The market acceptance and welfare impacts of genetic use restriction technologies (GURTS)

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THE MARKET ACCEPTANCE AND WELFARE IMPACTS OF GENETIC USE RESTRICTION TECHNOLOGIES (GURTS)

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Abstract

The paper develops a theoretical framework of heterogeneous consumers and producers to examine the market and welfare effects of the introduction of variety-level genetic use restriction technologies (V-GURTs) under the current No-Labeling regime of GMPs in the US market. Specifically, the study examines how the agronomic characteristics of GURTs, consumer perceptions and preferences regarding interventions in the production process (i.e., genetic modification) and producer cost structures (e.g., dependency on saving seed) affect the adoption of the technology by producers, the market acceptance of GURTs by consumers and consequently the innovator's incentive to introduce the new technology. Analytical results show that the introduction of GURTs may be welfare enhancing for consumers, producers and innovating firms when consumer aversion to GURTs is low, the agronomic benefits of the GURTs crop are high, and the expected penalty producers face when they cheat on their GM licensing agreements (e.g., due to inefficient or costly monitoring) is low.

Keywords: genetic use restriction technologies, genetic modification, producer and consumer welfare.

1. Introduction

An intellectual property rights (IPRs) system is effective when infringers can be identified, successfully sued for damages and deterred from further infringement. The effectiveness of IPRs in plant varieties is limited due to the high detection costs of

unauthorized use of seed that embodies intellectual property and high enforcement costs. There are two types of seed delivery systems, the formal regulated seed supply system, and the farmers' own seed supply system. Globally, the largest quantity of seed is produced by the farmers themselves; more than 75% of farmers, mainly farmers in developing countries, depend on saved seed as their primary seed source (RAFI, 2004).[1] Given that farmers are spread all over and seed reproduces naturally, monitoring the use of seed by farmers becomes very costly making the unauthorized use of seed a serious problem for seed providers. As a consequence, seed companies perform limited research and development (R&D) in self-pollinating plants mainly because seed saving limits their ability to recoup their investment.

The use of variety level genetic use restriction technologies (V-GURTs) is a biological way of restricting the unauthorized use of seed that embodies intellectual property that could be used by innovators/breeders to restrict farmers and competing breeders from reproducing their innovations. Specifically, V-GURTs, which are commonly referred to as terminator technology, are technologies that can restrict the use of the entire variety through interference with reproduction resulting in the production of sterile seeds.[2] Terminator technology could work more effectively than other IPR regimes (e.g., patents, breeder's rights or licenses) as an innovation rent appropriation mechanism for innovators/breeders because it makes it impossible for farmers to save and re-use

[1] In India, for instance, 83% of farmers use their own farm-saved seeds (Sharma 2005). Even in developed countries farmers rely on saving seed. By some estimates, 20-30% of all soybean fields in the US, in the Midwest and up to 50% of soybeans in the South are planted with farm-saved seeds (Taylor 1996) while according to other estimates, most North American wheat farmers typically rely on farm-saved seeds and return to the commercial market once every 4 years (ETC 1998). The percentage of farm-saved seed for UK is 30%, for Germany 46%, for France 35%, for Portugal 75%, for Spain 88% (Toledo 2002).

[2] On the other hand, T-GURTs are technologies that can restrict the use of a specific trait by regulating its expression. That is, one or more genes conferring a single trait are switched on or off through specific chemical inducers. The seed itself remains viable, but farmers need to buy the inducers to be able to take advantage of the specific trait.

seed. As a consequence, the introduction of GURTs might encourage innovating firms to invest more in R&D, especially in self-pollinating crops where hybrids are not effective (e.g., rice, wheat, soybean, cotton). More than fifty GURTs patents have been issued to date, nineteen of which relate to V-GURTs/terminator technology and are held by private firms, universities and the US Government (Pendleton 2004).[3]

Even though GURTs have not been commercialized yet, their potential introduction incites great controversy. The proponents of the GURTs technology claim that its introduction will strengthen the protection of intellectual property, will result in increased agricultural productivity through an increased degree of accuracy in production (e.g., precision agriculture) and in crops with better agro-ecological characteristics, could be used as a tool that prevents the escape of horizontal gene flow into neighboring crops or wild species, limiting the potential negative environmental effects of genetically modified (GM) crops (as the long-term effects of GM plants are not known) and could be viewed as a lever to encourage countries to provide greater IP protection to GM crops.[4]

On the other hand, a number of countries (e.g., India), consumer groups and non-governmental organizations oppose the introduction of GURTs.[5] The main argument of the opponents of terminator technology is that it is an unethical technology that deprives farmers of their traditional right to effectively save, use, and exchange seeds, which is the

[3] The first patent on GURTs was granted to Delta and Pine Land Co and the US Department of Agriculture in March 1998 (US patent 5,723,765, on the "Control of Plant Gene Expression"). This patent describes "a set of interacting genetic elements that allows the controlled expression of value-added trait or of seed viability in a crop plant" (Visser et al. 2001, p. 9). While current patent applications apply to plants, GURTs could be built into any organism (e.g., farm animals, fish and trees) (Visser et al. 2001).

[4] For instance, biotech companies can threaten to introduce terminator technology if a country does not improve its IPRs protection. In this case, a country that chooses to ban the technology looses the right to use the potentially valuable protected trait (Pendleton 2004).

[5] The Consultative Group on International Agricultural Research (CGIAR) pledged never to use any kind of terminator technology seeds and the Food and Agriculture Organization of the United Nations is against the use of terminator technology (Pendleton 2004).

foundation of independence and food security for poor and small farmers. In addition, critics are concerned about the environmental effects of gene flow from crops which are sterilized and could, thus, sterilize other plants and have serious effects on the ecosystem (Jefferson 1999; Crouch 1998).[6] The opponents of the terminator technology also claim that it would restrict access to genetic resources and hinder the efforts of public institutions and farmers to make new discoveries through breeding, as terminator seeds produce sterile seeds and would, thus, affect the innovative potential of small and medium enterprises, increasing the barriers between public and private gene pools, which could imply less innovation in the long run. Related to this last concern is the concern that terminator technology will create perpetual monopolies which would lead to the unequal distribution of economic rents between farmers, seed companies and consumers (Shinivasan and Thirtle 1999). Finally, there is concern that the introduction of terminator technology will lead to an increase in both horizontal concentration and vertical integration (between the seed breeding and agrochemical sectors) creating monopolies in agricultural R&D and a displacement of investment may occur away from biotechnological options that might be more beneficial to farmers in developing countries.

An ex-ante economic and/or ecological/environmental analysis of the impact of the introduction of terminator technology is a formidable task. The majority of the existing studies focus on the potential impacts of GURTs from an environmental, biosafety and moral point of view and discuss the possible welfare effects of the technology for farmers, firms and the society in a heuristic way (Visser et al. 2001; Gary

[6] Thus, even those farmers who reject the use of GURTs might be affected by its introduction as the fertility of their seeds could be affected by the gene flows from GURTs.

2002; Eaton et al. 2002; Pendleton 2004). Another group of empirical studies uses data from the introduction of hybrid technology that shares some degree of use restriction with V-GURTs to make inferences about its potential economic effects (Swanson and Goeschl 2000, 2002c; Goeschl and Swanson 2000, 2002a, 2002b, 2003; Srinivasan and Thirtle 2000, 2002, 2003).[7] The above studies shows that hybridization enabled seed companies to capture greater profits and has attracted more private investment into plant breeding which could also occur in the case of GURTs (Srinivasan and Thirtle 2000; 2002; 2003).

Even though the above studies have shed some light into understanding the potential benefits and costs associated with GURTs, very few studies have developed a formal analytical framework to examine the economic effects of GURTs. Lence et al. (2005) estimate the impact of changes in the strength of the IPR regime on the welfare of consumers, producers and the R&D sector, without explicitly considering the case of GURTs; instead the study assumes that the introduction of GURTs is similar to a case where infinite IPR protection is granted. Burton et al. (2005) use a two-period principal-agent model to examine the property rights protection of GM crops and compare sterile GM seed to short and long term contracts between seed producers and farmers in terms of their efficiency in protecting IPRs. Finally, Ambec et al. (2005) develop a two-period model that studies the impact of crop trait durability on pricing strategies, switching decisions and self-production and focus on inefficiencies due to market power and the seed's ability to self-produce.

This study extends the existing literature by developing an analytical framework

[7] Hybridization can be viewed as a weaker version of GURTs where the germplasm remains available to farmers and competing breeders for further breeding but where the crops grown from saved seed do not exhibit the desirable features of the initial seed (the loss from replanting hybrids is generally 25-30%, while the expected yield loss from using GURTs seeds is 100%).

of heterogeneous consumers and producers to examine the potential market and welfare effects of the introduction of GURTs for the innovator of the new technology, producers, and the consumers of the final good. Specifically, the study examines how the agronomic characteristics of GURTs (relative to 1st generation, producer-oriented GM and conventional products), consumer perceptions and preferences regarding interventions in the production process (i.e., genetic modification) and producer cost structures (e.g., dependency on saving seed) affect the adoption of the technology by producers, the market acceptance of GURTs by consumers and, consequently, the innovator's incentive to introduce the new technology. The analysis analyzes the market effects of the introduction of GURTs under the current No-Labeling regime of GMPs in the US. The market outcomes from the introduction of GURTs are compared to the status quo where GURTs are not present in the market.

Analytical results show that the consumer welfare effects of the introduction of GURTs depend on a number of factors such as the production share of GURTs in the total production of the non-labeled product, consumer aversion to GURTs relative to their aversion to GMPs and the relative product prices before and after the introduction of GURTs. In general, the lower is the price of the product produced with GURTs and the smaller is its production share in the total production of the non-labeled product, the more likely it is that the introduction of GURTs will lead to welfare gains for consumers with low levels of aversion to genetic modification and the lower are the welfare losses for consumers with high levels of aversion to genetic modification. The producer welfare effects of the introduction of GURTs depend on the relative product and seed prices before and after the introduction of GURTs, the agronomic benefits of the GURTs seed

over the GM seed, producers' ability to save seed and the expected penalty producers face when they cheat on their GM seed licensing agreements. Specifically, the greater are the agronomic benefits of the GURTs crop, the higher is the price of the non-labeled product and the lower is the GURTs seed price, the greater are the welfare gains of the introduction of GURTs for producers with low dependency on saving seed and the more likely it is that producers with relatively high dependency on saving seed will find it profitable to switch their production from the conventional and the GM crop to the GURTs crop. Finally, the results show that the lower is consumer aversion to genetic modification and the lower is the expected penalty producers face when they cheat on their GM licensing agreements (e.g., due to inefficient or costly monitoring), the greater is the incentive of the seed company to introduce the GURTs technology as the greater are the profits that can be captured by the innovating firm.

The remainder of the paper is organized as follows. Section two develops the heterogeneous consumer and producer models, presents the market outcome and the decisions of the innovating firm, followed by section three where the welfare analysis is carried out. Section four concludes the study and makes suggestion for future research.

2. Market Effects of the Introduction of V-GURTs

The model developed is based on the analytical framework introduced by Fulton and Giannakas (2004) who study the market decisions and welfare of consumers, producers and life science companies under different labeling regimes for GM products. The current model assumes that the available products in the market are vertically differentiated, that is, if all products are offered in the market at the same price, only one product – the product that is perceived as the high quality product – will have a positive market share.

The players in this model are:

- consumers who are concerned about interventions in the production process and may differ in their willingness to pay for GURTs versus GM and conventional food products;
- producers who differ with respect to their location, agricultural conditions, skills and experience, production costs, size and dependency on saving seed;
- a firm/monopolist who has invented GURTs and is introducing GURTs seed into the market.

The model assumptions concerning consumer perceptions and preferences regarding GURTs, producer heterogeneity with respect to costs of production and their dependency on saving seed, the agronomic effects of GURTs, and the characteristics of the innovating firm that introduces GURTs seed into the market are discussed in the sections that follow. The analysis considers two cases: the status quo where GURTs are not present in the market and the case where GURTs are introduced.

2.1 Consumer purchasing decisions

This study explicitly accounts for differences in consumer preferences regarding their aversion to interventions in the production process of GM, GURTs, and conventional food products. To capture the difference in consumers' attitudes towards GM and GURTs products, consumers are assumed to differ in the utility they receive from the consumption of GM and GURTs products and, thus, in their willingness to pay for these products. This consumer heterogeneity in terms of preferences for different food products is important in explaining the possible coexistence of markets for products produced through different production processes (Giannakas and Fulton 2002).

The market examined consists of a product which could become available in a conventional, a GM, and a GURTs form as well as of a substitute to the above products. Consumers cannot detect certain product qualities by either search or experience in consumption. The differentiating attribute among the different forms of the final products is the process through which the products are produced which is a credence attribute. Since the physical characteristics of the different types of products are indistinguishable, consumers have to rely on labels for informed consumption decisions.

As consumers are concerned about the health and environmental effects of genetic modification, it is assumed that they are averse to interventions in the production process and that the greater is the degree of the intervention in the production process of a given product, the greater is the utility discount received by consumers from the consumption of this product. It follows then that consumers differ in their willingness-to-pay (WTP) for the products available in the market. Based on the above, if the prices of the conventional, the GM, and the GURTs products were the same, and consumers could differentiate between these products, then all consumers would buy the conventional product. So the coexistence of markets for products produced through different production processes is the result of differences in product prices and differences in consumers' WTP for the process attributes. The differences in consumers' WTP for products are very important in understanding how GM, conventional and substitute demands exist and how consumers react to the introduction of GURTs. Consumers may differ in their willingness to pay because of differences in their income, age, education, geographical location, among other factors. To be able to analyze consumers' purchasing decisions we need to determine the utility derived by consumers from the consumption of

the products available in the market.

In the market considered here consumers are heterogeneous, uniformly distributed in the interval $[0,1]$. Thus, consumers are differentiated with respect to a characteristic c, where $c \in [0,1]$. Each consumer buys one unit of the type of product they prefer and this purchasing decision represents a small share of their budget.

Consumers' utility function is given by equation (1):

$$
(1)\quad
\begin{cases}
U_c = U - p_c & \text{if a unit of conventional product is consumed} \\
U_{gm} = U - p_{gm} - \lambda c & \text{if a unit of GM product is consumed} \\
U_{gurt} = U - p_{gurt} - \mu c & \text{if a unit of GURTs product is consumed, and} \\
U_s = U - p_s & \text{if a unit of a substitute product is consumed}
\end{cases}
$$

where U_c, U_{gm}, U_{gurt} and U_s are, respectively, the utilities derived from the consumption of one unit of the conventional, the GM, the GURTs, and the substitute product, respectively. The parameter U is a base level of utility associated with the physical characteristics of the product and, therefore, is the same for all four types of products. The parameters p_c, p_{gm}, p_{gurt}, and p_s represent the market prices of the conventional, the GM, the GURT, and the substitute products, respectively. The parameters λ and μ are non-negative utility discount factors that are constant across consumers and along with the parameter c determine consumers' level of aversion to interventions in the production process. The greater are those parameters the higher is the aversion of consumers to interventions in the production process; if $\lambda = 0$ or $\mu = 0$ then consumers would be indifferent between the types of products when these products are sold at the same price. The characteristic *c* differs across consumers and, as was

mentioned earlier, it captures consumers' aversion towards intervention in the production process and, thus, their WTP for the products available. As $c \in [0,1]$, those consumers who have larger values of c prefer the conventional product rather than the GM or the GURTs product, all else equal. The terms λc and μc give the discount in the level of utility from the consumption of the GM and the GURTs product, respectively. It is assumed that consumers' aversion towards GURTs is at least as high as their aversion towards GMPs, i.e., $\mu \geq \lambda$. This assumption is introduced to capture expressed consumer concerns about the inability of producers to save and replant seed (ETC group 1998; 2003; Pendleton 2004). Thus, if consumers view GURTs as any other GM product then $\mu = \lambda$, while if they are concerned about producers' inability to save seed then $\mu > \lambda$.

Consumers are making decisions as to which product to buy based on the relative utilities associated with the consumption of the four products. This depends on the base utility, on the price of the products, and on their level of aversion to genetic modification.

Status Quo

Before the introduction of GURTs, the market consists of a GM, a conventional, and a substitute product. Considering the current situation in the US market, it is assumed that the GM and the conventional product are marketed together as a non-labeled product. Thus, consumers face two products: the non-labeled product (which consists of the GM and the conventional products) and the substitute product. Because the GM and the conventional products are marketed together, the market price is the same for both products and is denoted by p_{nl}. Assume that there is a probability denoted by ψ that the non-labeled product purchased by a consumer is GM, and probability of $(1-\psi)$ that the

non-labeled product is conventional. It is assumed that consumers have rational expectations so that ψ represents the production share of the GM product in the total production of the non-labeled product. Consumer utility derived from the consumption of the non-labeled product is then given by:

(2) $U_{nl} = \psi U_{gm} + (1-\psi)U_c \Rightarrow U_{nl} = U - p_{nl} - \psi\lambda c$.

