Best Response to GMOs in Developing Countries

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Abstract

This article examines the dilemma of a large exporting Country for an agricultural product having to determine its domestic agricultural policy as well as its level of IPRs enforcement. The analysis explicitly considers the possibility of two frauds by farmers: mislabeling of GM products as conventional and smuggling of illegal GM seeds. In doing so this paper makes two points: the approval decision of the products of the biotechnology is specific to the labeling regime and a large country has always an incentive to enforce its IPR regime.

Introduction

Regulatory responses to the products of the biotechnology have been subject to a lot of controversy from both sides of the Atlantic. While the European Union advocates mandatory labeling based on its precautionary principle, the United State based on the principle of substantive equivalence has argued that there is no need for labeling of these products. In between, Developing Countries are left with the intricate task of determining the optimal standard for Genetically Modified (GM) products. While producers should benefit from the approval of the producer-oriented first generation of GM products, productivity gain could be severely impaired by the loss of strategic markets.

When considering developing economies, it is important to pose the question of enforcement of Intellectual Property Rights (IPRs). Indian agricultural minister Sharad Pawar recently admitted in parliament that there is a flourishing illegal market in GM cotton seeds, strengthening allegations by the industry that more than half of all the GM cotton now growing in the country is from unapproved varieties (Jayaraman, 2004). Developing countries are not only lacking in the financial and technical capacities necessary to enforce IPRs but also in the incentive to do so. Enforcement of IPRs like labeling and approval of the GM products, is a strategic decision (Moschini, Lapan, and Sobolevsky, 2000; Giannakas, 2002; Chattopadhyay and Horbulyk, 2004). Interestingly while the questions of the optimal standard for GM products and the level of IPRs enforcement have received separate attention from the literature; for policy makers it constitutes an intertwined strategic choice (for a comprehensive review on the labeling of GM products see Fulton and Giannakas, 2004; Lapan and Moschini, 2004; and Veyssiere and Giannakas, 2006). IPRs enforcement, furthermore, encompasses not only the protection of the innovator rent but also the protection of the label GM free (Gray, Moss and Schmitz, 2004). Because of the credence attribute of the GM products with a price premium for conventional products, it is by no mean insured that producers will correctly label their products as GM. For instance Schnepf, Dohlman and Bolling (2001) reported that 40 % of soybean production was of GM origin, while at that time the use of GM seeds was not authorized in Brazil. This has led the Economist (2003, (a)) to wonder about the credibility of a Brazilian label GM free.

The object of this article is to examine the dilemma of a large producing country, having to determine its agricultural policy orientation as well as its level of IPRs enforcement. In doing so mislabeling as well as smuggling of illegal GM seeds by farmers are explicitly considered.

The article is organized as follow. The first section discusses the methodology and assumptions employed in our analysis. The next section develops a stylized three region trade model with heterogeneous consumers and producers. The third section examines the approval decision of the products of the biotechnology. The next section analyses the enforcement decision of both smuggling and mislabeling frauds and its welfare implications. The next section concludes the article.

Methodology and Assumptions

This article develops a stylized trade framework. In this stylized trade framework a supplying country (named hereafter Country 1) is competing with a producing region for access to a world market for an agricultural product. The producing region represents the rest of the producing countries (named hereafter the Rest Of the World: ROW). The ROW is assumed to have approved the GM technology without any labeling requirement. Producers in both Country 1 and the ROW are assumed to be heterogeneous in terms of the net returns perceived for the different crops. To producers in both Country 1 and the ROW, a set of foreign innovating companies (named hereafter Innovator) are supplying an official GM technology (when approved), while a black market provides smuggled GM seeds to producers (even if not approved). Finally, on the world market, heterogeneous consumers in terms of preference toward the conventional and GM products make their purchasing decisions, observing the price and the nature of the products supplied.

The focus of our analysis is on the Policy decision of Country 1. This decision is modeled as a two-period sequential game between Country 1, producers and consumers. In the first stage of the game Country 1 determines its agricultural Policy orientation. In the second stage, observing Country 1 decision, consumers and producers make their purchasing and planting decisions, respectively. Country 1 can either approve or not approve the GM products and impose or not a labeling regime. As a result four policies emerge:

Policy 1: The GM technology is not authorized and there is no labeling requirement for agricultural products.

Policy 2: The GM technology is not authorized and the labeling of agricultural products is mandatory.

Policy 3: The GM technology is authorized and there is no labeling requirement for agricultural products.

Policy 4: The GM technology is authorized and the labeling of the agricultural products is mandatory.

It is important to understand that while the Policy regime in the ROW is fixed (Approval and No labeling of the GM products which corresponds to Policy 3) Country 1 Policy decision will affect the nature of its supply as well as the nature of the supply to the world market.

Finally farmers can commit two frauds: smuggling and mislabeling. While smuggling of illegal GM seeds constitutes an infringement of the IPRs inherent to the innovator, mislabeling constitutes an infringement of the IPRs inherent to the label GM free. In absence of enforcements, such practices will generalize among farmers. In addition of its agricultural Policy, Country 1 has to determine whether to deter or not such frauds. Given that Country 1 is a producing country its objective, while making its policy and enforcement decisions, is to maximize aggregate producer welfare. Therefore to understand its Policy decision, Country 1 level of aggregate producer welfare has to be systematically derived for each Policy.

The Model

This section presents the methods used to derive aggregate producer surplus under each Policy. For illustration this methods are applied to Policy 4 (Approval and labeling) that provides the most complex and richest Policy environment.[1].

Supply Side

The production decision of heterogeneous farmers in terms of the net return for different crops is modeled via a framework similar to Fulton and Keyowski (1999); Giannakas (2002) and Chattopadhyay and Horbulyk (2004).

Production Decisions in Country 1

Let $A \in [0, \overline{A}]$ denotes the attribute that differentiates farmers. For tractability farmers are assumed uniformly distributed between the polar values of A and to produce at most one unit. Under Policy 4, farmers in Country 1 are left with the choice to either grow a labeled-conventional crop or a GM-labeled crop or an alternative crop. To each crop a producer with differentiating attribute A associates the following per unit net returns:

- $\pi^4_{gm1} = P^4_{gm} - w_{gm1} + \alpha_1 A$ If one unit of GM crop is produced with official seeds
- $\pi^4_{t1} = P^4_t - w^l_{t1} + \beta_1 A$ If one unit of conventional crop is produced
- $\pi_{a1} = \chi_1 A$ If one unit of alternative crop is produced

Where, P^4_{gm} and P^4_t stand for the per unit price of labeled-GM and labeled-conventional crops under Policy 4, respectively. It is assumed that a price premium is offered to producers of conventional crops, hence: $P^4_t > P^4_{gm}$.

The parameters w^l_{t1} and w_{gm1} represent the per unit base cost associated with the production of conventional and GM crops, respectively. To capture the producer orientation of the first generation of GM products, it is assumed that $w_{gm} < w_t$.

While α_1, β_1 and χ_1 stand for non negative return premium factors associated with the production of GM, conventional and alternative crops, respectively. To avoid infinite supply it is assumed that: $\chi > \beta$, and to capture the observed coexistence of GM markets and conventional markets, the GM technology is assumed relatively less effective: $\alpha < \beta$.

However, as previously mentioned, farmers can commit two frauds: smuggling and mislabeling. The net return associated with smuggling for a farmer with differentiating attribute A is:

- $\pi^4_{gmi} = P^4_{gm} - \tau_{s1}\delta_1 A$ If one unit of smuggled crop is produced

For tractability, and to capture the lower agronomic performance of the unofficial technology (Morse, Bennet and Ismael, 2005), the non negative return premium factor associated with the use of smuggled seeds is assumed equal to zero.

