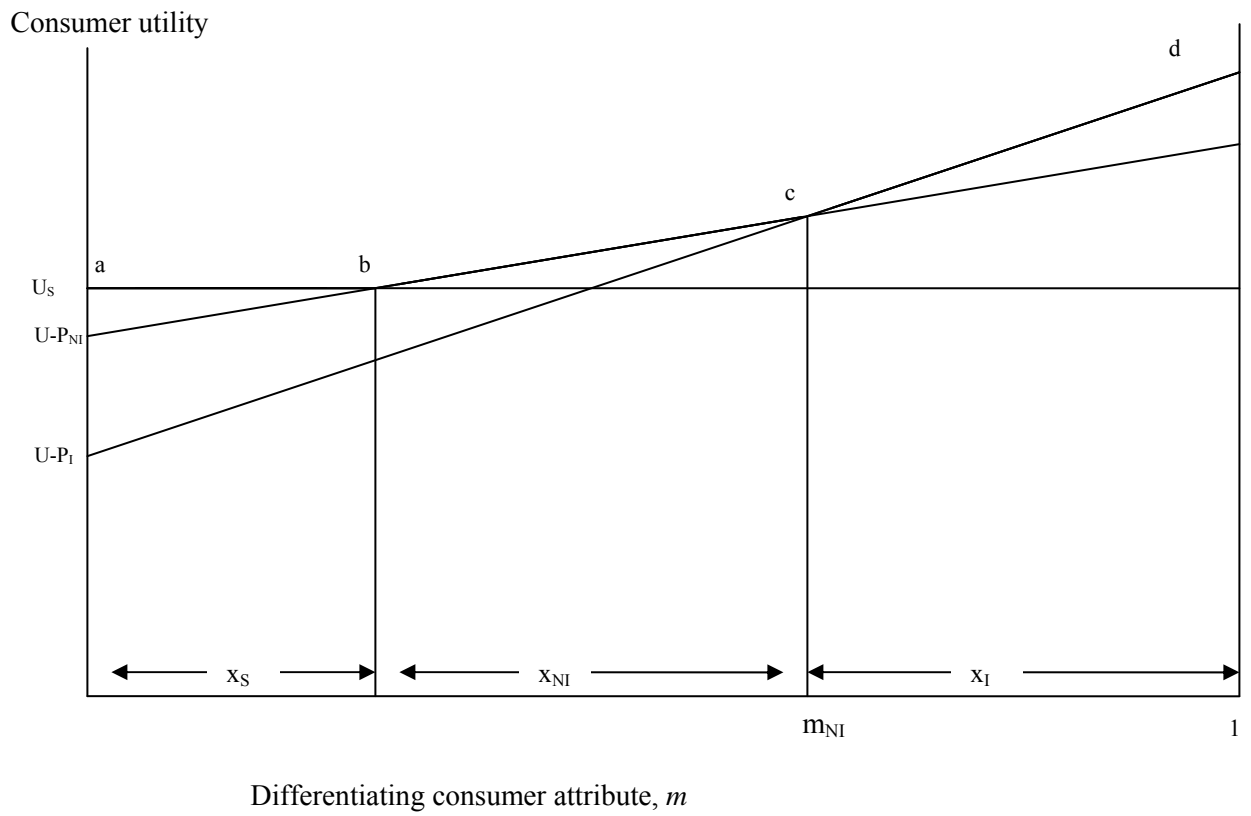


Figure 2: Demand and marginal revenue curve for the IP-type and NIP-type product

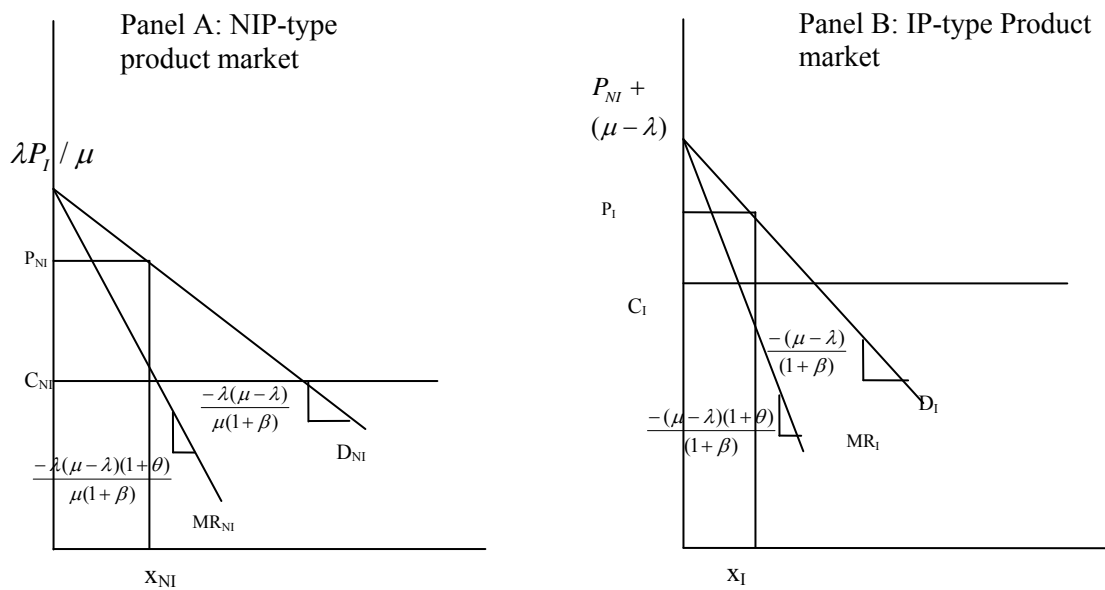




Figure 3. Utility curves and consumer surplus