Thus, U_{nl} is the expected utility associated with the consumption of the non-labeled product and represents a weighted average of the utilities derived from the consumption of the GM and the conventional products. A consumer chooses which product to buy by comparing the utilities they get from purchasing the non-labeled and the substitute product. The consumer with characteristics $\hat{c}_{nl} : U_{nl} = U_s \Rightarrow \hat{c}_{nl} = \frac{p_s - p_{nl}}{\psi\lambda}$ is indifferent between consuming the non-labeled product and the substitute product, since the utility derived from the consumption of these products is the same.

Figure 1 shows that consumers with $c \in [0, \hat{c}_{nl})$ will consume the non-labeled product, and those with $c \in (\hat{c}_{nl}, 1]$ will consume the substitute product. When consumers are uniformly distributed with respect to their aversion to interventions in production process, $\hat{c}_{nl}$ determines the market share of the non-labeled product, denoted by s_{nl}. By normalizing the mass of consumers to one, s_{nl} gives the consumer demand for the non-labeled product:

(3) $s_{nl} = \hat{c}_{nl} = \frac{p_s - p_{nl}}{\psi\lambda}$.

Equation (3) indicates that for the non-labeled product to capture a positive market share it should be priced below the substitute product.

The inverse demand for the non-labeled product is then:

(4) $p_{nl} = p_s - \psi\lambda s_{nl}$.

The demand for the substitute product is given by:

(5) $s_s = 1 - s_{nl} \Rightarrow s_s = 1 - \frac{p_s - p_{nl}}{\psi\lambda}$

from which the inverse form can be derived:

(6) $p_s = p_{nl} + \psi\lambda - \psi\lambda s_s$.

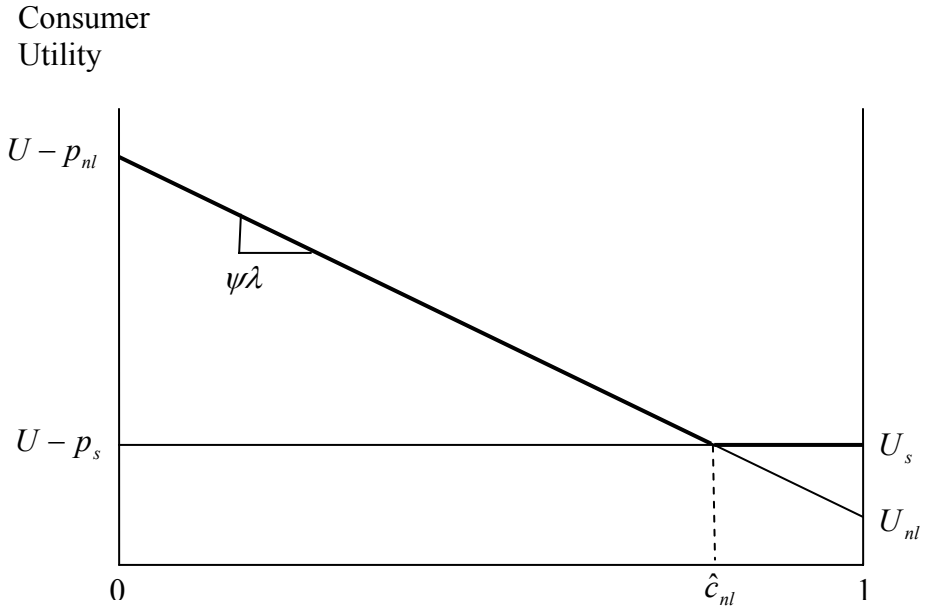


Figure 1. Consumption decisions before the introduction of GURTs.

After the introduction of GURTs

After the introduction of GURTs, the GURTs, GM and conventional products are marketed together as a non-labeled product. Thus, the analysis examines the general case where after the introduction of GURTs, the GM and the conventional product will continue to be supplied in the market. Other possible outcomes are analyzed as special

cases. Given that GURTs are genetically modified products that also result in seed sterility and consumers are averse to the process of genetic modification, it is assumed that GURTs producers, like GM producers, will not have an incentive to voluntarily label their product. Thus, after the introduction of GURTs consumers face two products: the non-labeled product (which now consists of the GURTs, the GM, and the conventional products) priced at p_{nl}^{G} and the substitute product, priced at p_s. Assume that there is a probability denoted by θ that the non-labeled product purchased by consumers is GURTs; a probability denoted by α that the non-labeled product purchased is GM (but not GURTs), and a probability of $(1-\theta-\alpha)$ that the non-labeled product purchased is conventional. The consumer utility derived from the consumption of the non-labeled product after the introduction of GURTs is now given by:

(7) $$U_{nl}^{G} = \theta U_{gurt} + \alpha U_{gm} + (1-\theta-\alpha)U_c \Rightarrow U_{nl}^{G} = U - p_{nl}^{G} - (\theta\mu + \alpha\lambda)c\,.$$

The consumer with characteristics $\hat{c}_{nl}^{G} : U_{nl}^{G} = U_s \Rightarrow \hat{c}_{nl}^{G} = \frac{p_s - p_{nl}^{G}}{(\theta\mu + \alpha\lambda)}$ is indifferent between consuming the non-labeled and the substitute product, because the utility derived from the consumption of these products is the same. Consumers with $c \in \left[0,\, \hat{c}_{nl}^{G}\right)$ will consume the non-labeled product, and those with $c \in \left(\hat{c}_{nl}^{G}, 1\right]$ will consume the substitute product. This outcome is depicted in Figure 2. Since consumers are uniformly distributed with respect to their aversion to interventions in the production process, $\hat{c}_{nl}^{G}$ also determines the market share of the non-labeled product, denoted by s_{nl}^{G} which, as previously discussed, also gives the consumer demand for the non-labeled product:

(8) $$s_{nl}^{G} = \hat{c}_{nl}^{G} = \frac{p_s - p_{nl}^{G}}{(\theta\mu + \alpha\lambda)}.$$

Given the above, for the non-labeled product to have a positive market share, its price should be below the price of the substitute product.

The inverse demand for the non-labeled product is then given by:

(9) $$p_{nl}^{G} = p_s - (\theta\mu + \alpha\lambda)s_{nl}^{G}.$$

The demand for the substitute product is given by:

(10) $$s_s^{G} = 1 - s_{nl}^{G} = 1 - \frac{p_s - p_{nl}^{G}}{(\theta\mu + \alpha\lambda)}$$

and its inverse form can be expressed as:

(11) $$p_s = p_{nl}^{G} + (\theta\mu + \alpha\lambda) - (\theta\mu + \alpha\lambda)s_s^{G}.$$

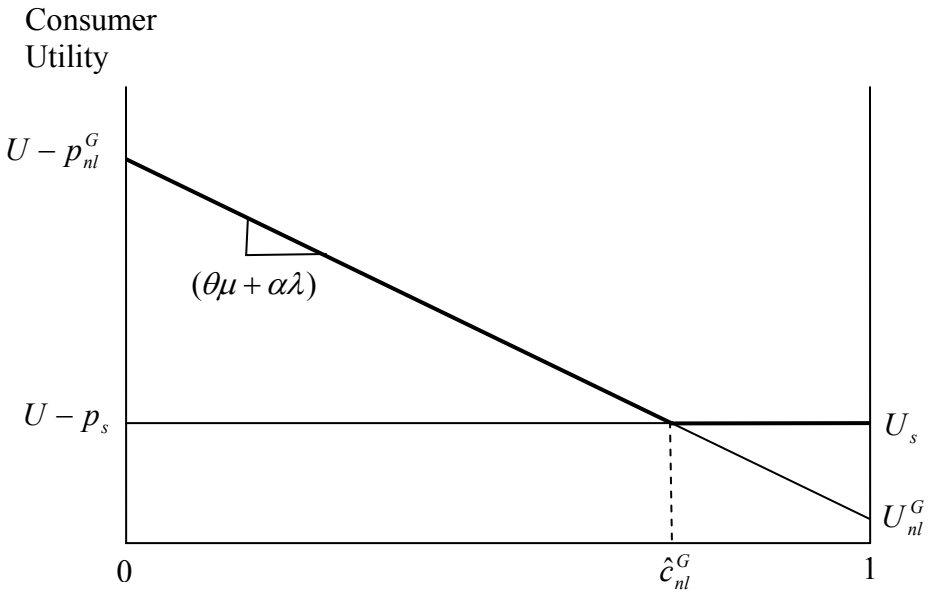


Figure 2. Consumption decisions after the introduction of GURTs.

2.2 Producer production decisions

This study also explicitly accounts for producer heterogeneity with respect to their costs

of producing the GM, the GURT, the conventional and the alternative crops and, thus, with respect to the net returns producers receive from the production of the four crops. Producer heterogeneity in terms of production costs depends on factors like their dependency on saving seeds, location, agricultural conditions, skills and experience, size and education and is important in explaining the production of different crops.

The use of genetically modified seed is assumed to generate production cost savings for producers while having no effect on product characteristics that are observable by consumers. Thus, the GM product considered is a producer-oriented, 1st generation GMP rather than a consumer-oriented, 2nd generation GMP (e.g., vitamin A enriched rice, high oleic acid soybean oil). However, there is no consensus in the literature as to the potential benefits of GURTs (i.e., on productivity of GURT seeds vs. GM seeds) for producers and how these benefits compare to benefits received from the use of 1st generation GM seed.[8] Thus, different scenarios will be examined where farmers have some agronomic benefits from using GURTs versus GM seed and where such benefits do not exist.

What is known is that producers cannot save and re-use seed the following year and have to return to the market every year if they use the GURTs seed. In this context, for producers to find it optimal to adopt GURTs, the expected benefits associated with the added attribute of the GURTs seed (e.g., increased productivity or drought resistance) should be greater than the expected costs (costs of returning to the market every year). In

[8]For instance, Budd (2004) argues that even though GURTs might succeed in countries like Australia only if they offer large agronomic advantages to growers, he does not discuss what the agronomic benefits of GURTs might be. Pendleton (2004, p. 20) states that "even assuming that TT-protected seed has a higher cost than normal GM seed because … it must be purchased every year, the increased cost could be outweighed by the gains produced by the value-added traits, such as improved yield, improved chemical content, reduced need for chemical inputs…". Shinivasan and Thirtle (2000; 2002; 2003) state that unlike GM varieties that offer agronomic benefits to farmers, TT offers only economic benefits to seed companies.

addition, under current law farmers can save non-GM seed (Ozertan et al. 2002). In the case of GM seed, however, there are Technology Use Agreements which prohibit re-use or sale of GM seed (Ozertan et al. 2002). Thus, producers who decide to use GM seed need to decide whether they will cheat on their licensing agreement or not.

To capture these elements, producers are assumed to be uniformly distributed in the interval $[0,1]$ and to differ with respect to an attribute A, where $A \in [0,1]$. The parameter A captures differences in the producers' ability to save seed and other characteristics that affect their production costs (e.g., skills, experience, quality of land etc.). For simplicity it is assumed that every producer produces one unit of output. So the producer with an attribute A, who produces one unit of the product, has the net return/profit given by equation (12) before GURTs are introduced and by equation (13) after GURTs are introduced:

$$
\begin{cases}
\Pi_c = p_{nl}^f - w_c A - \beta A & \text{if a unit of conventional product is produced} \\
\Pi_{gm}^{NC} = p_{nl}^f - w_{gm} - \delta A & \text{if a unit of GM product is produced and producers never cheat (no cheating)} \\
\Pi_{gm}^{C} = p_{nl}^f - w_{gm} A - \delta A - \rho(A,\varepsilon)h & \text{if a unit of GM product is produced and producers cheat (cheating), and} \\
\Pi_a = 0 & \text{if a unit of an alternative product is produced}
\end{cases}
\tag{12}
$$

$$\Pi_c^G = p_{nl}^{f\,G} - w_c A - \beta A \quad \text{if a unit of conventional product is produced}$$

$$\Pi_{gm}^{NC\,G} = p_{nl}^{f\,G} - w_{gm}^G - \delta A \quad \text{if a unit of GM product is produced and producers never cheat (no cheating)}$$

(13)

$$\Pi_{gm}^{C\,G} = p_{nl}^{f\,G} - w_{gm}^G A - \delta A - \rho(A, \varepsilon)h \quad \text{if a unit of GM product is produced and producers cheat (cheating)}$$

$$\Pi_{gurt} = p_{nl}^{f\,G} - w_{gurt} - \gamma A \quad \text{if a unit of GURT product is produced, and}$$

$$\Pi_a = 0 \quad \text{if a unit of an alternative product is produced}$$

In equations (12) and (13), p_{nl}^f and $p_{nl}^{f\,G}$ denote the farm prices of the conventional, the GM, and the GURTs products, before and after the introduction of GURTs, respectively. Note that these products are marketed together as a non-labeled product both before and after the introduction of GURTs. The farm price includes all production costs except the cost of seed. The parameters w_c and w_{gm} denote the seed prices of the conventional and the GM product, respectively, before the introduction of GURTs, while w_{gm}^G and w_{gurt} denote the seed prices of the GM and the GURTs products, respectively, when GURTs are introduced. For simplicity and without loss of generality, it is assumed that the conventional seed supply sector is perfectly competitive so that under the constant returns to scale technology the introduction of GURTs seed does not affect the price of the conventional seed, w_c. In this model, however, the price of GM seed is determined by the monopolist who introduces GURTs seed into the market so the price of GM seed after the

introduction of GURTs, w_{gm}^{G}, may be different from the price of GM seed under the status quo, w_{gm}. The parameters β, δ and γ are non-negative cost-enhancement factors and are constant across producers. It is assumed that $0 < \delta < \beta$, which means that the GM crop is more cost effective than the conventional crop. It is also assumed that $\gamma \leq \delta$, which means that the GURTs crop is at least as cost effective as the GM crop. Thus, if $\gamma < \delta$ the GURT crop producers have some agronomic benefits over the GM crop producers, while if $\gamma = \delta$ there are no additional agronomic benefits from using GURTs seed over GM seed. The parameter ρ is the probability of being caught saving GM seed, which, as discussed previously, is illegal, and h is the penalty the producer has to pay in the case he is caught cheating.

Given the specification of the profit functions in equations (12) and (13), a producer with an A value of zero realizes higher profits than a producer with an A value of one. Note, for instance, that a producer who produces the conventional product and has an $A = 0$ realizes profits $\Pi_c = p_{nl}^{f}$ or $\Pi_c^{G} = p_{nl}^{f\,G}$, while a producer with an $A = 1$ that produces this product realizes profits $\Pi_c = p_{nl}^{f} - w_c - \beta$ and $\Pi_c^{G} = p_{nl}^{f\,G} - w_c - \beta$ before and after the introduction of GURTs, respectively. In addition, it is assumed that producers with a value of $A = 0$ save 100% of the seeds they need (i.e., they are the most efficient in reproducing their own seed) while producers with a value of $A = 1$ buy all their seeds from the market. Thus, the producers who are expected to be most affected from the introduction of GURTs are those with low A values.

In the net returns for the conventional product, Π_c and Π_c^{G}, those farmers who find it profitable to save seed from the previous harvest will do so and will incur only a

fraction of the cost of seed $w_c A$ (which depends on each individual producers' ability to save seed, A). For simplicity it is assumed that the cost of saving and reusing seed is zero. Thus, $w_c A$ represents the effective price the producer pays for the conventional seed.

Producers who decide to use GM seed need to decide whether they will cheat on their agreement or not. If GM producers do not cheat, their profits, before and after the introduction of GURTs, are given by the profit function Π_{gm}^{NC} and $\Pi_{gm}^{NC\,G}$, respectively. In this case, producers are buying GM seed every year regardless of their ability to save seed. If GM producers cheat on their agreement, their profits before and after the introduction of GURTs are given by Π_{gm}^{C} and $\Pi_{gm}^{C\,G}$, respectively. In this case, producers cheat and save GM seed based on their ability to save seed, A, and they pay a penalty when they are caught cheating. The term ρh denotes the expected penalty paid when the producer cheats on the licensing agreement and it is a function of the producer's ability to save seed; the higher is the value of A, the lower is the producer's ability to save seed, and the smaller is the expected penalty the producer faces when he cheats on the agreement. The expected penalty, ρh, is a function of the producer's ability to save seed , A, either because the probability of getting caught cheating, ρ, or the penalty paid by farmers when caught cheating, h, or both, are a function of A. For tractability (i.e., to avoid non-linearities) it is assumed that only the probability of getting caught cheating is a function of the producer's ability to save seed, A, while the penalty paid when caught cheating is independent of the value of A. For simplicity, the penalty, h, is determined

by a regulator and is assumed to be exogenous to the seed company[9].