The parameter τ_{s1} stands for the penalty endured by a farmer, caught using smuggling seeds and $\delta_1 A$ for the audit probability. Following Giannakas (2002) and Chattopadhyay and Horbulyk (2004), the audit probability depends on farm specific characteristics. Finally some farmers can find optimal to mislabel as conventional: GM crops. The net return associated with mislabeling is given by:

- $\pi^4_{ml1} = P^4_t - \delta_1 \tau_{ml1} A$ If one unit of mislabeled crop is produced[2]

Where τ_{ml1} stands for the penalty endured by a farmer, caught mislabeling seeds. Because of the plurality of the crimes (smuggling and mislabeling) it is assumed that $\tau_{ml1} > \tau_{s1}$. While smuggling and mislabeling correspond to two different frauds, it is important to understand that their preventions are linked via the audit probability: $\delta_1 A$. The above net returns have been graphed in Figure 1.

Given that farmers are uniformly distributed and assumed to supply a single unit of output, the farmer indifferent between smuggling and mislabeling determines the quantity of products mislabeled. Graphically this farmer corresponds to the intersection of the net return functions associated with smuggling and mislabeling. Mathematically, the quantity of mislabeled products is given by:

$$A^4_{ml1} = \frac{P^4_t - P^4_{gm}}{\delta_1 (\tau_{ml1} - \tau_{s1})} \tag{1}$$

Consistent with a priori expectation the incentive to mislabel a GM product as conventional is driven by the price premium offered to the conventional product. A necessary conditions for A^4_{ml1} being positive is $P^4_t - P^4_{gm} > 0$.Similarly, the quantity of smuggled crops can be written as:

$$A^4_{s1} = \frac{w_{gm1}}{\alpha_1 + \delta_1 \tau_{s1}} \tag{2}$$

While the quantity of GM crops supplied is given by:

$$A_{gm1}^{4}=\frac{\left(P_{gm}^{4}-w_{gm1}\right)-\left(P_{t}^{4}-w_{t1}^{l}\right)}{\beta_{1}-\alpha_{1}} \tag{3}$$

The total quantity produced corresponds to:

$$A_{T1}^{4}=\frac{P_{t}^{4}-w_{t1}^{l}}{\chi_{1}-\beta_{1}} \tag{4}$$

The quantity of the conventional supplied is given by:

$$A_{t1}^{4}=A_{T1}^{4}-A_{gm1}^{4}=\frac{P_{t}^{4}-w_{t1}^{l}}{\chi_{1}-\beta_{1}}-\frac{\left(P_{gm}^{4}-w_{gm1}\right)-\left(P_{t}^{4}-w_{t1}^{l}\right)}{\beta_{1}-\alpha_{1}} \tag{5}$$

However, the quantity supplied labeled as conventional corresponds to:

$$A_{t1}^{l4}=A_{t1}^{4}+A_{ml1}^{4}=\frac{P_{t}^{4}-w_{t1}^{l}}{\chi_{1}-\beta_{1}}-\frac{\left(P_{gm}^{4}-w_{gm1}\right)-\left(P_{t}^{4}-w_{t1}^{l}\right)}{\beta_{1}-\alpha_{1}}+\frac{P_{t}^{4}-P_{gm}^{4}}{\delta_{1}\left(\tau_{ml1}-\tau_{s1}\right)} \tag{6}$$

While the quantity supplied labeled as GM is:

$$A_{gm1}^{l4}=A_{gm1}^{4}-A_{ml1}^{4}=\frac{\left(P_{gm}^{4}-w_{gm1}\right)-\left(P_{t}^{4}-w_{t1}^{l}\right)}{\beta_{1}-\alpha_{1}}-\frac{P_{t}^{4}-P_{gm}^{4}}{\delta_{1}\left(\tau_{ml1}-\tau_{s1}\right)} \tag{7}$$

Finally the total aggregate producer welfare can be expressed as:

$$\begin{aligned}\Pi_{1}^{4} \;=\; & \left(P_{t}^{4}-w_{t1}^{l}\right)A_{T1}^{4}+\beta_{1}\frac{\left(A_{T1}^{4}\right)^{2}}{2}+\left(\beta_{1}-\alpha_{1}\right)\frac{\left(A_{gm1}^{4}\right)^{2}}{2} \\ & +\left(\alpha_{1}+\delta_{1}\tau_{s1}\right)\frac{\left(A_{si}^{4}\right)^{2}}{2}+\delta_{1}\left(\tau_{ml1}-\tau_{s1}\right)\frac{\left(A_{ml1}^{4}\right)^{2}}{2}+\Xi^{4}\end{aligned} \tag{8}$$

Where Ξ^{4} corresponds to the surplus derived from the production of the alternative crops under Policy 4.

Production Decisions in the Rest of the World

Recall that the Policy regime is fixed in the ROW: approval without any labeling requirements of the products of the biotechnology (Policy 3). Hence producers in the ROW have the choice between planting a non-labeled GM or conventional crop or an alternative crop. The per unit net returns associated to each crop by a farmer with differentiating attribute A can be expressed as:

- $\pi^4_{gm2} = P^4_{nl} - \delta_2 \tau_{s2} A$ If one unit of smuggled crop is produced
- $\pi^4_{gm2} = P^4_{nl} - w_{gm2} + \alpha_2 A$ If one unit of GM crop is produced
- $\pi^4_{t2} = P^4_{nl} - w^{nl}_{t2} + \beta_2 A$ If one unit of conventional crop is produced
- $\pi_{a2} = \chi_2 A$ If one unit of alternative crop is produced

In contrast with a labeling regime no price premium is offered to the production of conventional crops. Farmers receive a per unit price, P^4_{nl}, for the non-labeled crop irrespective of their production choice. Notice that w^{nl}_t denotes the per unit base costs inherent to the production of the conventional crop under a no labeling regime. Because of the segregation costs incurred under a labeling regime, it is assumed that $w^{nl}_t < w^l_t$. The above net returns have been graphed in Figure 2.The relevant quantities are derived following the reasoning already applied to Country 1. The quantity of smuggled crops can be written as:

$$A_{s2} = \frac{w_{gm2}}{\alpha_2 + \delta_2 \tau_{s2}} \tag{9}$$

The quantity of GM crops is given by:

$$A_{gm2} = \frac{w^{nl}_{t2} - w_{gm2}}{\beta_2 - \alpha_2} \tag{10}$$

The total quantity supplied corresponds to:

$$A^4_{nl2} = \frac{P^4_{nl} - w^{nl}_{t2}}{\chi_2 - \beta_2} \tag{11}$$

While the total quantity of conventional crops is given by:

$$A^4_{t2} = \frac{P^4_{nl} - w^{nl}_{t2}}{\chi_2 - \beta_2} - \frac{w^{nl}_{t2} - w_{gm2}}{\beta_2 - \alpha_2} \tag{12}$$

Determination of the World Supplies

Based on these results, the total world supplies for each product under Policy 4 can be established. Under Policy 4, Country 1 is the sole supplier of GM and conventional-labeled products. Hence, its inverse supply of both GM and conventional-labeled products correspond to the respective world supplies. Similarly, the ROW is the unique supplier of the non-labeled product. Hence, its inverse supply provides the total supply of the non-labeled product to the world market. The world supply of the GM product under Policy 4 can be expressed as:

$$P_{gm}^{4} = (\chi_1 - \alpha_1) A_{gm1}^{l4} + (\chi_1 - \beta_1) A_{t1}^{l4} + w_{gm1} \tag{13}$$

While the world supply of the non-labeled product is given by:

$$P_{nl}^{4} = (\chi_2 - \beta_2) A_{nl}^{4} + w_{t2}^{nl} \tag{14}$$

Finally the world supply for the conventional product can be written as:

$$P_{t}^{4} = (\chi_1 - \beta_1) A_{t1}^{l4} + (\chi_1 - \beta_1) A_{gm1}^{l4} + w_{t1}^{l} \tag{15}$$

Demand Side

The methodological framework utilized in the analysis of consumption decisions derives from the models of vertical product differentiation developed by Giannakas and Fulton (2002), Fulton and Giannakas (2004) and Veyssiere and Giannakas (2006). This framework of analysis allows for heterogeneous consumers preferences for GM and conventional products.