for the country with no unauthorized crops when there are trade restrictions.

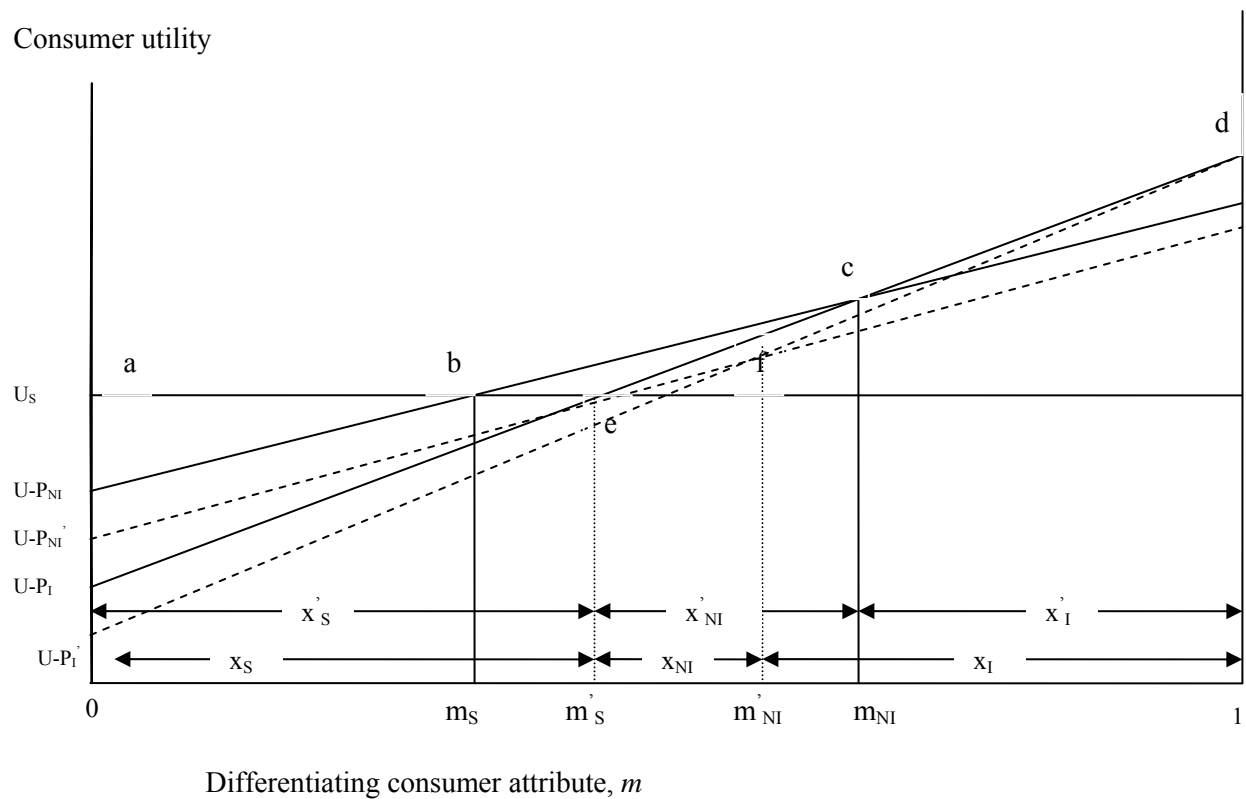


Figure 4: Utility curves and consumer surplus for the country where GM crops are not approved