The probability of being caught cheating, ρ, is a function of the effort, ε, the seed company puts into detecting producers, where $\varepsilon \in [0,1]$, and the characteristics of the producers, i.e., their ability to save seed, A. The probability ρ is given by $\rho = \varepsilon(1-A)$ which implies that the more effort the company puts into detecting producers, the higher is the probability of detecting producers that cheat, everything else constant. Also, the lower is the value of A (i.e., the greater is the amount of seed saved by the producer), the greater is the probability that the producer will be caught cheating, everything else constant. As an example, when $\varepsilon = 1$ the company exerts the maximum possible effort in identifying cheaters so that for the producer that saves seed 100% ($A = 0$) the probability of being caught cheating is equal to one ($\rho = \varepsilon = 1$). Note that, when $A = 1$ then $\rho = 0$, which implies that since a producer with characteristic $A = 1$ cannot save seed she will never get caught cheating. Given the above, the profits associated with the production of the GM product with illegally used seed before and after the introduction of GURTs are given by $\Pi_{gm}^{C} = p_{nl}^{f} - w_{gm}A - \delta A - \varepsilon(1-A)h$ and $\Pi_{gm}^{C\,G} = p_{nl}^{f\,G} - w_{gm}^{G}A - \delta A - \varepsilon(1-A)h$ in equations (12) and (13), respectively.

In the profit function for the GURTs product, Π_{gurt}, the cost of buying the seed, w_{gurt}, is not affected by the value of A (the producer's ability to save seed). The reason is that the seed of a GURTs plant is sterile and all producers have to buy their seeds in the market.

[9]In reality, companies set their own penalties. For example, Monsanto imposes a penalty of 15$ per acre for every acre planted with Roundup Ready canola seed not covered by the technology use agreement and if the grower sells, gives or transfers any seed containing the Roundup Ready gene for each acre capable of being planted using that seed (Network of Concerned Farmers, *Copy of Technology User Agreement*, 2003, http://www.non-gm-farmers.com/news_details.asp?ID=310).

For simplicity, the profits of producing the alternative crop are normalized to zero. This assumption allows us to concentrate on the profits of the conventional, the GM and the GURTs products.

Status Quo

Producers are making decisions as to which product to produce taking the market price as given, i.e., thus, the market for the farm product is assumed to be competitive. The decisions of producers are based on the profits they earn, which depends on the market price and the cost of producing each product type.

Note that at $A = 0$ the net returns realized when the conventional product is produced are greater than the net returns realized when the GM product is produced and producers do not cheat, $\Pi_c(A = 0) > \Pi_{gm}^{NC}(A = 0)$ and the slope of the profit curve Π_c is greater in absolute terms than the slope of the profit curve Π_{gm}^{NC} (i.e., $w_c + \beta > \delta$ since $0 < \delta < \beta$). The above imply that both the conventional product and the GM product that is produced by producers who do not cheat can coexist in the market. In addition, at $A = 0$ the profits realized when the conventional product is produced are greater than the profits realized when the GM product is produced and producers cheat, $\Pi_c(A = 0) > \Pi_{gm}^{C}(A = 0)$ as long as $\varepsilon h > 0$. Thus, for both the conventional and the GM product that is produced by producers who cheat to coexist in the market, the slope of the profit curve of the conventional product, Π_c must be steeper than the slope of the profit curve of the GM product under cheating, Π_{gm}^{C} (i.e., $w_c + \beta > w_{gm} + \delta - \varepsilon h$). At $A = 1$, $\Pi_{gm}^{C}(A = 1) = \Pi_{gm}^{NC}(A = 1) = p_{nl}^{f} - w_{gm} - \delta$ since producers with characteristic $A = 1$ do not save seed. At $A = 0$, $\Pi_{gm}^{C} > \Pi_{gm}^{NC}$ when $\varepsilon h < w_{gm}$. Thus, when $\varepsilon h < w_{gm}$ then $\Pi_{gm}^{C} > \Pi_{gm}^{NC}$

for any $A \in [0,1)$; $\Pi_{gm}^{C} = \Pi_{gm}^{NC}$ for $A = 1$. This implies that, if the penalty or the effort exerted by the seed company in identifying cheaters or both are low enough, the profits realized by producers that produce the GM product and cheat are greater than the profits realized by producers who produce the GM product and do not cheat. On the other hand, when $\varepsilon h > w_{gm}$ then $\Pi_{gm}^{NC} > \Pi_{gm}^{C}$ at $A = 0$, which, given that at $A = 1$ $\Pi_{gm}^{C} = \Pi_{gm}^{NC}$, implies that all producers who find it profitable to produce the GM product will not cheat on their agreements.

The analysis proceeds assuming that all producers who find it profitable to produce the GM product will cheat on their licensing agreements according to their ability to save seed (A); thus, it is assumed that $\varepsilon h < w_{gm}$. Note that the above does not imply that all producers who produce the GM product will cheat; producers with an A value equal to one will not cheat on their agreements. The analysis focuses on the producers who produce the GM product and cheat to better capture what is observed in practice and allow for the study of the incentives of the seed provider to introduce the GURTs variety where, due to the nature of the technology embodied in the seed, producers are unable to cheat. Note that if all producers who produce the GM product did not cheat regardless of their ability to save seed, then the seed company would not have an incentive to introduce the new type of sterile seed.

Figure 3 depicts the case where the conventional product and the GM product produced by producers who cheat coexist in the market. For illustrative purposes, the profit function Π_{gm}^{NC} is also depicted.

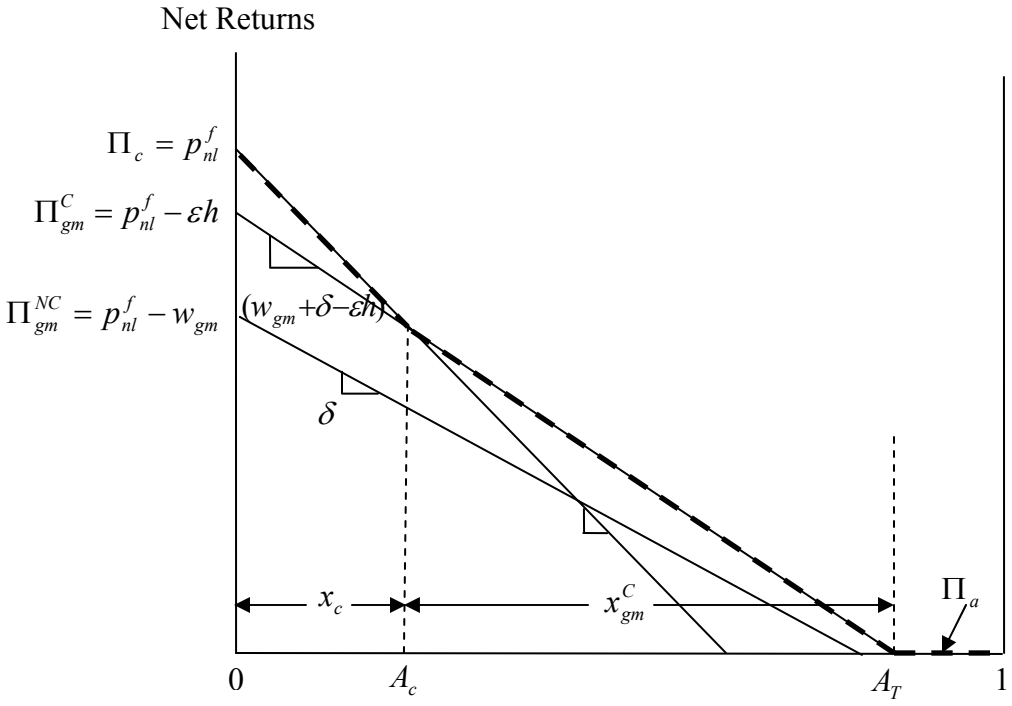


Figure 3. Production decisions before the introduction of GURTs.

The producer who is indifferent between producing the conventional product and the GM product while cheating is denoted by A_c, where:

$$(14) \qquad A_c : \Pi_c = \Pi_{gm}^C \Rightarrow A_c = \frac{\varepsilon h}{w_c - w_{gm} + \beta - \delta + \varepsilon h}.$$

When producers are uniformly distributed between $[0,1]$, A_c gives the supply of the conventional product, $x_c = \dfrac{\varepsilon h}{(w_c + \beta) - (w_{gm} + \delta - \varepsilon h)}$. Note that if cheating while producing the GM product is 'costless' to the producer, $\varepsilon h = 0$ (either because the effort exerted by the seed provider in identifying cheating or the penalty paid when caught cheating, or both, are zero), then $x_c = 0$; that is, all producers would produce the GM

product and the conventional product would not be produced.

The producer who is indifferent between producing the GM product and the alternative product is denoted by A_T, where:

$$(15) \qquad A_T : \Pi_{gm}^C = \Pi_a \Rightarrow A_T = \frac{p_{nl}^f - \varepsilon h}{w_{gm} + \delta - \varepsilon h}.$$

The supply of the GM crop produced by producers who cheat depending on their ability to save seed is given by:

$$(16) \qquad x_{gm}^C = A_T - A_c \Rightarrow x_{gm}^C = \frac{p_{nl}^f - \varepsilon h}{w_{gm} + \delta - \varepsilon h} - \frac{\varepsilon h}{(w_c + \beta) - (w_{gm} + \delta) + \varepsilon h}$$

$$\Rightarrow x_{gm}^C = \frac{p_{nl}^f (w_c + \beta - w_{gm} - \delta + \varepsilon h) - \varepsilon h (w_c + \beta)}{(w_{gm} + \delta - \varepsilon h)(w_c + \beta - w_{gm} - \delta + \varepsilon h)}$$

and the supply of the alternative crop is given by:

$$(17) \qquad x_a = 1 - A_T \Rightarrow x_a = 1 - \frac{p_{nl}^f - \varepsilon h}{w_{gm} + \delta - \varepsilon h} = \frac{w_{gm} + \delta - p_{nl}^f}{w_{gm} + \delta - \varepsilon h}.$$

Thus, producers with $A \in [0, A_c)$ find it more profitable to produce the conventional product, producers with $A \in (A_c, A_T)$ produce the GM product and cheat, and producers with $A \in (A_T, 1]$ produce the alternative product. Hence, producers at $A = 0$ who save 100% of their seed produce the conventional crop, while producers at $A = 1$ who buy all the seed they need in the market produce the alternative crop.

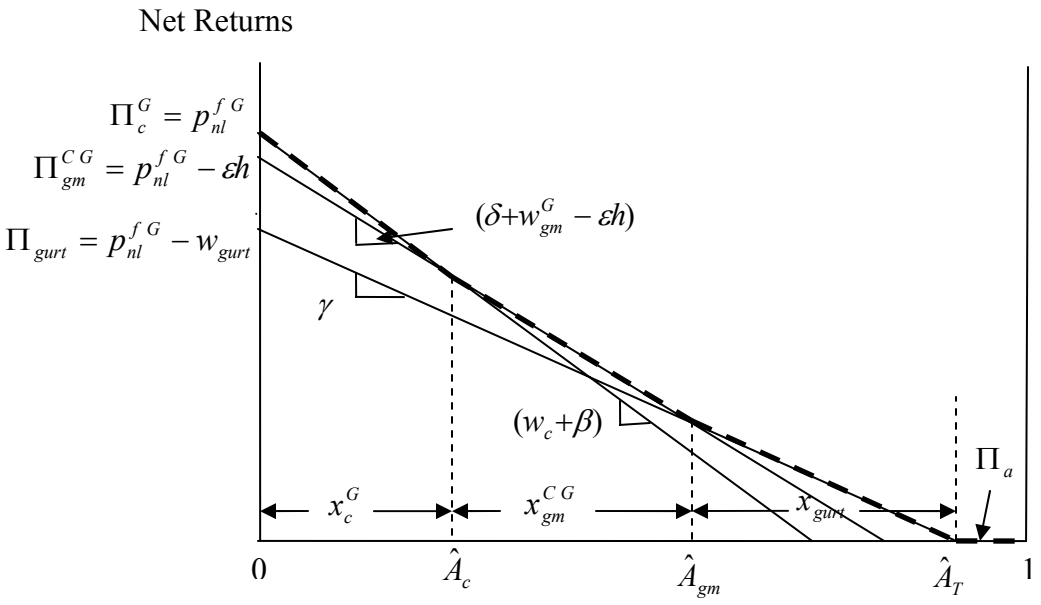
After the introduction of GURT

After the introduction of GURTs, producers need to decide whether to produce the GURTs product or not. This decision depends on the net returns they earn, which depend on a number of factors such as the relative seed and product prices before and after the

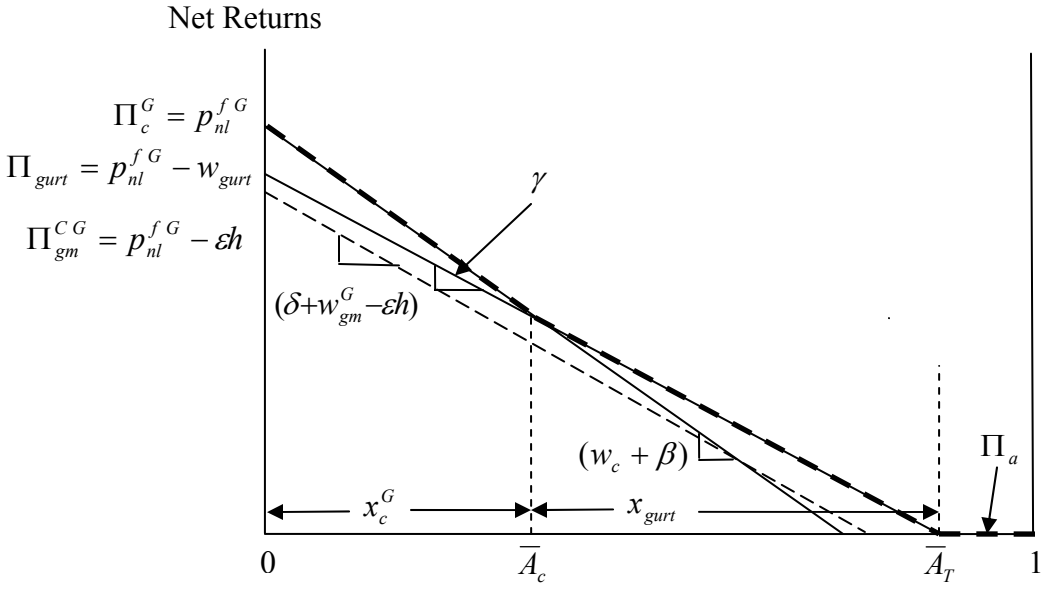
introduction of GURTs, the agronomic benefits of GURTs relative to the agronomic benefits of GMPs, the probability of being caught cheating and the penalty paid when caught cheating.

As previously discussed, there are either no additional agronomic benefits from using the GURTs seed over the GM seed (i.e., $\gamma = \delta$), or the use of GURTs seed has some agronomic benefits over the GM seed (i.e., $\gamma < \delta$). Given that $\gamma \leq \delta$ and $0 < \delta < \beta$ the slopes of the profit curves $\Pi_{gm}^{C\,G}$ and Π_{c}^{G} are greater in absolute terms than the slope of the profit curve Π_{gurt} (i.e., $\delta + w_{gm}^{G} - \varepsilon h > \gamma$ and $w_c + \beta > \gamma$, respectively). At $A = 0$, $\Pi_{c}^{G} > \Pi_{gurt}$ and $\Pi_{gm}^{C\,G} > \Pi_{gurt}$ when $\varepsilon h < w_{gurt}$. This outcome is depicted in Figure 4, panel (i); the conventional, the GM and the GURTs products coexist in the market where the alternative product is also supplied.

On the other hand, when $\varepsilon h > w_{gurt}$ then $\Pi_{gm}^{C\,G} < \Pi_{gurt}$ at $A = 0$. In this case, after the introduction of GURTs only the conventional, the GURTs and the alternative product will be supplied in the market. This outcome is depicted in Figure 4, panel (ii).



Panel (i): All products are produced in the market.



Panel (ii): The GM product is not produced.

Figure 4. Production decisions after the introduction of GURTs.

When all products coexist in the market (Figure 4, panel (i)), the producer who is

indifferent between producing the conventional product and the GM product is denoted by $\hat{A}_c$, where:

$$(18) \qquad \hat{A}_c : \Pi_c^G = \Pi_{gm}^{C\,G} \Rightarrow \hat{A}_c = \frac{\varepsilon h}{w_c - w_{gm}^G + \beta - \delta + \varepsilon h}.$$

In equation (18) $\hat{A}_c$ gives the supply of the conventional product when the GURTs product is in the market, $x_c^G = \frac{\varepsilon h}{(w_c + \beta) - (w_{gm}^G + \delta - \varepsilon h)}$.

The producer who is indifferent between producing the GM product and the GURTs product is denoted by $\hat{A}_{gm}$, where:

$$(19) \qquad \hat{A}_{gm} : \Pi_{gm}^{C\,G} = \Pi_{gurt} \Rightarrow \hat{A}_{gm} = \frac{w_{gurt} - \varepsilon h}{w_{gm}^G + \delta - \gamma - \varepsilon h}$$

implying that when $w_{gurt} = \varepsilon h$ the GM product will not be supplied.