Let $c \in [0, C]$ be the differentiating attribute that differentiates consumers. For simplicity consumers are assumed uniformly distributed between the polar values of c. Consider a consumer with differentiating attribute c. Under Policy 4, he has the choice of purchasing either a labeled GM or conventional product or a non-labeled product or a substitute. Assuming that he only purchases one unit, his utility can be expressed as:

- $E\left[U_t^4\right] = U - \left[\mu + \varphi_{ml}^4 (\lambda - \mu)\right] c - P_t^4$ If one unit of the conventional product is purchased

- $E\left[U_{nl}^4\right] = U - \left[\mu + \psi_{ml}^4 \left(\lambda - \mu\right)\right] c - P_{nl}^4$ If one unit of the non-labeled product is purchased

- $U_{gm}^4 = U - \lambda c - P_{gm}^4$ If one unit of the GM-labeled product is purchased

- $U_s = U - P_s$ If one unit of the substitute is purchased

Where U stands for a per unit base level of utility common to all consumers associated with consumption. P_s stands for the per unit retail price of the substitute product. μ and λ stand for positive utility discount factors associated with the consumption of conventional and GM products, respectively. To capture the expressed consumers opposition to GM products, it is assumed that $\lambda > \mu$ with the difference $\lambda - \mu$ reflecting the level of consumers aversion to the GM product. φ_{ml}^4 stands for the proportion of mislabeled products present into the supply of products labeled as GM free (i.e. labeled-conventional products), $\varphi_{ml}^4 = A_{ml1}^4 / A_t^4$. While Ψ_{gm}^4 stands for the production share of GM products within the supply of non-labeled products , $\Psi_{gm}^4 = A_{gm2}/A_{nl}^4$.

Because of the credence attribute of the GM product, consumers are uncertain about the nature of the non-labeled product as well as the labeled-conventional product. Assuming that consumers have rational expectations, the utility derived from the consumption of the non-labeled product and the labeled-conventional product are proportional to the production share of GM products into the supply of non-labeled product and the production share of mislabeled product into the supply of labeled-conventional product, respectively. As a result, the demand is no more independent of the supply (on this issue see also Giannakas and Fulton (2002), Fulton and Giannakas (2004) and Veyssiere and Giannakas (2006)).

Proposition 1 *The markets for labeled as conventional and non-labeled products will coexist, if the proportion of mislabeled products in the total supply of the conventional product is lower than the production share of GM products in the total supply of the non-labeled product.*

Proof. *As indicated by the per unit utility function, if $\varphi_{ml}^4 > \Psi_{gm}^4$,since $P_t^4 > P_{nl}^4$ then $E\left[U_{nl}^4\right] > E\left[U_t^4\right]$ for all consumers.* ■

Figure 3 graphs the per unit utility functions. The consumer with differentiating attribute c_{gm}^4 is indifferent between purchasing the labeled-conventional product and the non-labeled product. Therefore consumers located to the left of c_{gm}^4 prefer purchasing the GM product, while consumers located to the right buy either the non-labeled product or labeled-conventional product or the substitute. Because consumers are uniformly distributed between $[0, C]$, c_{gm}^4 gives the demand for the GM product. Mathematically:

$$c_{gm}^4 = \frac{P_{nl}^4 - P_{gm}^4}{(\lambda - \mu)\left(1 - \psi_{gm}^4\right)} \tag{16}$$

The total quantity demanded corresponds to:

$$c_T^4 = \frac{P_s - P_t^4}{\left[\mu + \varphi_{ml}^4 (\lambda - \mu)\right]} \tag{17}$$

The total quantity of the non-labeled product demanded is given by:

$$c_{nl}^4 = \frac{P_t^4 - P_{nl}^4}{\left(\psi_{gm}^4 - \varphi_{ml}^4\right)(\lambda - \mu)} - \frac{P_{nl}^4 - P_{gm}^4}{\left(1 - \psi_{gm}^4\right)(\lambda - \mu)} \tag{18}$$

Finally the quantity of the conventional product demanded is given by:

$$c_t^4 = \frac{P_s - P_t^4}{\left[\mu + \varphi_{ml}^4 (\lambda - \mu)\right]} - \frac{P_t^4 - P_{nl}^4}{\left(\psi_{gm}^4 - \varphi_{ml}^4\right)(\lambda - \mu)} + \frac{P_{nl}^4 - P_{gm}^4}{\left(1 - \psi_{gm}^4\right)(\lambda - \mu)} \tag{19}$$

From (16), (18) and (19) the inverse global demand can be deduced. For conventional product it is given by:

$$P_t^4 = P_s - \left[\mu + \varphi_{ml}^4 (\lambda - \mu)\right] c_t^4 - \left[\mu + \varphi_{ml}^4 (\lambda - \mu)\right] c_{nl}^4 - \left[\mu + \varphi_{ml}^4 (\lambda - \mu)\right] c_{gm}^4 \tag{20}$$

For the non-labeled product by:

$$P_{nl}^4 = P_s - \left[\mu + \varphi_{ml}^4 (\lambda - \mu)\right] c_t^4 - \left[\mu + \psi_{gm}^4 (\lambda - \mu)\right] c_{nl}^4 - \left[\mu + \psi_{gm}^4 (\lambda - \mu)\right] c_{gm}^4 \tag{21}$$

While for the GM product it corresponds to:

$$P_{gm}^4 = P_s - \left[\mu + \varphi_{ml}^4 (\lambda - \mu)\right] c_t^4 - \left[\mu + \psi_{gm}^4 (\lambda - \mu)\right] c_{nl}^4 - \lambda c_{gm}^4 \tag{22}$$

Market Outcomes: Aggregate Producer Welfare

Utilizing the supply and demand expressions, the market equilibrium conditions determine the prices and quantities of the relevant products, as well as, the level of aggregate producer welfare.

As indicated in Table 1, under Policy 4 there are three markets: one for GM-labeled products, one for non-labeled products and one for conventional-labeled products. The market clearing conditions in each market imply that:

$$A_{t1}^{l4} = c_t^4 = X_t^4 \tag{23}$$

$$A_{nl}^4 = c_{nl}^4 = X_{nl}^4 \tag{24}$$

$$A_{gm1}^{l4} = c_{gm}^4 = X_{gm}^4 \tag{25}$$

Where X_t^4, X_{nl}^4 and X_{gm}^4 are the equilibrium quantities of conventional, non labeled and GM products traded in the world market, respectively. Substituting the expressions for the inverse demands (equations (20), (21) and (22)) and the supplies (equations (13) ,(14) and (15)) for the relevant parameters in equations (23) , (24) and (25) , and solving the system of equations, we get the equilibrium quantities in the different markets. They can be expressed as:

$$X_{gm}^4 = \frac{1}{(\beta_1 - \alpha_1) + (\lambda - \mu)} \left(w_{t1}^{nl} - w_{gm1} - (\lambda - \mu) A_{gm2} \right) \tag{26}$$

$$X_t^4 = \frac{1}{(\chi_1 - \beta_1) + \mu} P_s - \frac{1}{(\chi_1 - \beta_1) + \mu} w_{t1}^l - \frac{\mu}{(\chi_1 - \beta_1) + \mu} X_{nl}^4 - X_{gm}^4 \tag{27}$$

$$X_{nl}^4 = \frac{A + \sqrt{(A)^2 - 4BC}}{2B} \tag{28}$$

with

$$\begin{aligned} A \;=\; & \frac{(\chi_1 - \beta_1)}{(\chi_1 - \beta_1) + \mu} P_s - \mu X_{gm}^4 + \mu \left(\frac{1}{(\chi_1 - \beta_1) + \mu} + \frac{1}{(\beta_1 - \alpha_1) + (\lambda - \mu)} \right) w_{t1}^l \\ & - \frac{\mu}{(\beta_1 - \alpha_1) + (\lambda - \mu)} w_{gm1} - w_{t2}^{nl} - \left[\frac{\mu}{(\beta_1 - \alpha_1) + (\lambda - \mu)} + 1 \right] (\lambda - \mu) A_{gm2} \end{aligned}$$

$$B = (\chi_2 - \beta_2) + \mu - \frac{\mu\mu}{(\chi_1 - \beta_1) + \mu}$$

$$C = (\lambda - \mu) A_{gm2} X_{gm}^4$$

Substituting the equations into the expressions for the farm prices in equations (13) ,(14) and (15), we get the equilibrium market prices as:

$$P_{gm}^{4*} = (\chi_1 - \alpha_1) X_{gm1}^4 + (\chi_1 - \beta_1) X_{t1}^4 + w_{gm1} \tag{29}$$

$$P_{nl}^{4*} = (\chi_2 - \beta_2) X_{nl}^4 + w_{t2}^{nl} \tag{30}$$

$$P_t^{4*} = (\chi_1 - \beta_1) X_{t1}^4 + (\chi_1 - \beta_1) X_{gm1}^4 + w_{t1}^l \tag{31}$$

Finally, substituting the above equations into (8) the level of aggregate producer welfare in Country 1 is given by:

$$\Pi_1^{4*} = \left(P_t^{4*} - w_{t1}^l\right) X_{T1}^4 + \beta_1 \frac{\left(X_{T1}^4\right)^2}{2} + (\beta_1 - \alpha_1) \frac{\left(X_{gm1}^4\right)^2}{2} + (\alpha_1 + \delta_1 \tau_{s1}) \frac{\left(X_{s1}^4\right)^2}{2} + \Xi^4 \tag{32}$$

By repeating the above analysis for the three remaining Policies the Payoff matrix of Country 1 (Table 2) can be established. Country 1 will choose its agricultural Policy by comparing the level of aggregate producer welfare under each Policy[3].

Approval Decision

In this section to understand the Country 1 approval decision two simplifying assumptions are made:

- **Assumption 1:**: Nature arbitrarily sets the level of IPRs enforcement. Hence Country 1 when making its Policy decision takes the strength of IPRs enforcement as given.
- **Assumption 2:** Farmers fully comply with the labeling Policy. The supply of conventional products is solely made of conventional crops.

These assumptions would be relaxed in the next section. Two Propositions regarding Country 1 approval decision are provided by the analysis of the payoff matrix.

Approval Decision under a No Labeling Regime

Proposition 2 *In the absence of any labeling requirements for agricultural products, non approval of the GM technology is the best response of an exporting Country wishing to maximize its aggregate producer welfare .*

Proof. See in the Appendix. ■

This proposition is the result of the comparison of Policy 1 and 3. Since farmers can smuggled GM seeds, despite non approval of the GM technology the supply of non-labeled products contains illegal GM crops. Hence the difference between Policy 1 (non approval) and 3 (approval) holds on the nature of the GM contents, in the supply of non-labeled product. While under approval (Policy 3) the supply of non-labeled product contains both official GM and smuggled crops; under non approval (Policy 1) it only contains illegal smuggled crops.

The reasoning behind proposition 2 is as follow. With approval of the GM technology some farmers turn to the production of official GM crops because more profitable. As a result the production of GM product in Country 1 increases, which in turn raises the total production share of GM products. On the world market consumers estimate that the likelihood to purchase a GM crops while purchasing a non-labeled products has also increased. This change in belief about the nature of the non-labeled products reduces the demand for non labeled products along with its price. The drop in the world price for non-labeled products reduces the profit of all producers in Country 1. As a result under a no labeling regime, non approval of the GM technology should be Country 1 best response.

Approval Decision under a Labeling Regime

Proposition 3 *In the presence of a mandatory labeling regime for agricultural products, approval of the GM technology is the best response of a large exporting Country wishing to maximize its aggregate producer welfare.*

Proof. See in the Appendix. ■

This Proposition is the result of the comparison of Policy 2 and 4. The reasoning behind this Proposition is as follow. With approval of the GM technology, some farmers in Country 1 turn to the production of GM crops because more profitable. As a result the supply to the world market of labeled-conventional products by Country 1 diminishes, while the supply of GM products increases. On the world market, with a labeling regime consumer demands are unaffected by supplies changes. Therefore the shifts in Country 1 supplies lead to a reduction in the price of labeled-GM products, while the price premium for labeled-conventional products increases. This increase in the price premium raises the profits of conventional producers under approval of the GM technology. Therefore with a labeling regime the approval of GM technology is welfare enhancing for all producers in Country 1 and should be Country 1 best response.

According to Propositions 2 and 3 approval of the GM technology appears specific of the labeling regime. As a result Country 1 best response can either be Policy 1 and 4[4].

Frauds Enforcement

In this section Assumptions 1 and 2 are successively relaxed and their implications on the Policy decision discussed.

Endogenous IPRs Enforcement

With assumption 1 relaxed Country 1 has to determine whether to enforce or not its level of IPRs.

Effects of IPRs Enforcement under Approval: Policy 4

An increase in the strength of IPRs enforcement is captured by an increase in the audit probability: δ_1. Under Policy 4 (Approval and Labeling), an increase in this probability not only decreases the number of producers smuggling but it also increases the price of the GM technology (for detail see Giannakas, 2002). This translates into a reduction of the supply by Country 1 of labeled-GM products and an increase in its supply of labeled-conventional products. Given that under a labeling regime the demand does not depend on the nature of the supply. These supply changes result in a lower price premium for conventional producers. On the other hand for GM producers the price of GM products rises but not sufficiently to compensate the profits losses caused by a more expensive GM technology. Therefore under Policy 4 enforcement of IPRs causes a reduction in aggregate producer welfare. Hence Country 1 should be better off with a lax IPRs enforcement under approval of the GM technology (Policy 4).

Effects of IPRs Enforcement under Non Approval: Policy 1

With a no labeling regime and an unauthorized GM technology, IPRs enforcement holds on the deterrence of smugglers. A rise in δ_1 decreases the number of smugglers. This results in a world supply of non-labeled products exhibiting a lower production share of GM products. This change in the nature of the world supplies will positively affects consumer belief. Now while purchasing a non-labeled product, consumers believe the likelihood to consume a GM products to be lower. As a result the demand along with the price for non-labeled product will increase. The rise in price enhances producer profit in Country 1. Therefore under a no labeling regime Country 1 should be willing to enforce its IPRs. Note that developing Countries lacking of the technical and financial capacities necessary to enforce IPRs can endure severe welfare losses due to an uncontrolled spread of the GM technology via smuggling. Such waning aggregate producer welfare can restrict Country 1 Policy choice to Policy 4. The next section illustrates this argument.

A Numerical Illustration

To make IPRs enforcement endogeneous, the deterrence of smuggling of GM seeds in Country 1 is assumed to be financed by taxpayer. It is assumed to be increasing with Country 1 tax payer cost: TC_1. For simplicity the audit probability is calibrated as: $\delta_1 = \phi_1 {TC_1}^5$. Here ϕ_1 denotes the marginal increase in the audit probability via additional financial capacity. This parameter is a measure of Country 1 level of technical capacity available to deter smuggling: the larger this parameter the more effective the prevention of smuggling. To constraint δ_1 to be between 0 and 1, it is assumed that $\phi_1 = \frac{1}{\overline{TC}_1}$, with $\overline{TC}_1$ capturing Country 1 financial capacity (i.e. $TC_1 \leq \overline{TC}_1$). Note that the cost of enforcing IPRs (TC_1) has to be discounted by the revenue of the penalty collected on producers caught smuggling. Following Chattopadhyay and Horbulyk (2004) the penalty revenue can be expressed as:

$$PR_1 = \delta_1 \tau_{s1} \int_0^{A_{s1}} A dA \qquad (33)$$

Taking into account the presence of the tax payer, aggregate welfare under Policy i , in Country 1 is now given by:

$$\Delta_i = \Pi_1^i + PR_1 - TC_1 \qquad (34)$$

Therefore the new objective of Country 1 is to maximize aggregate producer welfare at the lowest cost. As previously mentioned Country 1 will either select approval under a labeling regime

(Policy 4) or non approval under a no labeling regime (Policy 1). In the numerical application, the values assigned to each parameter of the models are reported in Table 2 .