The supply of the GM product is given by:

$$(20) \qquad x_{gm}^{C\,G} = \hat{A}_{gm} - \hat{A}_c \Rightarrow x_{gm}^{C\,G} = \frac{w_{gurt} - \varepsilon h}{w_{gm}^G + \delta - \gamma - \varepsilon h} - \frac{\varepsilon h}{(w_c + \beta) - (w_{gm}^G + \delta - \varepsilon h)}$$

$$\Rightarrow x_{gm}^{C\,G} = \frac{w_{gurt}(w_c + \beta - w_{gm} - \delta + \varepsilon h) - \varepsilon h(w_c + \beta - \gamma)}{((w_{gm}^G + \delta - \gamma - \varepsilon h)\left((w_c + \beta) - (w_{gm}^G + \delta - \varepsilon h)\right)}.$$

The producer who is indifferent between producing the GURTs product and the alternative product is denoted by $\hat{A}_T$, where:

$$(21) \qquad \hat{A}_T : \Pi_{gurt} = \Pi_a \Rightarrow \hat{A}_T = \frac{p_{nl}^{f\,G} - w_{gurt}}{\gamma}.$$

The supply of the GURTs crop is given by:

(22) $$x_{gurt} = \hat{A}_T - \hat{A}_{gm} \Rightarrow x_{gurt} = \frac{p_{nl}^{f\,G} - w_{gurt}}{\gamma} - \frac{w_{gurt} - \varepsilon h}{w_{gm}^G + \delta - \gamma - \varepsilon h}$$

$$\Rightarrow x_{gurt} = \frac{p_{nl}^{f\,G}\left(w_{gm}^G + \delta - \gamma - \varepsilon h\right) - w_{gurt}\left(w_{gm}^G + \delta - \varepsilon h\right) - \gamma\varepsilon h}{\gamma\left(w_{gm}^G + \delta - \gamma - \varepsilon h\right)}.$$

The supply of the alternative crop is given by:

(23) $$\hat{x}_a = 1 - \hat{A}_T \Rightarrow \hat{x}_a = 1 - \frac{p_{nl}^{f\,G} - w_{gurt}}{\gamma} = \frac{\gamma - p_{nl}^{f\,G} + w_{gurt}}{\gamma}.$$

Thus, producers with $A \in \left[0,\, \hat{A}_c\right)$ find it more profitable to produce the conventional product, producers with $A \in \left(\hat{A}_c,\, \hat{A}_{gm}\right)$ produce the GM product, producers with $A \in \left(\hat{A}_{gm},\, \hat{A}_T\right]$ produce the GURTs product, and producers with $A \in \left(\hat{A}_T,\, 1\right]$ produce the alternative product. Hence, producers at $A = 0$ who save 100% of their seed produce the conventional crop, while producers at $A = 1$ who buy 100% of their seed produce the alternative crop. Those producers who are located closer to $A = 1$, however, switch to the production of the GURTs crop.

When only the conventional and the GURTs products are in the market along with the alternative product (Figure 4, panel (ii)), the producer who is indifferent between producing the conventional product and the GURTs product is denoted by $\overline{A}_c$, where:

(24) $$\overline{A}_c : \Pi_c = \Pi_{gurt} \Rightarrow \overline{A}_c = \frac{w_{gurt}}{w_c + \beta - \gamma}.$$

In equation (24) $\overline{A}_c$ gives the supply of the conventional product when the GURTs product is in the market and the GM product is not produced, $\overline{x}_c^G = \frac{w_{gurt}}{w_c + \beta - \gamma}$.

The producer who is indifferent between producing the GURTs product and the

alternative product is denoted by $\overline{A}_T$ and is given by:

$$(25) \qquad \overline{A}_T : \Pi_{gurt} = \Pi_a \Rightarrow \overline{A}_T = \frac{p_{nl}^{f\,G} - w_{gurt}}{\gamma}.$$

The supply of the GURTs product is given by:

$$(26) \qquad \bar{x}_{gurt} = \overline{A}_T - \overline{A}_c \Rightarrow \bar{x}_{gurt} = \frac{p_{nl}^{f\,G} - w_{gurt}}{\gamma} - \frac{w_{gurt}}{w_c + \beta - \gamma} \Rightarrow$$

$$\bar{x}_{gurt} = \frac{p_{nl}^{f\,G}\left(w_c + \beta - \gamma\right) - w_{gurt}\left(w_c + \beta\right)}{\gamma\left(w_c + \beta - \gamma\right)}.$$

The supply of the alternative product is given by:

$$(27) \qquad \bar{x}_a = 1 - \overline{A}_T \Rightarrow \bar{x}_a = 1 - \frac{p_{nl}^{f\,G} - w_{gurt}}{\gamma} = \frac{\gamma - p_{nl}^{f\,G} + w_{gurt}}{\gamma} \text{ and } \hat{x}_a = \bar{x}_a.$$

Equations (23) and (27) show that the supply of the alternative product is the same regardless of whether the GM product is in or out of the market, this is because the analysis focuses on what is happening among the other products, i.e., GURTs, GM and alternative. When the GM product is out of the market that shows that GURTs capture the whole share of the GM production and/or some share of the alternative products.

Thus, producers at $\left[0, \overline{A}_c\right)$ find it more profitable to produce the conventional product, producers at $\left(\overline{A}_c, \overline{A}_T\right)$ produce the GURTs product and producers at $\left(\overline{A}_T, 1\right]$ produce the alternative product. Similar to the previous analysis, producers at $A = 0$ who save all their seed, produce the conventional crop, while producers at $A = 1$ who buy all their seed, produce the alternative crop. Those located closer to $A = 1$, however, switch to the production of the GURTs crop.

2.3 Market Outcome

The market outcome is found by simultaneously solving the demand and supply

equations. To enable the analysis of the monopolist's pricing decision an additional variable and equation are introduced in the demand and supply systems as in Fulton and Giannakas (2004). Let y_{gm} and y_{gm}^{G} be the GM seed sales of the monopolist before and after the introduction of GURTs, respectively, and y_{gurt} the GURTs seed sales of the monopolist.

Note that x_{gm}^{C} and $x_{gm}^{C\,G}$ is the total quantity supplied of the GM product before and after the introduction of GURTs, respectively, and x_{gurt} is the total quantity supplied of the GURTs product. Unlike the GM quantity that is produced by both saved and bought seed, the GURTs quantity is produced only by purchased seed since GURTs seed cannot be saved and reused by producers. In addition, assuming fixed proportions between farm and seed levels, $x_{gurt} = y_{gurt}$. The quantity of the GM seed produced, however, is a function of the producer's ability to save seed, A. The monopolist sells y_{gm} amount of GM seed before the introduction of GURTs and y_{gm}^{G} amount of GM seed after the introduction of GURTs and these quantities are a function of x_{gm}^{C} and $x_{gm}^{C\,G}$, respectively, i.e., $y_{gm} = f(x_{gm}^{C})$ and $y_{gm}^{G} = f(x_{gm}^{C\,G})$. Thus, the sales of the monopolist are a function of the producers' ability to save seed; the greater is the value of A, the smaller is the producers' ability to save seed, and the greater is the quantity of seed sold by the monopolist. If all producers had an A value of zero ($A = 0$), they would save 100% of their seed and would not demand seed from the monopolist; in this case, the monopolist seed sales before and after the introduction of GURTs would be given by $y_{gm} = 0$ and $y_{gm}^{G} = 0$, respectively. Therefore, when $A = 0$ for all producers, x_{gm}^{C} is produced only by

saved seed. If all producers had an A value of one ($A = 1$), they would buy 100% of their seed from the monopolist. In this case, given our assumption of fixed proportions between the farm level and the monopoly level, the monopolist's seed sales before and after the introduction of GURTs would be given by $y_{gm} = x_{gm}^{C}$ and $y_{gm}^{G} = x_{gm}^{C\ G}$, respectively. Therefore, when $A = 1$ for all producers, x_{gm}^{C} and $x_{gm}^{C\ G}$ are produced only by purchased seed.

Given the above and our assumption that producers are uniformly distributed along the interval $[0, 1]$ and each producer produces one unit of the product, the total quantity of GM product produced with purchased seed before the introduction of GURTs is given by aggregating among all producers who produce the GM product, that is, producers located in the interval (A_c, A_T) (see Figure 3). Thus, $y_{gm} = \int_{A_c}^{A_T} A\, dA = \frac{A_T^2 - A_c^2}{2}$ is the quantity of GM seed sold by the monopolist when GURTs are not introduced into the market. Substituting the expressions from equations (15) and (14) into the above expression gives the quantity of GM seed sold by the monopolist before GURTs are introduced as:

$$(28) \qquad y_{gm} = \frac{(p_{nl}^{f} - \varepsilon h)^2}{2(w_{gm} + \delta - \varepsilon h)^2} - \frac{\varepsilon^2 h^2}{2(w_c - w_{gm} + \beta - \delta + \varepsilon h)^2}.$$

To get the total quantity of GM product produced with bought seed when GURTs enter the market, we aggregate among all producers located at $(\hat{A}_c, \hat{A}_{gm})$ (see Figure 4, panel (i)). Thus, $y_{gm}^{G} = \int_{\hat{A}_c}^{\hat{A}_{gm}} A\, dA = \frac{\hat{A}_{gm}^2 - \hat{A}_c^2}{2}$ is the quantity of GM seed sold by the monopolist after the introduction of GURTs. Substituting the expressions from equations

(19) and (18) the quantity of GM seed sold by the monopolist after GURTs are introduced is given by:

$$(29) \qquad y_{gm}^{G} = \frac{(w_{gurt} - \varepsilon h)^2}{2(w_{gm}^{G} + \delta - \gamma - \varepsilon h)^2} - \frac{\varepsilon^2 h^2}{2(w_c - w_{gm}^{G} + \beta - \delta + \varepsilon h)^2}.$$

Status Quo

Given the assumption of fixed proportions and taking into account a constant marketing margin, mm, between the farm and the consumer prices, we have $p_{nl} = p_{nl}^{f} + mm$. The marketing margin mm is assumed to be the same under the status quo and when GURTs are introduced since the product remains non-labeled (there are no identity preservation costs) and for simplicity it is assumed to equal zero, thus $p_{nl} = p_{nl}^{f}$. The non-labeled product retail price under the status quo is obtained by equating the demand and supply equations, $s_{nl} = x_{nl}$. The demand is given by equation (3), while the supply of the non-labeled product, denoted by x_{nl}, is derived through the summation of the quantities supplied by the producers of the conventional, x_c, and the GM products, x_{gm}^{C}, which are given by equations (14) and (16), respectively. Thus, the supply curve for the non-labeled product is a kinked curve since it contains two different products with different production costs, i.e., two different supply curves with different slopes. The supply curve for the non-labeled product under the status quo is depicted in Figure 5. The total quantity of the non-labeled product supplied is given by:

$$(30) \qquad x_{nl} = x_c + x_{gm}^{C} \Rightarrow x_{nl} = \frac{p_{nl}^{f} - \varepsilon h}{w_{gm} + \delta - \varepsilon h}.$$

Note that equation (30) gives the supply of the non-labeled product when only the GM

product is produced (since $A_{gm} : \Pi_{gm}^{C} = \Pi_a \Rightarrow A_{gm} = \frac{p_{nl}^{f} - \varepsilon h}{w_{gm} + \delta - \varepsilon h}$). Similarly, if only the conventional product was produced then the supply of the non-labeled product would be given by $x_{nl} = \frac{p_{nl}^{f}}{w_c + \beta}$ (since $A_c' : \Pi_c = \Pi_a \Rightarrow A_c' = \frac{p_{nl}^{f}}{w_c + \beta}$). Figure (5) below depicts the market equilibrium under the status quo.

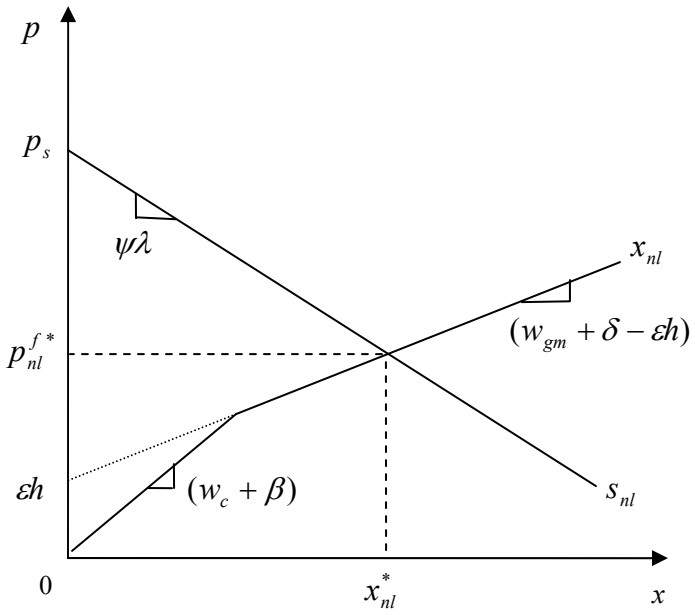


Figure 5. Market equilibrium under the status quo.

Thus, the retail price of the non-labeled product and the price of the GM seed are found by simultaneously solving $s_{nl} = x_{nl}$, $p_{nl} = p_{nl}^{f}$ and the equality in equation (28). Given the complexity of the above equations, we can not get an analytical solution of the equilibrium retail and GM seed prices. However, these prices will be a function of known parameters as expressed in equations (31) and (32) below.

(31) $p_{nl} = f(\varepsilon, h, \psi, \beta, \delta, \lambda, p_s, w_c, y_{gm})$

(32) $$w_{gm} = f(\varepsilon, h, \psi, \beta, \delta, \lambda, p_s, w_c, y_{gm})$$

After the Introduction of GURTs

The demand for the non-labeled product after the introduction of GURTs is given by equation (8), while the supply of the non-labeled product, denoted by x_{nl}^{G}, is derived through the summation of the quantities supplied by the producers of the conventional, x_c^G, the GM, $x_{gm}^{C\,G}$, and the GURTs products, x_{gurt}, which are given by equations (18), (20), and (22), respectively. Thus, the supply curve for the non-labeled product is a kinked curve since it contains three different products with different production costs (see Figure 6 below). The total quantity of the non-labeled product supplied is given by:

(33) $$x_{nl}^{G} = x_c^G + x_{gm}^{C\,G} + x_{gurt} \Rightarrow x_{nl}^{G} = \frac{p_{nl}^{f\,G} - w_{gurt}}{\gamma}.$$

Note that equation (33) gives the supply of the non-labeled product when only the GURTs product is produced (since $A_{gurt} : \Pi_{gurt} = \Pi_a \Rightarrow A_{gurt} = \frac{p_{nl}^{f\,G} - w_{gurt}}{\gamma}$). Similarly, if only the conventional product was produced, then the supply of the non-labeled product would be given by $x_{nl}^{G} = \frac{p_{nl}^{f\,G}}{w_c + \beta}$ (since $A_c^G : \Pi_c^G = \Pi_a \Rightarrow A_c^G = \frac{p_{nl}^{f\,G}}{w_c + \beta}$), while, if only the GM product was produced, then the supply of the non-labeled product would be given by $x_{nl}^{G} = \frac{p_{nl}^{f\,G} - \varepsilon h}{w_{gm}^{G} + \delta - \varepsilon h}$ (since $A_{gm}^G : \Pi_{gm}^{C\,G} = \Pi_a \Rightarrow A_{gm}^G = \frac{p_{nl}^{f\,G} - \varepsilon h}{w_{gm}^{G} + \delta - \varepsilon h}$).

The retail price of the non-labeled product and the price of the GM and the GURTs seeds are found by simultaneously solving $s_{nl}^{G} = x_{nl}^{G}$, $p_{nl}^{G} = p_{nl}^{f\,G}$, $y_{gurt} = x_{gurt}$ and the equality in equation (29). Given the complexity of the above equations we can not get

an analytical solution of the equilibrium retail and GURTs seed prices. However, these prices will be a function of known parameters as expressed in equations (34), (35) and (36) below.

(34) $$p_{nl}^{G} = f(\varepsilon, h, \psi, \theta, \alpha, \beta, \delta, \lambda, \gamma, \mu, p_s, w_c, y_{gm}^{G}, y_{gurt})$$

(35) $$w_{gm}^{G} = f(\varepsilon, h, \psi, \theta, \alpha, \beta, \delta, \lambda, \gamma, \mu, p_s, w_c, y_{gm}^{G}, y_{gurt})$$

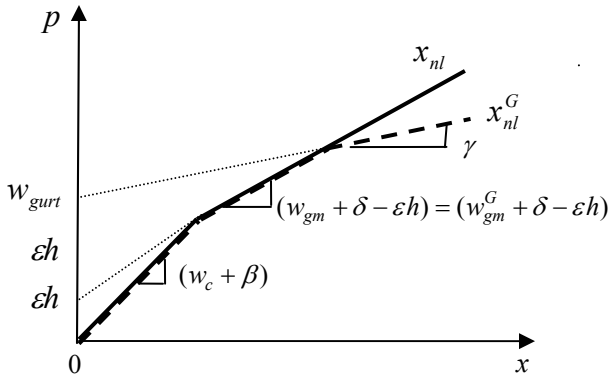
(36) $$w_{gurt} = f(\varepsilon, h, \psi, \theta, \alpha, \beta, \delta, \lambda, \gamma, \mu, p_s, w_c, y_{gm}^{G}, y_{gurt})$$

To determine the market equilibrium after the introduction of GURTs we need to determine how the introduction of GURTs will affect the supply of and the demand for the non-labeled product. The possible changes in the supply of the non-labeled product due to the introduction of GURTs are examined first, followed by the analysis of the possible changes in the demand for the non-labeled product.