Figure 4 graphs aggregate producer welfare under both Policy 1 and 4 as the audit probability, δ_1, increases. This simple numerical application has been repeated for three distinct penalty levels: $\tau_{s1} = 0.5$, $\tau_{s1} = 1$ and $\tau_{s1} = 1.5$. As the level of penalty increases the cost of enforcing IPRs decreases, since penalty revenue increases.

The level of Aggregate Producer welfare under approval and labeling of GM products (Policy 4) is represented by a flat line irrespective of the penalty levels. As previously mentioned Country 1 is better off with lax IPRs enforcement under approval (Policy 4). Therefore to minimize its cost and maximizing aggregate producer welfare, it is optimal for Country 1 to not enforce IPRs at all ($\delta_1 = 0$).

Under non approval and no labeling of the GM products (Policy 1) aggregate producer welfare is rising as the audit probability increases but under a low penalty level ($\tau_{s1} = 0.5$). In this case, decreasing level of aggregate producer welfare indicates that the benefits from stronger IPRs enforcement are outweighed by its cost. Hence for $\tau_{s1} = 0.5$, Country 1 will be better off with approval and labeling of the GM products. Otherwise as illustrated strong IPRs enforcement (i.e. $\delta_1 > 0.5$) should reward Country 1 with an higher level of aggregate welfare under non approval of the GM technology and a no labeling regime.

Finally as illustrated in Figure 4, if the financial and technical capacity of the Country are such that $\delta_1 < 0.5$, Country 1 is better off approving the GM technology and labeling its agricultural production. This numerical example illustrates how financial and technical capacities can constrain a country agricultural policy decision.

Mislabeling

Let now relax Assumption 2. With farmers committing mislabeling frauds the demand for labeled-conventional products becomes also function of consumer belief about the nature of its supply. An increase of the quantity of mislabeled products will raise the proportion of GM products into the supply of labeled-conventional products. As a result on the world market the likelihood to purchase a GM product while purchasing a labeled-conventional product increases. This change in consumer belief decreases the demand and the price premium for labeled-conventional products. This drop in the price premium entails a fall in the level of aggregate producer welfare. Therefore Country 1 should be better off deterring mislabeling frauds.

However, as previously mentioned, the enforcement of IPRs and the protection of the label GM free are linked via the audit probability. Hence the protection of the label GM free results in an increase in the audit probability and thereby a stronger IPRs enforcement. Therefore Country 1, when making its frauds enforcement decision faces a tradeoff between the gain from an higher price premium for conventional product (caused by the prevention of mislabeling frauds) and the welfare losses from a more expensive GM technology (caused by the deterrence of smuggling frauds). Therefore frauds enforcement under approval is a tedious choice.

Finally, according to Proposition 1, for Policy 4 to be feasible, the following condition has to be verified: $\varphi^4_{ml1} \leq \Psi^4_{gm}$. A developing country unable to prevent smuggling and mislabeling frauds might not have the capacity to fullfill this condition, and thus to credibly enforce a label GM free. As a result its Policy choice will be restricted to non approval of the GM technology under a no labeling regime (Policy 1). As previously illustrated under non approval (Policy 1) without deterrence of smuggling a Country is exposed to reduction in welfare. Therefore a large country without the capacity to enforce IPRs can endure severe welfare loss with the introduction of the GM technology.

Conclusion

This article develops a stylized three-region model of heterogeneous producers and consumers to analyze the best response of a large Country that has to determine the optimal standard for GM products along with the optimal level of IPRs enforcement. Specifically, our analysis utilizes the methodological framework developed in Veyssiere and Giannakas (2006) that analyzes the effect of the strategic interdependence in labeling decision by GM producing countries. Unlike Veyssiere and Giannakas (2006), however, our study explicitly accounts for a GM free Country having to decide in addition to its labeling Policy whether to approve or not the marketing of GM products. To our knowledge, the approval of the products of the biotechnology by a large GM free country strategically interacting with the Rest of the World has not been considered previously.

The approval decision is modeled in this article as a sequential strategic game played by a large GM free Country having to determine the optimal standard for its agricultural products (adopt or not and/or label or not GM products). In doing so, the article establishes that the approval decision is specific of the labeling regime. In particular, under conditions favorable to a mandatory labeling regime, approval of the GM technology should be the Country best response. On the other hand, in the absence of labeling requirements, to not authorize the marketing of GM crops should be the Country best response.

Also unlike Veyssiere and Giannakas (2006), the level of IPRs enforcement is not given to the Country but part of the Country Policy decision. To our knowledge the simultaneous consideration of the IPRs enforcement decision as well as the choice of the optimal standard for agricultural products has not yet been considered by the relevant literature. Moreover, while the recent literature on the economy of IPRs of the products of the biotechnology has focused on small economy (Giannakas, 2002 and Chattopadhyay and Horbulyk, 2004), this article explicitly considers IPRs infringement in large economy.

Our results show that in contrast with a small economy, a large economy should benefit from strong level of IPRs enforcement. The motives for IPRs protection are also specific to the labeling regime. Under a no labeling regime, the introduction of the GM technology results in an externality that if not controlled via stronger IPRs protection, will negatively affect aggregate welfare. Under a labeling regime mislabeling piracies by farmers also result in an externality that negatively alter producers aggregate benefits as mislabeling practices generalize. In this context, stronger IPRs protection by deterring the traffic of illegal GM seeds facilitates the protection of the label GM free.

However, developing Countries might not have at their disposal the financial and technical capacity necessary to enforce IPRs. Therefore the financial burden associated with IPRs and label protection can constitute an impediment to the official adoption of the GM technology and their incapacity to deter smuggling can entail severe welfare losses.

In addition to providing insights to Policy makers in their regulatory decision towards GM products, these results rationalize the recent approval by Brazil and the European Union of GM products under a mandatory labeling regime (The Economist, 2003 (a)) as well as the surprising refusal of food aid containing GM products by Ethiopia (The Economist, 2003 (b)). Interesting extension of this research could include the consideration of private actors such as the processing and retailing industry in the approval and enforcement of IPRs.

Notes

[1]Equilibrium quantities and prices for the other Policies have been reported in the Appendix. Details on their derivations are available upon request to the author.

[2]In this example, it is assumed that sole the smuggling farmers are mislabeling their products. However it is possible for GM producers using the official GM technology to mislabel their products, as well. In this context, the net returns function associated with mislabeling is given by: $\pi^4_{ml1} = P^4_{gm} - w_{gm1} + (\alpha_1 - \delta_1 \tau_{ml1})\, A$

[3]To simplify our analysis, given that the Innovator depicts foreign companies, Country 1 has not been constrained to provide a minimum rent to the Innovator under approval of the GM technology. In practice this needs not to be the case (for details see Giannakas, 2002 and Evenson, 2004). This simplifying assumption, however, does not affect the qualitative nature of our result.

[4]For details on the labeling decision see Veyssiere and Giannakas (2006). Numerical applications showing that their results are valid in our analysis are available upon request to the author.

[5]In practice δ_1 is likely to increase with a rise in TC_1 at a decreasing rate (i.e. $\delta_1'(TC_1) \geqq 0$, $\delta_1''(TC_1) \leq 0$). Our naive specification, however, does not affect the qualitative nature of our illustration.