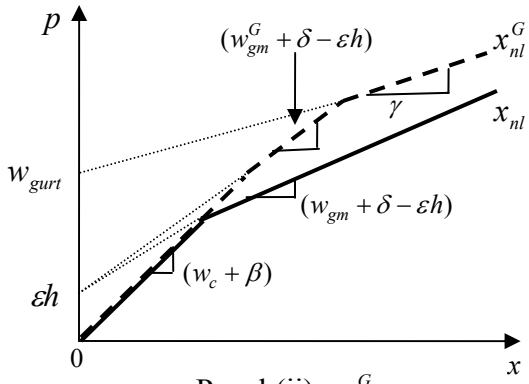
Figure 6 below depicts the possible changes in the supply of the non-labeled product after the introduction of GURTs, with the dashed and solid lines indicating the supply curve of the non-labeled product before and after the introduction of GURTs, respectively. The inverse supply of the non-labeled product before the introduction of GURTs consists of two segments: the inverse supply of the conventional product given by $p_{nl}^{f} = (w_c + \beta)x_{nl}$ (segment before the kink) and the inverse supply of the GM product given by $p_{nl}^{f} = \varepsilon h + (w_{gm} + \delta - \varepsilon h)x_{nl}$ (segment after the kink). The inverse supply of the non-labeled product after the introduction of GURTs consists of three segments: the inverse supply of the conventional product after GURTs given by $p_{nl}^{f\,G} = (w_c + \beta)x_{nl}^{G}$ (segment before the first kink), the inverse supply of the GM product after GURTs given by $p_{nl}^{f\,G} = \varepsilon h + (w_{gm}^{G} + \delta - \varepsilon h)x_{nl}^{G}$ (segment after the first kink) and the inverse supply of

the GURTs product given by $p_{nl}^{f\,G} = w_{gurt} + \gamma x_{nl}^{G}$ (segment after the second kink).

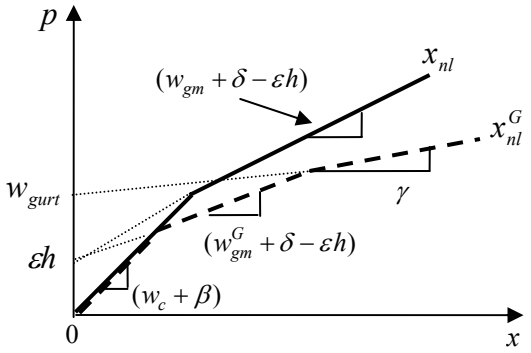
In Figure 6 panel (i) depicts the supply curve of the non-labeled product before and after the introduction of GURTs when there is no change in the price of the GM seed after GURTs enter the market, thus, leaving the slope of the segment of the supply of the non-labeled product that refers to the GM product unchanged, i.e., $w_{gm}^{G} + \delta - \varepsilon h = w_{gm} + \delta - \varepsilon h$. Panel (ii) depicts the change in the supply curve of the non-labeled product when the price of the GM seed increases after the introduction of GURTs, causing the slope of the segment of the supply curve of the non-labeled product that corresponds to the production of the GM product to become steeper, i.e., $w_{gm}^{G} + \delta - \varepsilon h > w_{gm} + \delta - \varepsilon h$. Note, that the intercept εh remains unchanged. Panel (iii) depicts the change in the supply curve of the non-labeled product when the price of the GM seed drops after the introduction of GURTs, causing the slope of the segment of the supply curve of the non-labeled product that corresponds to the production of the GM product to become flatter, i.e., $w_{gm}^{G} + \delta - \varepsilon h < w_{gm} + \delta - \varepsilon h$.



Panel (i): $w_{gm}^G = w_{gm}$



Panel (ii): $w_{gm}^G > w_{gm}$



Panel (iii): $w_{gm}^G < w_{gm}$

Figure 6. Possible changes in the supply of the non-labeled product due to the introduction of GURTs.

Having determined the possible changes in the supply of the non-labeled product due to the introduction of GURTs, we now examine the possible changes in the demand

for the non-labeled product caused by the introduction of GURTs. The inverse demand for the non-labeled product before and after the introduction of GURTs is given by $s_{nl}: p_{nl} = p_s - \psi\lambda s_{nl}$ and $s_{nl}^G: p_{nl}^G = p_s - (\theta\mu + \alpha\lambda)s_{nl}^G$, respectively. The intercept, p_s, is the price of the substitute product and it is assumed to be the same in both demand curves. It is thus assumed that the substitute product sector is perfectly competitive so the price of the substitute product does not change (i.e., the supply curve of the substitute product is perfectly elastic). Thus, the relationship between the slopes of the demand curves s_{nl} and s_{nl}^G determines how the demand for the non-labeled product is affected after the introduction of GURTs. All possible relationships between the slopes of the demand curves are captured in the following cases that describe different scenarios regarding changes in the demand due to the introduction of GURTs.

<u>*Case I:*</u> The demand curve for the non-labeled product does not change after the introduction of GURTs, i.e., the slopes of the demand curves, s_{nl} and s_{nl}^G, are equal, $\theta\mu + \alpha\lambda = \psi\lambda$.

For case I to emerge two conditions must be met, namely, the production shares of the GURTs and the GM products in the non-labeled product after the introduction of GURTs should equal to the production share of the GM product in the non-labeled product under the status quo, $\theta + \alpha = \psi \Rightarrow \frac{x_{gurt} + x_{gm}^G}{x_{nl}^G} = \frac{x_{gm}}{x_{nl}}$, and consumer aversion toward the GURTs product should equal to consumer aversion towards GMPs, $\mu = \lambda$. The above conditions that need to be satisfied for case I to emerge are satisfied only when the price of the GM seed after the introduction of GURTs is greater than the GM seed price before the introduction of GURTs, $w_{gm}^G > w_{gm}$, and when the total production of the

non-labeled product is greater after the introduction of GURTs than before GURTs are introduced, $x_{nl}^{G} > x_{nl}$. To see why this is the case, note that when $w_{gm}^{G} > w_{gm}$ the total quantity of the conventional product produced is greater after GURTs than before GURTs are introduced, i.e., $x_{c}^{G} > x_{c}$. This can be easily seen in Figure 3 where an increase in w_{gm} causes the GM profit curve, Π_{gm}^{C}, to rotate inwards while leaving the conventional product profit curve, Π_{c}, unaffected (see also Figure 7 below). Since for the demand to stay unchanged the production shares must stay the same, i.e., $\frac{x_{gm}^{G} + x_{gurts}}{x_{nl}^{G}} = \frac{x_{gm}}{x_{nl}}$ and $\frac{x_{c}^{G}}{x_{nl}^{G}} = \frac{x_{c}}{x_{nl}}$, $x_{c}^{G} > x_{c}$ implies that $x_{nl}^{G} > x_{nl}$ must hold true. This case is feasible and is depicted in Figure 7. Thus, under case I, the price of the non-labeled product is lower after the introduction of GURTs.

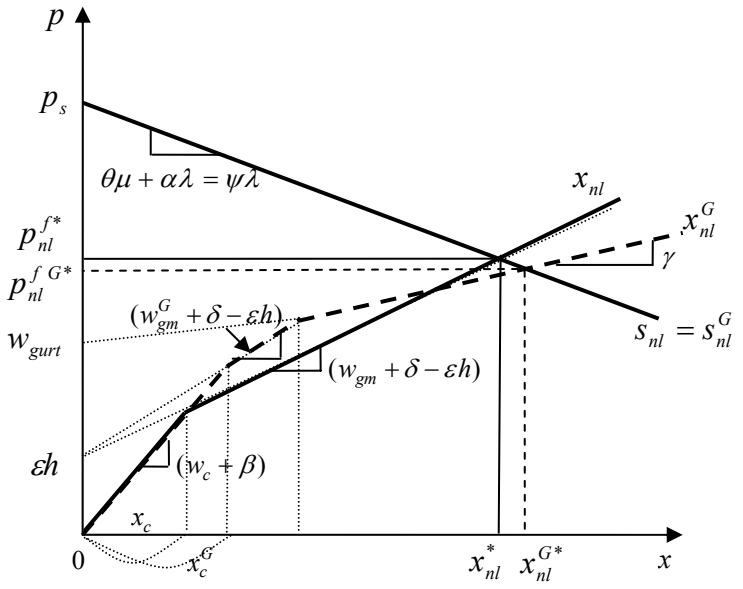


Figure 7. Case I is feasible when $w_{gm}^{G} > w_{gm}$ and $x_{nl}^{G} > x_{nl}$.

Note that, $w_{gm}^{G} = w_{gm}$ is not feasible under case I since if this condition was

satisfied it would imply that $x_c^G = x_c$ as explained above and given that for case I to emerge the production shares must remain unchanged $x_c^G = x_c$ in turn implies that $x_{nl}^G = x_{nl}$. It can be easily shown that when $w_{gm}^G = w_{gm}$ $x_{nl}^G > x_{nl}$ as the GURTs supply curve is flatter than the GM supply curve and, thus, it intersects the demand curve below the point that the GM supply curve intersects it, leading to a greater quantity of the non-labeled product being produced.

Also note that, $w_{gm}^G < w_{gm}$ is not feasible under case I since if this condition was satisfied it would imply that $x_c^G < x_c$ which would in turn imply that $x_{nl}^G < x_{nl}$. However, since the slope of the GURTs segment of the supply curve is always flatter than the slope of the GM segment of the supply curve, it never intersects the demand curve at the higher point than the GM segment intersects and the total quantity of the non-labeled product supplied in the market increases, which, contradicts the requirement that $x_{nl}^G < x_{nl}$.

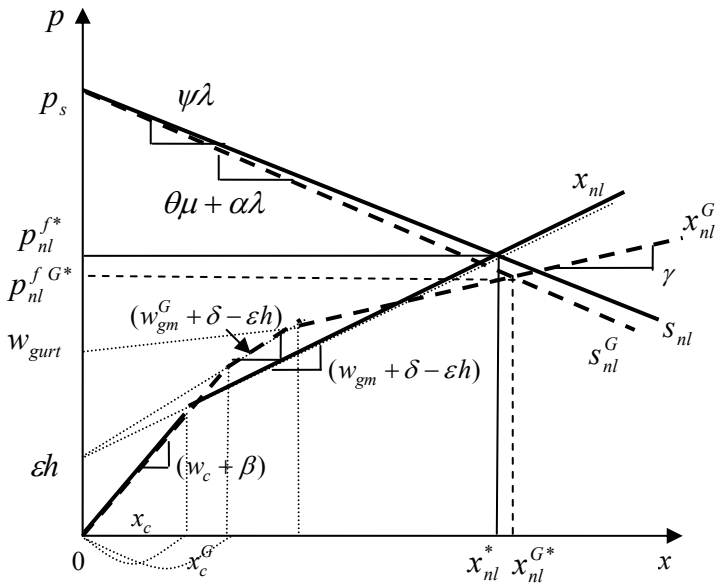
The above analysis shows that under case I, the price of the non-labeled product is always greater before than after GURTs are introduced in the market, i.e., $p_{nl}^{f*} > p_{nl}^{fG*}$.

<u>*Case II*</u>: The demand curve for the non-labeled product rotates to the left after the introduction of GURTs, i.e., the slopes of the new demand curve, s_{nl}^G, is greater than the slope of the old demand curve, s_{nl}, $\theta\mu + \alpha\lambda > \psi\lambda$.

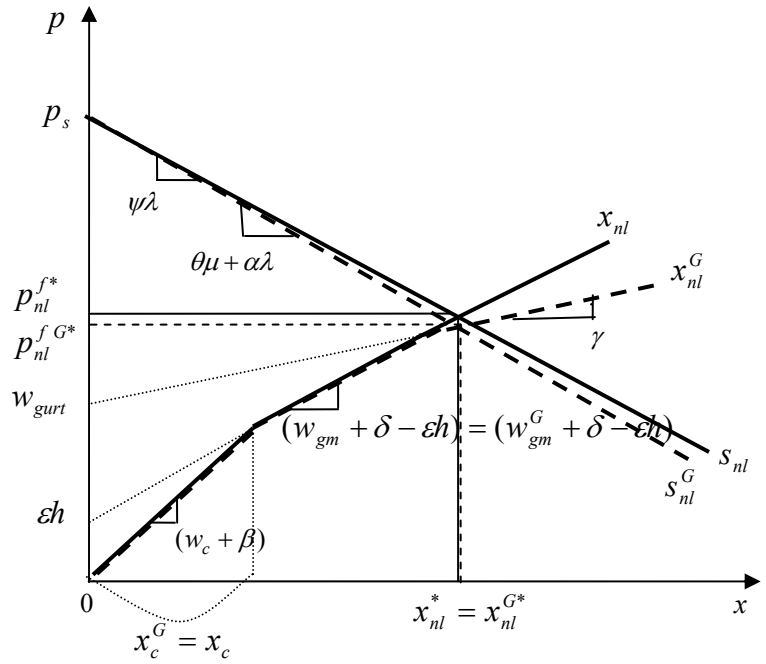
For case II to emerge, either the production shares of the GURTs and the GM products after the introduction of GURTs should be greater than the production share of the GM product under the status quo, $\theta + \alpha > \psi \Rightarrow \frac{x_{gurt} + x_{gm}^G}{x_{nl}^G} > \frac{x_{gm}}{x_{nl}}$, or consumer aversion toward the GURTs product should be greater than consumer aversion towards

GMPs, $\mu > \lambda$, or both.

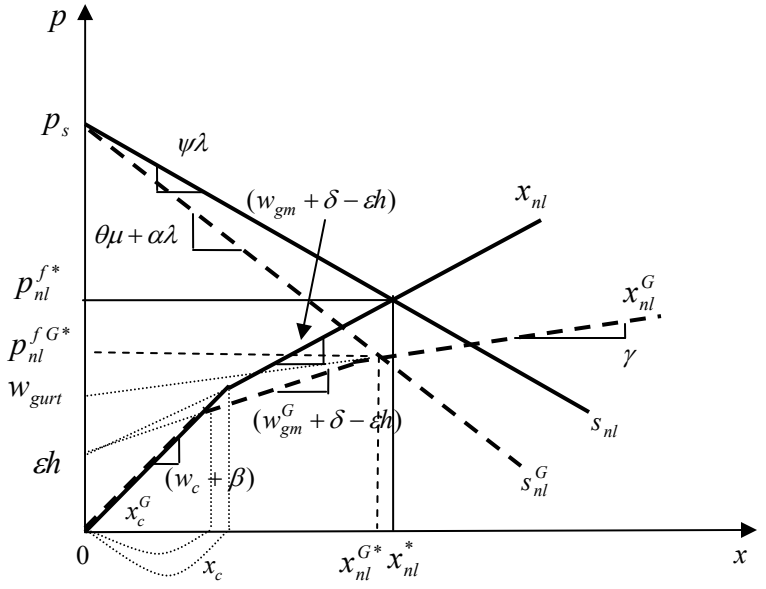
Case II_A. Consider first the case where the production shares of the GURTs and GM products in the non-labeled product after the introduction of GURTs are equal to the production share of the GM product in the non-labeled product under the status quo, $\theta + \alpha = \psi \Rightarrow \frac{x_{gurt} + x_{gm}^G}{x_{nl}^G} = \frac{x_{gm}}{x_{nl}}$, and $\mu > \lambda$. Note that, in this case, even though the shares are the same the demand rotates inward after the GURTs enter the market. This case is very similar to the Case I. The only difference is that under this case $w_{gm}^G \gtreqless w_{gm}$ are all feasible (see Figure 8 panel (i), (ii) and (iii) for $w_{gm}^G > w_{gm}$, $w_{gm}^G = w_{gm}$ and $w_{gm}^G < w_{gm}$, respectively) while under Case I only the case where $w_{gm}^G > w_{gm}$ and $x_{nl}^G > x_{nl}$ is feasible.



Panel (i) Case II_A is feasible when $w_{gm}^G > w_{gm}$, $x_{nl}^G > x_{nl}$.



Panel (ii): Case II_A is feasible when $w_{gm}^G = w_{gm}$ and $x_{nl}^G = x_{nl}$.