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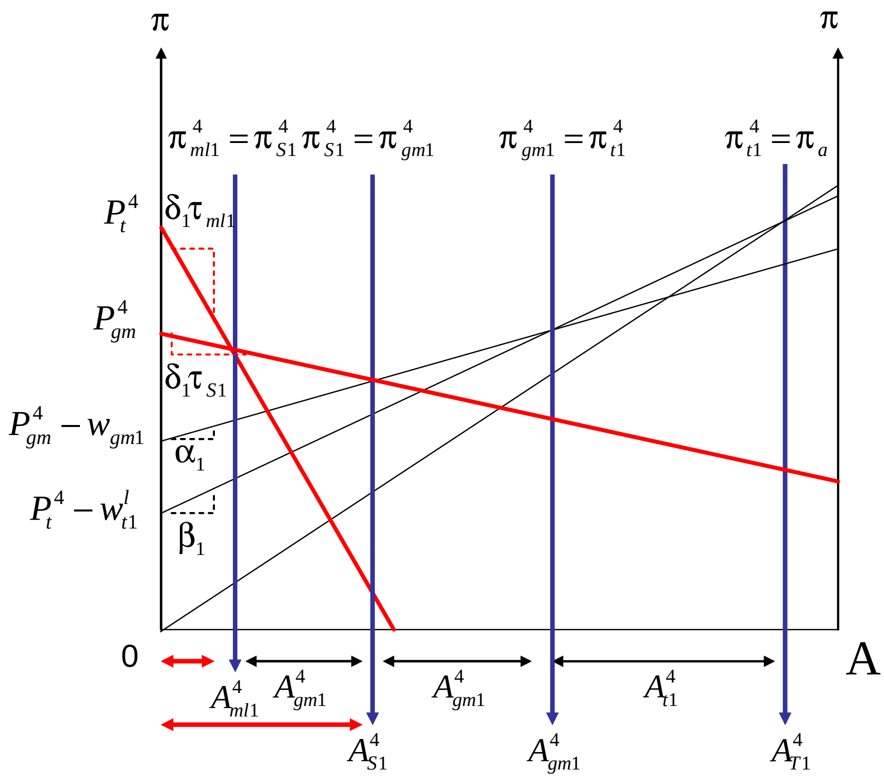