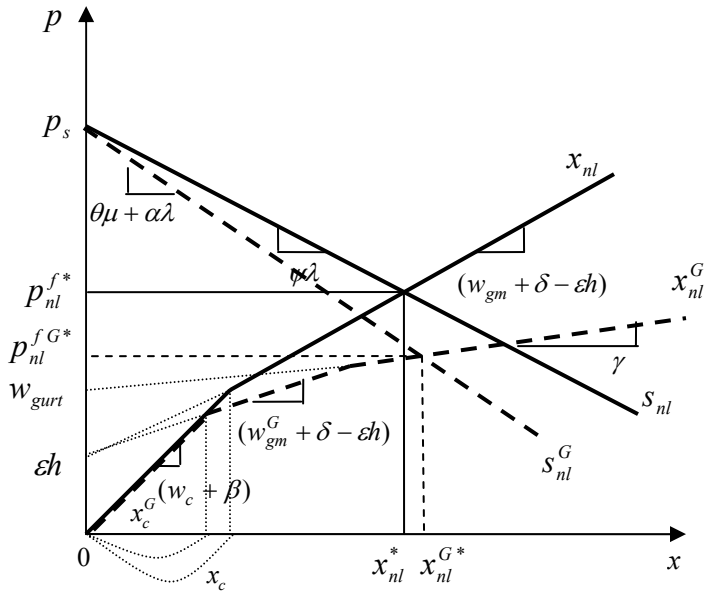
Panel (iii). Case II_A is feasible when $w_{gm}^G < w_{gm}$ and $x_{nl}^G = x_{nl}$.

Figure 8. Conditions under which case II_A is feasible.

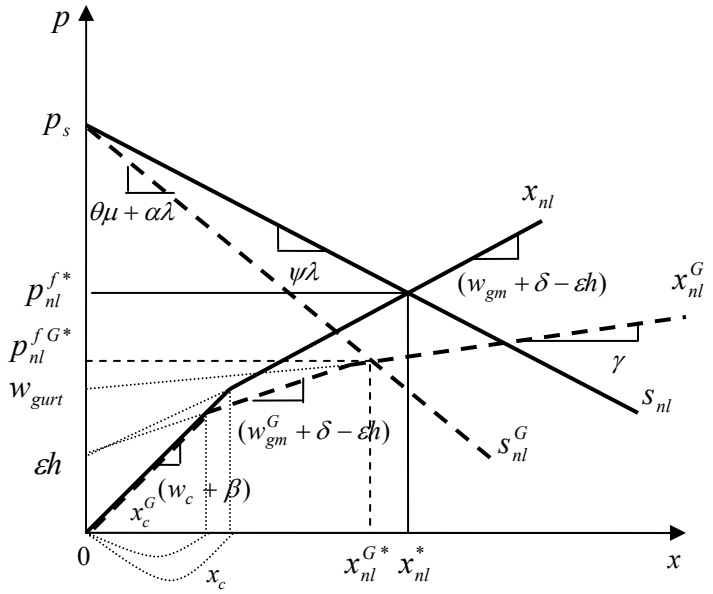
The above analysis shows that under case II_A, the price of the non-labeled product is always greater before than after GURTs are introduced in the market, i.e., $p_{nl}^{f*} > p_{nl}^{fG*}$.

Case II_B. We now consider the case where the production shares of the GURTs and GM products after the introduction of GURTs are greater than the production share of the GM product under the status quo, $\theta + \alpha > \psi \Rightarrow \frac{x_{gurt} + x_{gm}^{G}}{x_{nl}^{G}} > \frac{x_{gm}}{x_{nl}}$ and $\mu \geq \lambda$. Case II_B may emerge when the price of the GM seed after the introduction of GURTs is lower than the GM seed price before the introduction of GURTs, $w_{gm}^{G} < w_{gm}$, in which case the total production of the non-labeled product after the introduction of GURTs, is greater, lower than or equal to the production share of the non-labeled product under the status quo, $x_{nl}^{G} \gtreqless x_{nl}$. To see why this is the case, note that when $w_{gm}^{G} < w_{gm}$ the total quantity of the conventional product produced is lower after GURTs than before GURTs are introduced, i.e., $x_c^{G} < x_c$. This can be easily seen in Figure 3 where a decrease in w_{gm} causes the GM profit curve, Π_{gm}^{C}, to rotate outwards while leaving the conventional product profit curve, Π_c, unaffected (see also Figure 9 below). Since for the demand to rotate inwards the production shares of the GURTs and GM products after the introduction of GURTs should be greater than the production share of the GM product under the status quo, i.e., $\frac{x_{gurt} + x_{gm}^{G}}{x_{nl}^{G}} > \frac{x_{gm}}{x_{nl}}$, the production share of the conventional product under GURTs should be smaller than the production share of the conventional product under the status quo, $\frac{x_c^{G}}{x_{nl}^{G}} < \frac{x_c}{x_{nl}}$. Since $w_{gm}^{G} < w_{gm}$ implies that $x_c^{G} < x_c$ then $x_{nl}^{G} > x_{nl}$, $x_{nl}^{G} < x_{nl}$ and

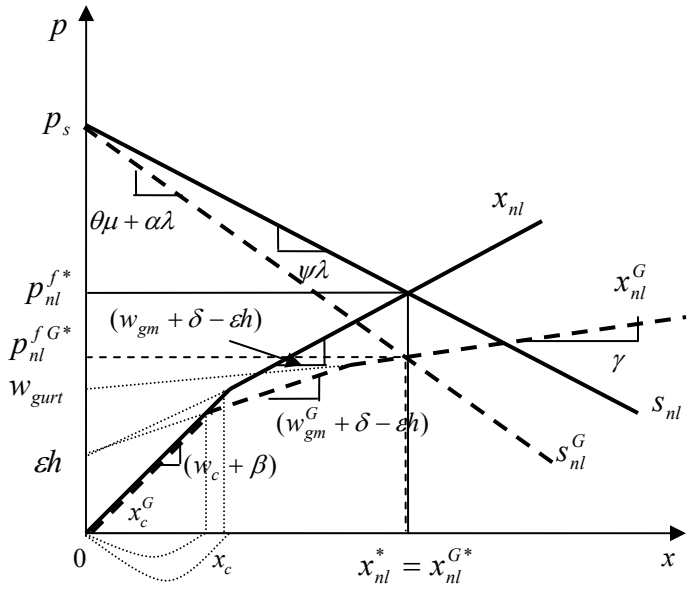
$x_{nl}^{G} = x_{nl}$ are all possible. This case is depicted in Figure 9, panels (i), (ii) and (iii), respectively.



Panel (i). Case II_B is feasible when $w_{gm}^{G} < w_{gm}$ and $x_{nl}^{G} > x_{nl}$.



Panel (ii). Case II_B is feasible when $w_{gm}^{G} < w_{gm}$ and $x_{nl}^{G} < x_{nl}$.



Panel (iii). Case II_B is feasible when $w_{gm}^G < w_{gm}$ and $x_{nl}^G = x_{nl}$.

Figure 9. Case II_B is feasible when $w_{gm}^G < w_{gm}$.

Case II_B may also emerge when the price of the GM seed after the introduction of GURTs is greater than the GM seed price before the introduction of GURTs, $w_{gm}^G > w_{gm}$, in which case the total production of the non-labeled product is greater after the introduction of GURTs than before GURTs are introduced, $x_{nl}^G > x_{nl}$. To see why this is the case, note that when $w_{gm}^G > w_{gm}$ the total quantity of the conventional product produced is greater after than before GURTs are introduced, i.e., $x_c^G > x_c$. This can be easily seen in Figure 3 where an increase in w_{gm} causes the GM profit curve, Π_{gm}^C, to rotate inwards while leaving the conventional product profit curve, Π_c, unaffected (see also Figure 10 below). Since for the demand to rotate inwards the production shares of the GURTs and GM products after the introduction of GURTs should be greater than the

production share of the GM product under the status quo, i.e., $\frac{x_{gurt} + x_{gm}^{G}}{x_{nl}^{G}} > \frac{x_{gm}}{x_{nl}}$ which implies that $\frac{x_c^G}{x_{nl}^G} < \frac{x_c}{x_{nl}}$. Since $w_{gm}^G > w_{gm}$ implies that $x_c^G > x_c$ then $x_{nl}^G > x_{nl}$ must hold true. This case is feasible and is depicted in Figure 10.

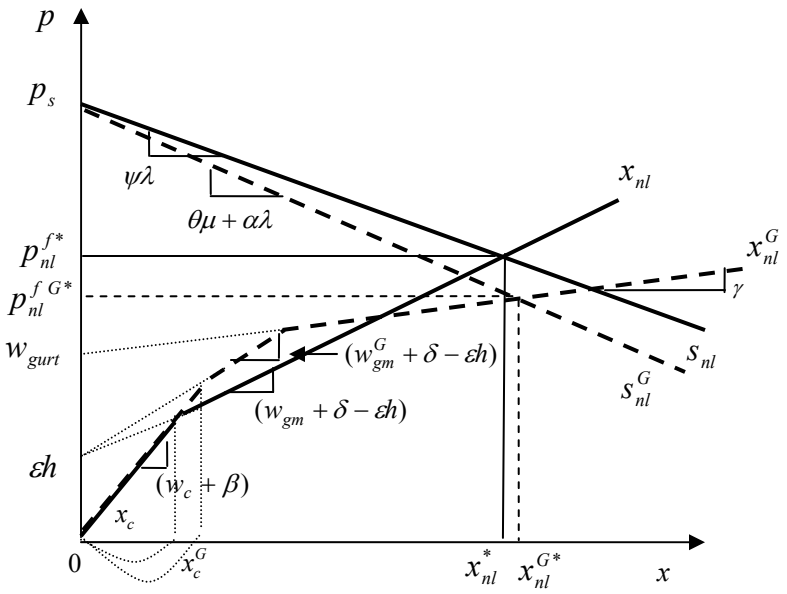


Figure 10. Case II_B is feasible when $w_{gm}^G > w_{gm}$ and $x_{nl}^G > x_{nl}$.

Case II_B also emerge when the price of the GM seed after the introduction of GURTs stays unchanged, $w_{gm}^G = w_{gm}$, in which case the total production of the non-labeled product is greater after the introduction of GURTs than before GURTs are introduced. $x_{nl}^G > x_{nl}$. To see why this is the case, note that $w_{gm}^G = w_{gm}$, the total quantity of the conventional product produced is the same after the introduction of GURTs, i.e., $x_c^G = x_c$. This can be easily seen in Figure 3 where an increase in w_{gm} causes the GM

profit curve, Π_{gm}^{C}, to rotate inwards while leaving the conventional product profit curve, Π_{c}, unaffected (see also Figure 11 below). Since for the demand to rotate inwards the production shares of the GURTs and GM products after the introduction of GURTs should be greater than the production share of the GM product under the status quo, i.e., $\frac{x_{gurt}+x_{gm}^{G}}{x_{nl}^{G}} > \frac{x_{gm}}{x_{nl}}$ which implies that $\frac{x_{c}^{G}}{x_{nl}^{G}} < \frac{x_{c}}{x_{nl}}$. Since $w_{gm}^{G} = w_{gm}$ implies that $x_{c}^{G} = x_{c}$ then $x_{nl}^{G} > x_{nl}$ must hold true. This case is feasible and is depicted in Figure 11.

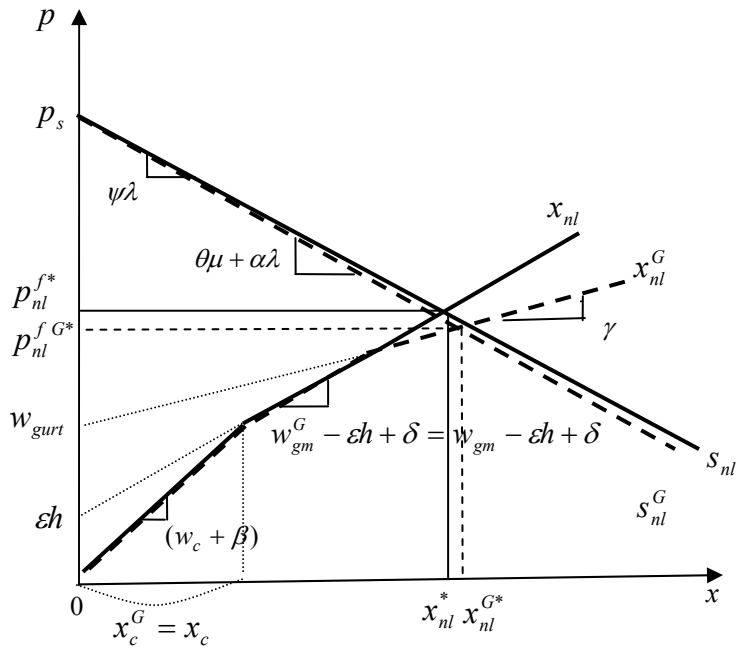


Figure 11. Case II_B is feasible when $w_{gm}^{G} = w_{gm}$ and $x_{nl}^{G} > x_{nl}$.

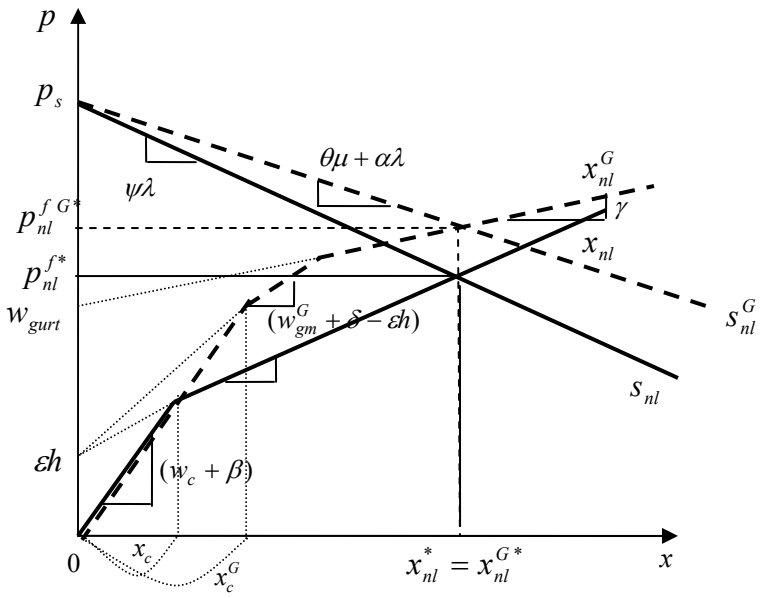
The above analysis shows that under case II_B, the price of the non-labeled product is always greater before than after GURTs are introduced in the market, i.e., $p_{nl}^{f*} > p_{nl}^{fG*}$.

Case III: The demand curve for the non-labeled product rotates to the right after the introduction of GURTs, i.e., the slope of the new demand curve, s_{nl}^{G}, is smaller than the

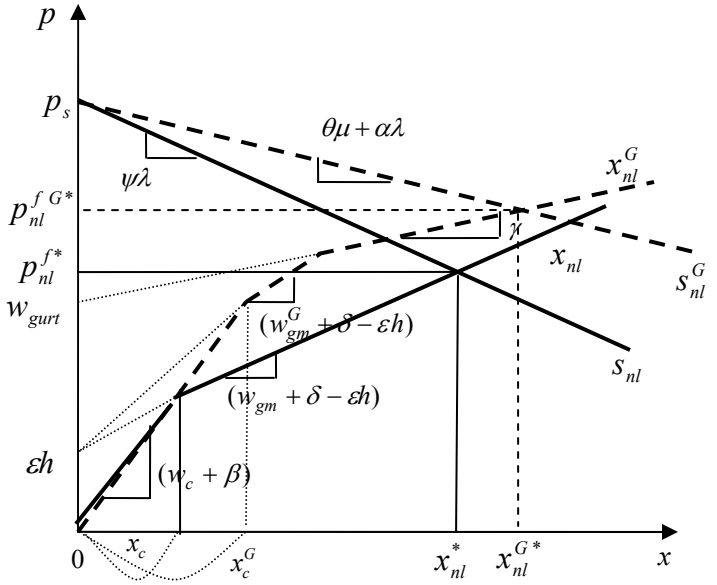
slope of the old demand curve, s_{nl}, $\theta\mu + \alpha\lambda < \psi\lambda$.

For case III to emerge the production shares of the GURTs and the GM products after the introduction of GURTs should be lower than the production share of the GM product under the status quo, $\theta + \alpha < \psi \Rightarrow \frac{x_{gurt} + x_{gm}^{G}}{x_{nl}^{G}} < \frac{x_{gm}}{x_{nl}}$. The above conditions that need to be satisfied for case III to emerge are satisfied when the price of the GM seed after the introduction of GURTs is greater than the GM seed price before the introduction of GURTs, $w_{gm}^{G} > w_{gm}$, and when the total production of the non-labeled product either remains the same or is greater after the introduction of GURTs than before GURTs are introduced, $x_{nl}^{G} \geq x_{nl}$. To see why this is the case, note that when $w_{gm}^{G} > w_{gm}$ the total quantity of the conventional product produced is greater after GURTs than before GURTs are introduced, i.e., $x_{c}^{G} > x_{c}$. This can be easily seen in Figure 3 where an increase in w_{gm} causes the GM profit curve, Π_{gm}^{C}, to rotate inwards while leaving the conventional product profit curve, Π_{c}, unaffected (see also Figure 12 below). Also, $\frac{x_{gurt} + x_{gm}^{G}}{x_{nl}^{G}} < \frac{x_{gm}}{x_{nl}}$ implies that the production share of the conventional product is greater after GURTs than before GURTs are introduced, $\frac{x_{c}^{G}}{x_{nl}^{G}} > \frac{x_{c}}{x_{nl}}$ (since $\frac{x_{c} + x_{gm}}{x_{nl}} = 1$ and $\frac{x_{c}^{G} + x_{gurt} + x_{gm}^{G}}{x_{nl}^{G}} = 1$).