Figure 1: Producers Decision Under Policy 4 in Country 1

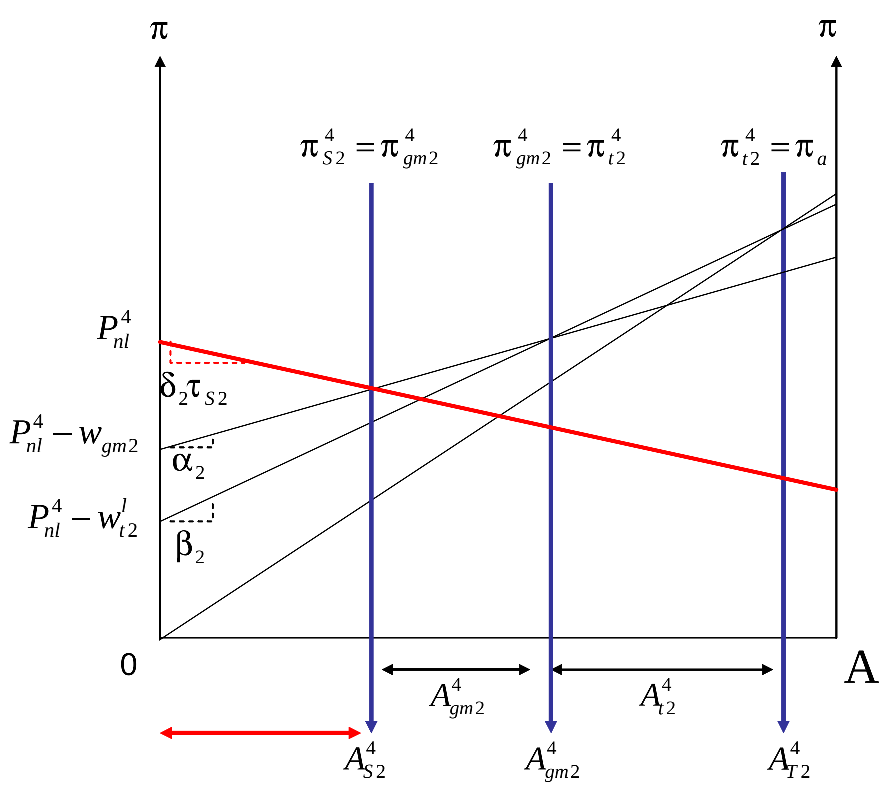

Figure 2: Producers Decision in the ROW

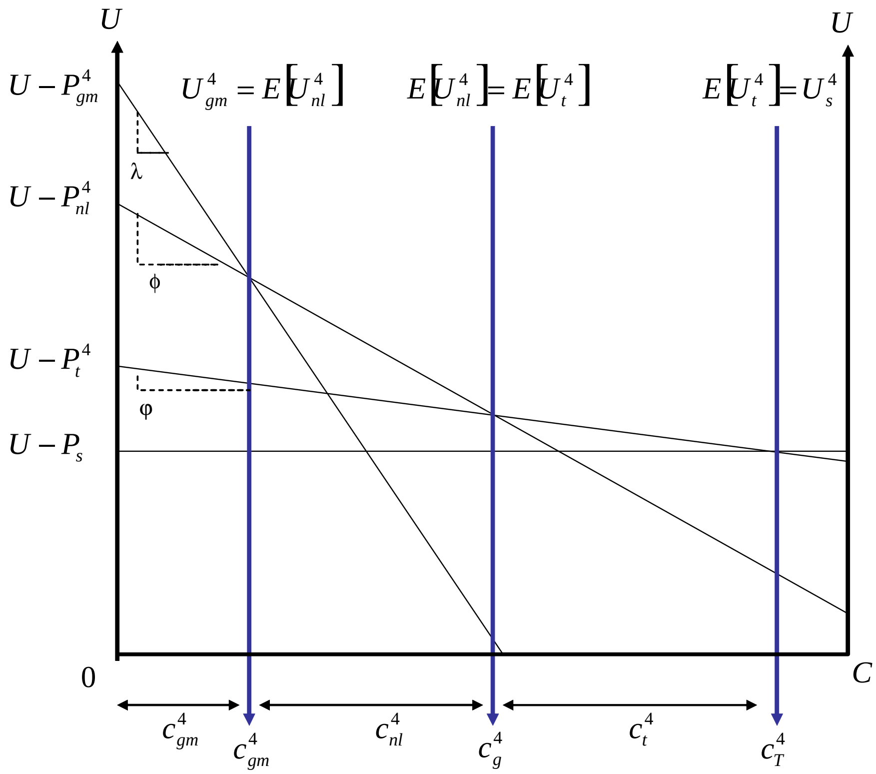

Figure 3: Consumers Decision Under Policy 4

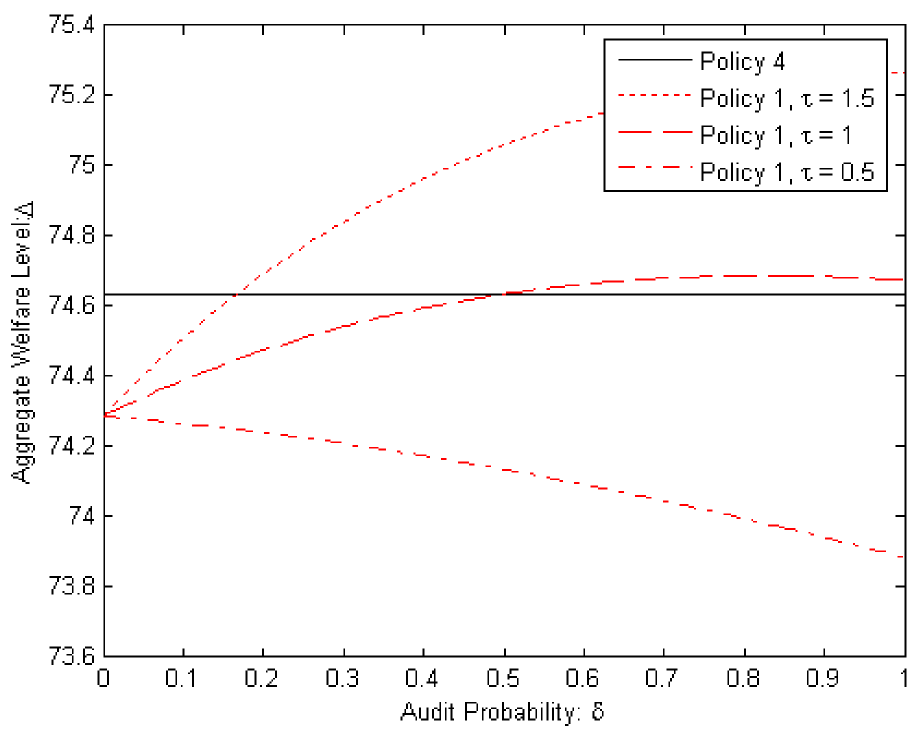

Figure 4: Welfare Effects of IPRs Enforcement under Different Level of Penalty: τ_{s1}

Table 1: Country 1 Payoff Matrix

Policies	*Level of Aggregate Producer Welfare*
Policy 1: Non Approval & No Labeling	$\Pi_1^{1*} = \left(P_{nl}^{1*} - w_{t1}^{nl}\right) X_{nl1}^1 + \beta_1 \frac{\left(X_{nl1}^1\right)^2}{2} + \left(\beta_1 + \delta_1 \tau_{s1}\right) \frac{\left(X_{s1}^1\right)^2}{2} + \Xi^1$
Policy 2: Non Approval & Labeling	$\Pi_1^{2*} = \left(P_t^{2*} - w_{t1}^{l}\right) X_t^2 + \beta_1 \frac{\left(X_t^2\right)^2}{2} + \Xi^2$
Policy 3: Approval & No Labeling	$\Pi_1^{3*} = \left(P_{nl}^{3*} - w_{t1}^{nl}\right) X_{nl1}^3 + \beta_1 \frac{\left(X_{nl1}^3\right)^2}{2} + \left(\alpha_1 + \delta_1 \tau_{s1}\right) \frac{\left(A_{s1}^3\right)^2}{2} + \left(\beta_1 - \alpha_1\right) \frac{\left(A_{gm1}\right)^2}{2} + \Xi^3$
Policy 4: Approval & Labeling	$\Pi_1^{4*} = \left(P_t^{4*} - w_{t1}^{l}\right) X_{T1}^4 + \beta_1 \frac{\left(X_{T1}^4\right)^2}{2} + \left(\beta_1 - \alpha_1\right) \frac{\left(X_{gm1}^4\right)^2}{2} + \left(\alpha_1 + \delta_1 \tau_{s1}\right) \frac{\left(A_{s1}^4\right)^2}{2} + \Xi^4$

Table 2: Parameter Values of the Numerical Illustration

	Country 1	**ROW**	**World Market**
Parameter Values	$w_{gm1} = 2$ $w_{t1}^{nl} = 3$ $w_{t1}^{l} = 3.505$ $\alpha_1 = 1$ $\beta_1 = 3$ $\chi_1 = 4$ $\overline{TC}_1 = 1.5$ $\phi_1 = 1/\overline{TC}_1$ $\delta_1 = \phi_1 TC_1$	$w_{gm2} = 2$ $w_{t2}^{nl} = 3$ $\alpha_2 = 1$ $\beta_2 = 3$ $\chi_2 = 4$	$P_S = 10$ $\lambda = 0.45$ $\mu = 0.1$

Appendix

Equilibrium Prices and Quantities for Policy 1, 2 and 3

Policy 1

Under Policy 1 both the Country 1 and the ROW are not labeling their products, but Country 1 has not approved the GM technology. However some farmers smuggle, therefore Country 1 despite non approval is supplying a quantity of illegal GM crops A_{s1}^{1}.The world supplies of non labeled product is given by:

$$P_{nl}^{1} = \frac{1}{(\chi_1 - \beta_1) + (\chi_2 - \beta_2)} \left\{ (\chi_1 - \beta_1)(\chi_2 - \beta_2) A_{nl}^{1} + (\chi_2 - \beta_2) w_{t1}^{nl} + (\chi_1 - \beta_1) w_{t2}^{nl} \right\} \tag{35}$$

while the global demand for non labeled product can be written as:

$$P_{nl}^{1} = P_s - \left(\mu + \Psi_{gm}^{1} (\lambda - \mu)\right) c_{nl}^{1} \tag{36}$$

with $\Psi_{gm}^{1} = \left(A_{s1}^{1} + A_{gm2}^{1}\right) / A_{nl}^{1}$. In the context of Policy 1, there is a unique market for non labeled product. Imposing the market clearing condition $A_{nl}^{1} = c_{nl}^{1} = X_{nl}^{1}$ provides:

$$X_{nl}^{1} = \frac{1}{D} \left\{ \begin{array}{c} (\chi_1 - \beta_1 + \chi_2 - \beta_2) P_s - (\lambda - \mu)(\chi_1 - \beta_1 + \chi_2 - \beta_2)(A_{gm2} + A_{S1}) \\ - (\chi_2 - \beta_2) w_{t1}^{nl} - (\chi_1 - \beta_1) w_{t2}^{nl} \end{array} \right\} \tag{37}$$

with,

$$D = (\chi_1 - \beta_1)(\chi_2 - \beta_2) + \mu (\chi_1 - \beta_1 + \chi_2 - \beta_2)$$

Here X_{nl}^{1} denotes the equilibrium quantity of non labeled product traded under Policy 1. Aggregate producer welfare has been reported in Table 2.

Policy 2

While the ROW is supplying a non labeled product containing GM ingredients, Country 1 now supplies a labeled conventional product. In this case of figure Country 1 differentiatesits production from the ROW. As a result two markets emerge: one for non labeled product and one for labeled conventional product. The total supply of the conventional-labeled product is given by:

$$P_t^{2} = (\chi_1 - \beta_1) A_t^{2} + w_{t1}^{l} \tag{38}$$

While the total supply for the non-labeled product corresponds to:

$$P_{nl}^{2} = (\chi_2 - \beta_2) A_{nl}^{2} + w_{t2}^{nl} \tag{39}$$

On the world market the total demands are given by:

$$P_t^{2} = P_s - \left(\mu + \varphi_{ml}^{2} (\lambda - \mu)\right) c_t^{2} - \left(\mu + \varphi_{ml}^{2} (\lambda - \mu)\right) c_{nl}^{2} \tag{40}$$

$$P_{nl}^{2} = P_s - \left(\mu + \varphi_{ml}^{2} (\lambda - \mu)\right) c_t^{2} - \left(\mu + \Psi_{gm}^{2} (\lambda - \mu)\right) c_{nl}^{2} \tag{41}$$

Again the market clearing conditions $A_{nl}^{2} = c_{nl}^{2} = X_{nl}^{2}$ (for the market of non labeled products) and $A_t^{2} = c_t^{2} = X_t^{2}$ (for the market of labeled conventional products) provide the following equilibrium quantities:

$$X_t^2 = \frac{1}{D}\left\{(\chi_2-\beta_2)P_s - (\mu + (\chi_2-\beta_2))w_{t1}^l + \mu w_{t2}^{nl} + \mu(\lambda-\mu)A_{gm2}\right\} \tag{42}$$

$$X_{nl}^2 = \frac{1}{D}\left\{\begin{array}{c}(\chi_1-\beta_1)P_s + \mu w_{t1}^l - ((\chi_1-\beta_1)+\mu)w_{t2}^{nl} \\ -(\lambda-\mu)((\chi_1-\beta_1)+\mu)A_{gm2}\end{array}\right\} \tag{43}$$

Policy 3

Finally, under approval and no labeling of GM product by Country 1, both Country 1 and the ROW supply a non labeled product to the world market. The total supply is given by:

$$P_{nl}^3 = \frac{1}{(\chi_1-\beta_1)+(\chi_2-\beta_2)}\left\{(\chi_1-\beta_1)(\chi_2-\beta_2)A_{nl}^3 + (\chi_2-\beta_2)w_{t1}^{nl} + (\chi_1-\beta_1)w_{t2}^{nl}\right\} \tag{44}$$

while the total demand:

$$P_{nl}^3 = P_s - \left(\mu + \Psi_{gm}^3(\lambda-\mu)\right)c_{nl}^3 \tag{45}$$

Hence the equilibrium quantity of non labeled product traded is:

$$X_{nl}^3 = \frac{1}{D}\left\{\begin{array}{c}(\chi_1-\beta_1+\chi_2-\beta_2)P_s - (\lambda-\mu)(\chi_1-\beta_1+\chi_2-\beta_2)(A_{gm2}+A_{gm1}) \\ -(\chi_2-\beta_2)w_{t1}^{nl} - (\chi_1-\beta_1)w_{t2}^{nl}\end{array}\right\} \tag{46}$$

Proof of Proposition 2

First substituting back into the relevant equilibrium quantities reported above into the equilibrium prices. The price of non labeled product under non approval (Policy 1) can be rewritten as:

$$P_{nl}^1 = \frac{1}{D}\left(\begin{array}{c}(\chi_1-\beta_1)(\chi_2-\beta_2)P_s + \mu(\chi_2-\beta_2)w_{t1}^{nl} + \mu(\chi_1-\beta_1)w_{t2}^{nl} \\ -(\lambda-\mu)(\chi_1-\beta_1)(\chi_2-\beta_2)\left(A_{gm2}+A_{S1}^1\right)\end{array}\right) \tag{47}$$

while under approval (Policy 3) it corresponds to:

$$P_{nl}^3 = \frac{1}{D}\left(\begin{array}{c}(\chi_1-\beta_1)(\chi_2-\beta_2)P_s + \mu(\chi_2-\beta_2)w_{t1}^{nl} + \mu(\chi_1-\beta_1)w_{t2}^{nl} \\ -(\lambda-\mu)(\chi_1-\beta_1)(\chi_2-\beta_2)\left(A_{gm2}+A_{gm1}^3\right)\end{array}\right) \tag{48}$$

Apparent from these expressions, the price of non labeled product is negatively correlated with the quantity of GM products present into its supply ($\partial P_{nl}/\partial A_{gm} < 0$). By definition under a no labeling regime all net return functions (associated with smuggling or the production one unit of conventional crop or GM crop) are positively correlated with the price of non labeled product. Hence a decrease in the price of non labeled product leads to a loss in aggregate producer welfare under a no labeling regime.

Also apparent from the above expressions, the difference between the prices of non labeled product under Policy 1 and 3 hinges on the difference between A_{S1}^1 and A_{gm1}^3. When $A_{gm1}^3 > A_{S1}^1$ then $P_{nl}^3 < P_{nl}^1$ and the reverse is true. Under official approval by Country 1 of the GM technology farmers will choose to adopt the GM technology when:

$$\frac{w_{gm1}}{\alpha_1 + \delta_1\tau_{s1}} \leq \frac{w_{t1}^{nl} - w_{gm1}}{\beta_1 - \alpha_1} \tag{49}$$

otherwise all farmers will prefer smuggling or producing a conventional crop. Under the above condition $A^3_{gm1} > A^1_{S1}$. Hence in that case the price of non labeled product is lower under approval of the GM technology (Policy 3). Thus producers smuggling and producing conventional crops are worse off. Since they perceive a lower price (P^3_{nl}) for their products.

Let now consider the GM adopters under approval (Policy 3). Note that the minium level of profit under non approval (Policy 1) corresponds to the producer with the differentiating attribute:

$$A^1_{s1} = \frac{w^{nl}_{t1}}{\beta_1 + \delta_1 \tau_{s1}} \tag{50}$$

A^1_{s1} also corresponds to the total quantity of smugglers under Policy 1. Under the condition given by equation (49) for the producer with the differentiating attribute A^1_{s1}, we have: $P^3_{nl} - w_{gm1} + \alpha_1 A^1_{s1} \leq P^1_{nl} - w_{t1} + \beta_1 A^1_{s1} = P^1_{nl} - \delta_1 \tau_{s1} A^1_{s1}$. Therefore the net return of the producers with differentiating attribute A^1_{s1}, if it produces a unit of GM crops under approval, are at least as large than if it does not (i.e. smuggle or produce conventional crop) under non approval (Policy 1). Given that $\beta_1 > \alpha_1$ by assumption, for $A > A^1_{s1}$, then: $P^1_{nl} - w_{t1} + \beta_1 A > P^3_{nl} - w_{gm1} + \alpha_1 A$. Therefore the level of aggregate producer welfare under Policy 3 is lower than under Policy 1.

Proof of Proposition 3

First we want to show that the total quantity sold by Country 1 under Policy 4 is larger than under Policy 2.

First note that equation (28) , since expressions B and C are positive, X^4_{nl} can be bounded as follow:

$$X^4_{nl} = \frac{A + \sqrt{(A)^2 - 4BC}}{2B} \leq \frac{A}{B} \tag{51}$$

Substituting back this expression into X^4_t the equilibrium quantity of conventional products traded (equation (27)), we get:

$$X^4_t \geqq \frac{1}{(\chi_1 - \beta_1) + \mu} P_s - \frac{1}{(\chi_1 - \beta_1) + \mu} w^l_{t1} - X^4_{gm} - \frac{\mu}{(\chi_1 - \beta_1) + \mu} \frac{A}{B} \tag{52}$$

Under Policy 4, Country 1 is the unique supplier of both the GM and conventional markets. Therefore the total quantity sold by Country 1 under Policy 4, X^4_1, corresponds to the sum of X^4_t and X^4_{gm}. Adding X^4_{gm} to the above expression and substituting back for the expressions of A and B we get:

$$X^4_1 \geqq \frac{1}{D} \left\{ (\chi_2 - \beta_2) P_s - (\mu + (\chi_2 - \beta_2)) w^l_{t1} - \mu w^{nl}_{t2} + \mu (\lambda - \mu) A_{gm2} \right\} \tag{53}$$

As reported above under Policy 2 the market equilibrium of labeled-conventional product traded is:

$$X^2_t = \frac{1}{D} \left\{ (\chi_2 - \beta_2) P_s - (\mu + (\chi_2 - \beta_2)) w^l_{t1} + \mu w^{nl}_{t2} + \mu (\lambda - \mu) A_{gm2} \right\} \tag{54}$$

Since under this Policy, Country 1 is the sole supplier of the conventional market. Under Policy 2, X^2_t, also corresponds to the total quantity traded by Country 1. Hence:

$$X^4_1 - X^2_1 \geqq 0 \tag{55}$$

Therefore the total quantity sold by Country 1 under Policy 4 is at least as large as its quantity sold under Policy 2. According to equation (4) this implies that the price of conventional product is higher under approval (Policy 4) than non approval of the GM technology (Policy 1). Note that if the labeling cost under Policy 1 and 4 were different, this need not necessary be the case. Hence conventional producers are better off because benefiting from a higher price premium. Given that conventional producers are all better off under Policy 4 and that there are only conventional producer under Policy 1, aggregate producer welfare is higher under Policy 4.