Thus, since $w_{gm}^{G} > w_{gm}$ implies that $x_{c}^{G} > x_{c}$, then $x_{nl}^{G} \geq x_{nl}$ must hold true. These cases are feasible and are depicted in Figure 12 panels (i) and (ii).



Panel (i): Case III is feasible when $w_{gm}^G > w_{gm}$ and $x_{nl}^G = x_{nl}$.



Panel (ii): Case III is feasible when $w_{gm}^G > w_{gm}$ and $x_{nl}^G > x_{nl}$.

Figure 12. Conditions under which case III is feasible.

Also note that, $w_{gm}^G = w_{gm}$ and $w_{gm}^G < w_{gm}$ are not feasible under case III since they would imply that $x_c^G = x_c$ and $x_c^G < x_c$, respectively, which would in turn imply that

$x_{nl}^G < x_{nl}$. However, when either $w_{gm}^G = w_{gm}$ or $w_{gm}^G < w_{gm}$, $x_{nl}^G > x_{nl}$, which, contradicts the requirement that $x_{nl}^G < x_{nl}$.

The above analysis shows that unlike cases I, II_A and II_B, were the introduction of GURTs leads to a reduction in the price of the non-labeled product, under case III, the price of the non-labeled product is always greater after than before GURTs are introduced in the market, i.e., $p_{nl}^{fG*} > p_{nl}^{f*}$.

2.4. Innovating firm

To determine the final equilibrium prices we need to examine the profit maximizing decisions of the firm supplying the GM and GURTs seed. The model assumes that the innovating firm is a monopoly who is supplying GM seed in the market before GURTs are introduced and once it develops the V-GURTs variety it supplies both GM and GURTs seed.[10] The firm decides on how to price its product or equivalently how much seed to supply which depends on its cost structure and on the demand it faces from farmers buying GM and GURTs seed and on how competing varieties are priced in the market.

<u>*Status Quo*</u>

The monopolist decides how to price the GM seed or, equivalently, how much to supply to the market, based on demand it faces from producers buying GM seed. The monopolist's profit function is given by:

$$\max_{y_{gm}} \pi = (w_{gm} - m_{gm}) y_{gm} \tag{37}$$

In equation (37) w_{gm} is the inverse derived demand faced by the monopolist given in

[10] This is equivalent to assuming that the firm has patent protection for both the GM and the GURTs variety that it develops.

implicit form in equation (3.32), m_{gm} is the constant marginal cost of producing the GM seed and y_{gm} is the amount of GM seed the monopoly sells before the introduction of GURTs. Since we were not able to get an analytical solution for the equilibrium retail and GM seed prices we can only get a numerical solution to the monopolist optimization problem through a calibration of the model.

After the Introduction of GURTs

The monopolist now decides how to price the GM and the GURTs seed or equivalently how much of each to supply to the market depending on the demand it faces from producers buying GM and GURTs seed, its cost structure and the prices of competing varieties in the market. The monopolist's profit function is given by:

$$\max_{y_{gm}^G,\, y_{gurt}} \pi_{gurt} = (w_{gm}^G - m_{gm}^G) y_{gm}^G + (w_{gurt} - m_{gurt}) y_{gurt} - FC \tag{38}$$

In equation (38) w_{gm}^G and w_{gurt} are the inverse derived demands for the GM and GURTs seed that the monopolist faces, the implicit form of which is given by equations (35) and (36), respectively, m_{gm}^G and m_{gurt} are the constant marginal costs of producing the GM seed and the GURT seed, respectively, y_{gm}^G and y_{gurt} is the amount of GM and GURTs seed the monopoly sells after the introduction of GURTs, respectively, and FC are fixed costs of the company which includes the costs of developing the seed (i.e., R&D costs). Since we were not able to get an analytical solution for the equilibrium retail, GM and GURTs seed prices, we can only get a numerical solution to the monopolist optimization problem through a calibration of the model.

3. Welfare Effects of the Introduction of GURTs

3.1 Consumer Welfare Effects

The consumer welfare effects of the introduction of GURTs depend on a number of factors such as the production share of GURTs in the total production, consumer aversion to GURTs relative to consumer aversion to GMPs and the relative input prices before and after the introduction of GURTs. The above factors determine the nature of the demand and supply functions for the non-labeled product after the introduction of GURTs which in turn determine the output and price levels of the non-labeled product after GURTs are introduced. The possible changes in the demand and supply of the non-labeled product and the consequent changes in its price caused by the introduction of GURTs were examined in section 2.3. Following is an analysis of how the changes in the price of the non-labeled product under the equilibrium outcomes examined previously (cases I, II_A, II_B, and III) affect the welfare of the consumers of the final product.

Under Case I, where the slopes of the demand curves, s_{nl}^G and s_{nl} are equal ($\theta\mu + \alpha\lambda = \psi\lambda$), and the equilibrium price of the non-labeled product decreases after GURTs are introduced ($p_{nl}^G < p_{nl}$), the utility derived by consumers from the consumption of the non-labeled product is greater after the introduction of GURTs – U_{nl}^G is above U_{nl} – for all c values. Thus, under case I, there is an undisputed increase in consumer welfare under the introduction of GURTs. This outcome is depicted in Figure 13, panel (i) as an upward parallel shift (since the demand slopes are equal and $p_{nl}^G < p_{nl}$) of the utility of the non-labeled product. Note also that the consumers who are located at $\left(\hat{c}_{nl}, \hat{c}_{nl}^G\right)$ switch from consuming the relatively less expensive substitute product to consuming the non-labeled product.

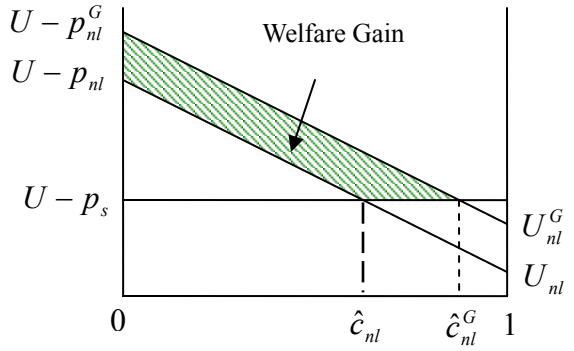
Under Case II (both II_A and II_B), where the slope of the new demand curve, s_{nl}^G, is

greater than the slope of the old demand curve, s_{nl}, ($\theta\mu + \alpha\lambda > \psi\lambda$), and the equilibrium price of the non-labeled product decreases after GURTs are introduced ($p_{nl}^{G} < p_{nl}$), different outcomes are possible, depending on the price difference of the non-labeled product before and after the introduction of GURTs. Thus, if the price difference is large enough, U_{nl}^{G} can be above U_{nl} for all c values, resulting in a gain in consumer welfare due to the introduction of GURTs (as depicted in Figure 13, panel (ii)). Note also that, the consumers who are located at $\left(\hat{c}_{nl}, \hat{c}_{nl}^{G}\right)$ switch from consuming the substitute product to consuming the now relatively less expensive non-labeled product. If the price difference is not too large, U_{nl}^{G} can be above U_{nl} for low c values and below U_{nl} for high c values resulting in a gain in consumer welfare for consumers with low c values and a loss in consumer welfare for consumers with high c values due to the introduction of GURTs. Thus, for consumers with low aversion to interventions in the production process, the lower price of the non-labeled product more than compensates for the increase in disutility due to the introduction of GURTs (either because $\theta + \alpha > \psi$ or $\mu > \lambda$) and these consumers experience a welfare gain while for consumers with relatively high levels of aversion, the decrease in price cannot compensate for the increase in disutility due to the introduction of GURTs and these consumers experience a welfare loss. This outcome is depicted in Figure 13, panel (iii). Thus, the consumers who are located at $\left[0, c_{nl}^{**}\right)$ receive higher utility from purchasing a unit of the non-labeled product, the consumers who are located at $\left(c_{nl}^{**}, \hat{c}_{nl}\right)$ receive lower utility from purchasing a unit of the non-labeled product, while those located at c_{nl}^{**} do not experience any change in their welfare due to the introduction of GURTs. Finally, the consumers who are located at

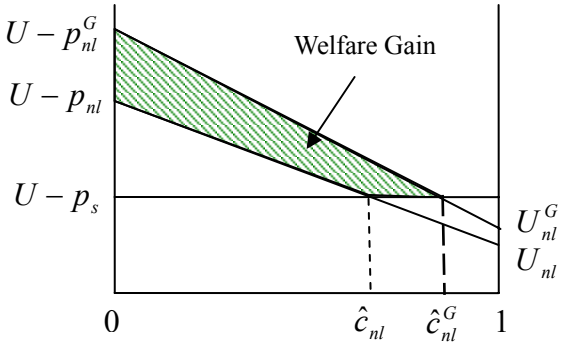
$\left(\hat{c}_{nl}^{G}, \hat{c}_{nl}\right)$ switch from consuming the non-labeled product to consuming the substitute product.

Under Case III, where the slope of the new demand curve, s_{nl}^{G}, is smaller than the slope of the old demand curve, s_{nl}, ($\theta\mu + \alpha\lambda < \psi\lambda$), and the equilibrium price of the non-labeled product increases after GURTs are introduced ($p_{nl}^{G} > p_{nl}$), different outcomes are possible, depending on the price difference of the non-labeled product before and after the introduction of GURTs. Thus, if the price difference is large enough U_{nl} can be above U_{nl}^{G} for all c values resulting in a loss of consumer welfare due to the introduction of GURTs (as depicted in Figure 13, panel (iv)). Note that, the consumers who are located at $\left(\hat{c}_{nl}^{G}, \hat{c}_{nl}\right)$ switch from consuming the now relatively more expensive non-labeled product to consuming the substitute product. If the price difference of the non-labeled product before and after GURTs are introduced is not too large, then U_{nl} can be above U_{nl}^{G} for low c values and below U_{nl}^{G} for high c values resulting in a loss in consumer welfare for consumers with low c values and a gain in consumer welfare for consumers with high c values due to the introduction of GURTs. This occurs because, for consumers with low levels of aversion to interventions in the production process, the decrease in utility due to the higher product prices is lower than the increase in utility due to the reduction in the production shares of the GM and the GURTs products. On the other hand, for those consumers with relatively high levels of aversion to interventions in the production process, the utility increase due to the decrease in the probability of getting the GM and the GURTs products more than compensates for the utility decrease due to the higher product price. This outcome is depicted in Figure 13, panel (v). Thus, the consumers who

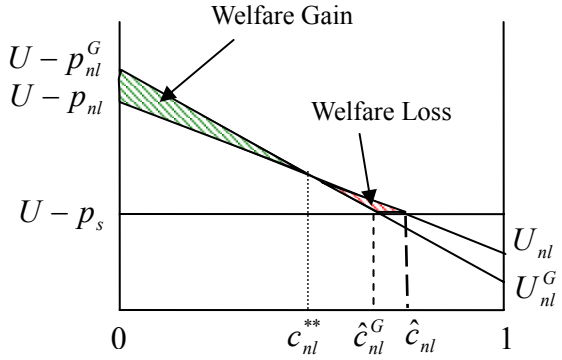
are located at $\left[0, c_{nl}^{**}\right)$ receive lower utility from purchasing a unit of the non-labeled product, the consumers who are located at $\left(c_{nl}^{**}, \hat{c}_{nl}^{G}\right)$ receive higher utility from purchasing a unit of the non-labeled product, while those located at c_{nl}^{**} do not experience any change in their welfare due to the introduction of GURTs.



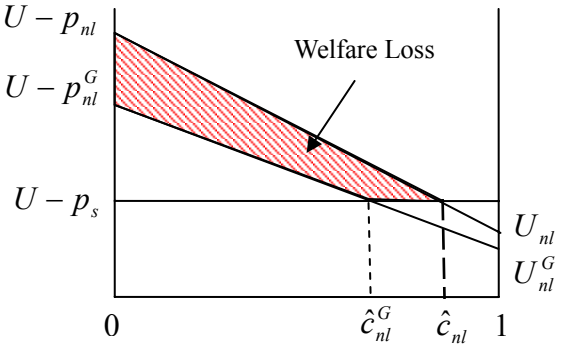
Panel (i): Case I - welfare gain ($\theta\mu + \alpha\lambda = \psi\lambda$ and $p_{nl}^G < p_{nl}$)



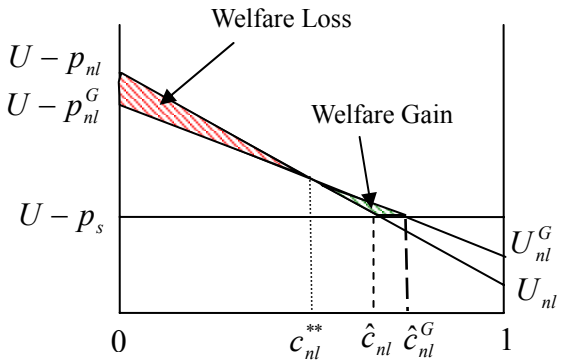
Panel (ii): Case II - welfare gain ($\theta\mu + \alpha\lambda > \psi\lambda$ and $p_{nl}^G < p_{nl}$)



Panel (iii): Case II - welfare gain and loss ($\theta\mu + \alpha\lambda > \psi\lambda$ and $p_{nl}^G < p_{nl}$)



Panel (iv): Case III - welfare loss ($\theta\mu + \alpha\lambda < \psi\lambda$ and $p_{nl}^G > p_{nl}$)



Panel (v): Case III - welfare loss and gain ($\theta\mu + \alpha\lambda < \psi\lambda$ and $p_{nl}^G > p_{nl}$)

Figure 13. Changes in consumer welfare due to the introduction of GURTs.

Given the above, the effect of the introduction of GURTs on consumer welfare depends on the price difference of the non-labeled product resulting from the introduction of GURTs and the magnitude of the price difference, consumer aversion to GURTs relative to their aversion to GMPs and the production shares of the GM, the GURTs and the conventional products.

As was discussed in section 2, the analysis was conducted under the assumption that consumers are uniformly distributed between zero and one, i.e., $c \in [0, 1]$. If the distribution of consumers between the c values is skewed, the magnitude of the welfare effects depends on the skewness of the distribution. For instance, in the case depicted in Figure 13, panel (iii), if relatively more consumers have low aversion to interventions in the production process (are closer to zero) it is more likely that the introduction of GURTs will result in welfare gains rather than in welfare losses.

3.2 Producer Welfare Effects

The producer welfare effects of the introduction of GURTs depend on the relative product and seed prices before and after the introduction of GURTs, the agronomic benefits of the GURTs seed over the GM seed, producers' ability to save seed and the expected penalty the producers pay when they cheat on the licensing agreements.

Following is an analysis of how producer welfare is affected by the introduction of GURTs under the equilibrium outcomes examined previously, i.e., cases I, II_A, II_B, and III. The impact in producer welfare is examined by comparing the profits producers receive from the production of different crops before and after GURTs are introduced.

Under case I, which emerges only when $w_{gm}^{G} > w_{gm}$ and $x_{nl}^{G} > x_{nl}$, there is a decrease in the equilibrium price of the non-labeled product due to the introduction of

GURTs, $p_{nl}^{G} < p_{nl}$. The above conditions are also observed under cases II_A, and II_B depicted in Figure 8, panel (i) and in Figure 10, in section 2. Figure 14, panel (i), depicts the changes in the profits of producers, when $p_{nl}^{fG} < p_{nl}^{f}$ and thus, $p_{nl}^{fG} - \varepsilon h < p_{nl}^{f} - \varepsilon h$, $w_{gm}^{G} > w_{gm}$ and thus, the slopes of the profit curve of the GM product are such that $\delta + w_{gm}^{G} - \varepsilon h > \delta + w_{gm} - \varepsilon h$, and $x_{nl}^{G} > x_{nl}$, i.e., $\hat{A}_T > A_T$. Note that, the solid and the dashed lines indicate the profit levels before and after the introduction of GURTs, respectively. From the graph we see that, under the above conditions, producers find it optimal to increase the production of the conventional product, reduce the production of the GM and the alternative products and start producing the GURTs product. The producers who are located at $[0, A_c)$, $(\hat{A}_c, \hat{A}_{gm})$ and $(\hat{A}_T, 1]$ do not switch their production and keep producing the conventional, the GM and the alternative products, respectively. The producers who find it optimal to switch their production after the introduction of GURTs are the producers who are located at $(A_c, \hat{A}_c)$ who switch from producing the now relatively more expensive GM product to producing the relatively less expensive conventional product; the producers who are located at $(\hat{A}_{gm}, A_T)$ who decide not to produce the relatively more expensive GM products and switch to the production of the GURTs products; and the producers who are located at $(A_T, \hat{A}_T)$ who produce the alternative products under the status quo but after the introduction of GURTs find it more profitable to produce the GURTs products. Recall that, for the GURTs product to be produced the following conditions need to hold; the price of the GURTs seed should be greater than the expected penalty producers face when they cheat on their GM licensing

agreement, $w_{gurt} > \varepsilon h$, and the slope of the GM profit curve should be greater than the slope of the GURTs profit curve (i.e., the production of the GURTs product is more cost efficient than the production of the GM product for producers with relatively low dependence on saving seed (high A values), $\delta + w_{gm}^{G} - \varepsilon h > \gamma$).

When comparing the profit levels the producers receive before and after the introduction of GURTs we notice that after the introduction of GURTs some producers experience a decrease in their profits, others an increase in their profits and some are not affected. Specifically, the producers located at $\left[0, A^{**}\right)$, who are those producing the conventional and the GM products and those producing the GURTs product and have relatively low A values (high dependency on saving seed), experience a decrease in their profits, while those located at $(A^{**}, \hat{A}_T)$ who are those producing the GURTs product and have relatively high A values (low dependency on saving seed) experience an increase in their profits. Obviously, the producers located at $\left(\hat{A}_T, 1\right]$ who produce the alternative product and at A^{**} do not experience any changes in their profits due to the introduction of GURTs.

The intuition behind this outcome is that those producers who save seed relatively more (i.e., those located closer to zero), loose after GURTs are introduced due to the lower price they receive for their product in the market (conventional, GM and lower A value GURTs producers), the higher GM seed price (GM producers) and their inability to save seed (lower A value GURTs producers). On the other hand, the producers who save seed relatively less (i.e., those located closer to one), gain after the introduction of GURTs since the reduction in their profits due to the lower price of the non-labeled

product is smaller than the increase in their profit due to the adoption of the relatively more cost efficient GURTs product.

The producer welfare effects under case II_A when $w_{gm} = w_{gm}^G$ (thus, when the slope of the profit curve of the GM product remains the same, i.e., $\delta + w_{gm}^G - \varepsilon h = \delta + w_{gm} - \varepsilon h$) and $x_{nl} = x_{nl}^G$ which lead to $p_{nl}^{f\,G} < p_{nl}^f$ are depicted in Figure 14, panel (ii). From the graph we see that, under the above conditions, producers find it optimal to keep the production of the conventional and the alternative products unchanged, reduce the production of the GM product and start producing the GURTs product. The producers who are located at $\left[0,\ \hat{A}_c\right)$, $\left(\hat{A}_c,\ \hat{A}_{gm}\right)$ and $\left(\hat{A}_T, 1\right]$ do not switch their production and keep producing the conventional, the GM and the alternative products, respectively. The producers who find it optimal to switch their production after the introduction of GURTs are the producers who are located at $\left(\hat{A}_{gm},\ \hat{A}_T\right)$ who switch from producing the GM product to producing the GURTs product after the introduction of GURTs. When comparing the profit levels the producers receive before and after the introduction of GURTs we notice that all producers who produce the non-labeled product (producers located at $\left[0, \hat{A}_T\right)$) experience a decrease in their profits due to the introduction of GURTs.

The intuition behind this outcome is that those producers who save seed relatively more (i.e., those located closer to zero), and even those who save seed relatively less (i.e., those located closer to one), loose after GURTs are introduced due to the lower price they receive for their product in the market (conventional, GM and GURTs producers) and their inability to save seed (lower A value GURTs producers loose more than higher A

value GURTs producers). For producers with high A values, even though it is more profitable to produce the GURTs than keep producing the GM product, the lose in profits due to the lower price they receive for their product is greater than the gain they experience by adopting the GURTs product; either the GURTs seed price is not as low or the agronomic benefits of the GURTs seed are not as high or both as in the case depicted in Figure 14, panel (i).

Under case II_A, when $w_{gm}^G < w_{gm}$ and $x_{nl}^G < x_{nl}$, there is a decrease in the equilibrium price of the non-labeled product due to the introduction of GURTs, $p_{nl}^G < p_{nl}$. The above conditions are also observed under case II_B depicted in Figure 9 panel (ii). Figure 14, panel (iii), depicts the changes in the profits of producers, when $p_{nl}^{fG} < p_{nl}^f$ and thus, $p_{nl}^{fG} - \varepsilon h < p_{nl}^f - \varepsilon h$, $w_{gm}^G < w_{gm}$ and thus, the slopes of the profit curve of the GM product are such that $\delta + w_{gm}^G - \varepsilon h < \delta + w_{gm} - \varepsilon h$, and $x_{nl}^G < x_{nl}$, i.e., $\hat{A}_T < A_T$. From the graph we see that, under the above conditions, producers find it optimal to reduce the production of the conventional, the GM and the alternative products and start producing the GURTs product. The producers who are located at $\lfloor 0, \hat{A}_c \rangle$, $\langle A_c, \hat{A}_{gm} \rangle$ and $\langle A_T, 1 \rfloor$ do not switch their production and keep producing the conventional, the GM and the alternative products, respectively. The producers who find it optimal to switch their production after the introduction of GURTs are the producers who are located at $\langle \hat{A}_c, A_c \rangle$ who switch from producing the relatively more expensive conventional product to producing the now relatively less expensive GM product; the producers who are located at $\langle \hat{A}_{gm}, \hat{A}_T \rangle$ who decide not to produce the GM products and switch to the production of

the GURTs products; and the producers who are located at $\left(\hat{A}_T, A_T\right)$ who produce the GM products under the status quo but after the introduction of GURTs find it more profitable to produce the alternative products.

When comparing the profit levels the producers receive before and after the introduction of GURTs we notice that all producers who produce the non-labeled product (producers located at $\left[0, \hat{A}_T\right)$) experience a decrease in their profits due to the introduction of GURTs. The intuition behind this outcome is similar to the outcome examined above and depicted in Figure 14, panel (ii), i.e., the lower product price results in losses that cannot be eliminated by gains due to the lower GM seed price and/or the adoption of the GURTs product.

The producer welfare effects under case II_B when $w_{gm} = w_{gm}^G$ (thus, when the slope of the profit curve of the GM product remains the same, i.e., $\delta + w_{gm}^G - \varepsilon h = \delta + w_{gm} - \varepsilon h$) and $x_{nl}^G > x_{nl}$ which lead to $p_{nl}^{f\,G} < p_{nl}^f$ are depicted in Figure 14, panel (vi). From the graph we see that, under the above conditions, producers find it optimal to keep the production of the conventional product unchanged, reduce the production of the GM and the alternative products and start producing the GURTs product. The producers who are located at $\left[0, \hat{A}_c\right)$, $\left(\hat{A}_c, \hat{A}_{gm}\right)$ and $\left(\hat{A}_T, 1\right]$ do not switch their production and keep producing the conventional, the GM and the alternative products, respectively. The producers who find it optimal to switch their production after the introduction of GURTs are the producers who are located at $\left(\hat{A}_{gm}, A_T\right)$ who decide not to produce the GM products and switch to the production of the GURTs products; and the producers who are located at $\left(A_T, \hat{A}_T\right)$ who produce the alternative products under the

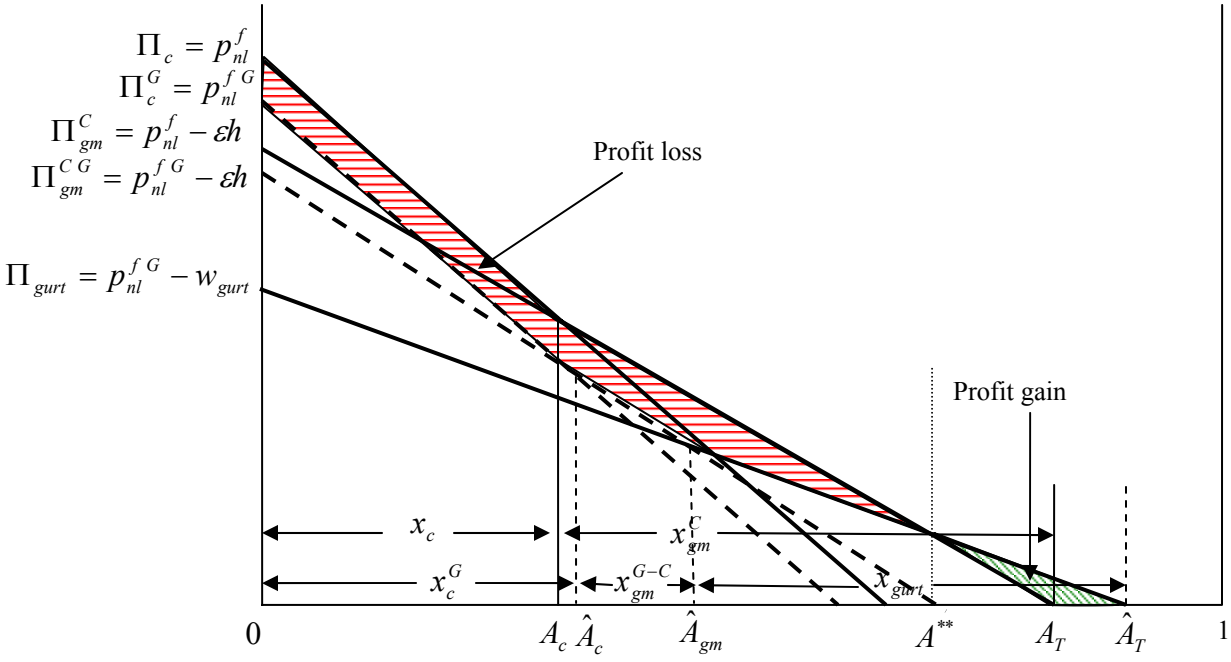
status quo but after the introduction of GURTs find it more profitable to produce the GURTs products.

When comparing the profit levels the producers receive before and after the introduction of GURTs we notice that after the introduction of GURTs some producers experience a decrease in their profits, others an increase in their profits and some are not affected. Specifically, the producers located at $[0, A^{**})$, who are those producing the conventional and the GM products and those producing the GURTs product and have relatively low A values (high dependency on saving seed), experience a decrease in their profits, while those located at $(A^{**}, \hat{A}_T)$ who are those producing the GURTs product and have relatively high A values (low dependency on saving seed) experience an increase in their profits. Obviously, the producers located at $(\hat{A}_T, 1]$ who produce the alternative product and at A^{**} do not experience any changes in their profits due to the introduction of GURTs.

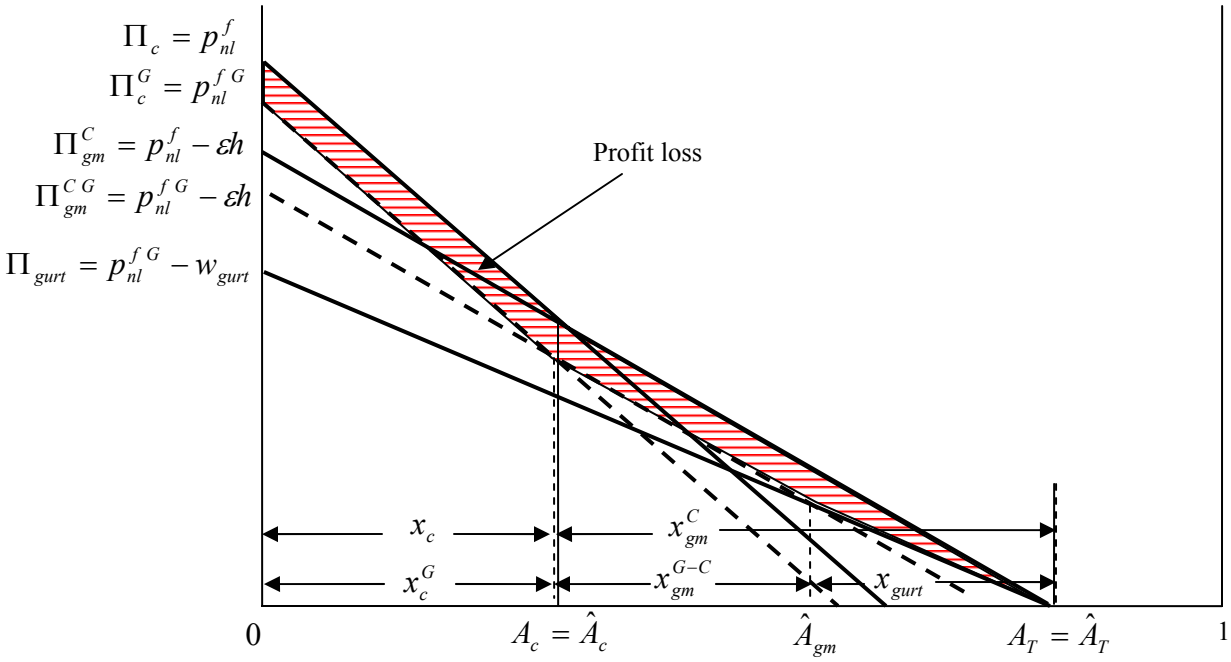
The intuition behind this outcome is that those producers who save seed relatively more (i.e., those located closer to zero), loose after GURTs are introduced due to the lower price they receive for their product in the market (conventional, GM and lower A value GURTs producers), the higher GM seed price (GM producers) and their inability to save seed (lower A value GURTs producers). On the other hand, the producers who save seed relatively less (i.e., those located closer to one), gain after the introduction of GURTs since the reduction in their profits due to the lower price of the non-labeled product is smaller than the increase in their profit due to the adoption of the relatively more cost efficient GURTs product.

In essence, what we observe is that when the equilibrium price of the non-labeled

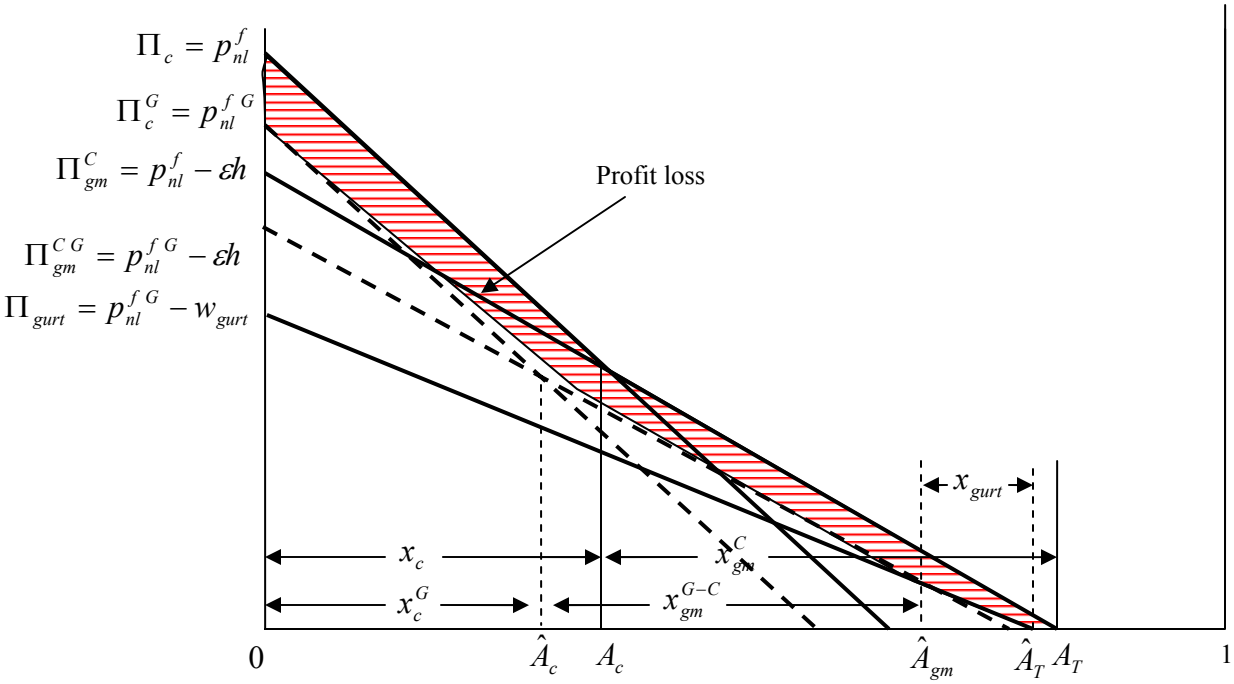
product is lower after than before GURTs are introduced, profit gains can be realized only by those producers who find it optimal to adopt the GURTs product and have relatively low dependency on saving seed (high A values). These profit gains are experienced only when the total quantity of the non-labeled product produced increases when GURTs are introduced, $x_{nl}^{G} > x_{nl}$ as depicted in Figure 14, panel (i). This outcome also emerges under case II_B, when $w_{gm}^{G} < w_{gm}$, $x_{nl}^{G} > x_{nl}$, and $p_{nl}^{G} < p_{nl}$, depicted in Figure 14, panel (iv). On the other hand, as long as the total quantity of the non-labeled product produced decreases or remains unchanged when GURTs are introduced, $x_{nl}^{G} \leq x_{nl}$, a reduction in the equilibrium price of the non-labeled product results in welfare losses for all producers as depicted in Figure 14, panels (ii) and (iii). This outcome also emerges under case $II_{B,}$ when $w_{gm}^{G} < w_{gm}$, $x_{nl}^{G} = x_{nl}$ and $p_{nl}^{G} < p_{nl}$, depicted in Figure 14, panel (v).



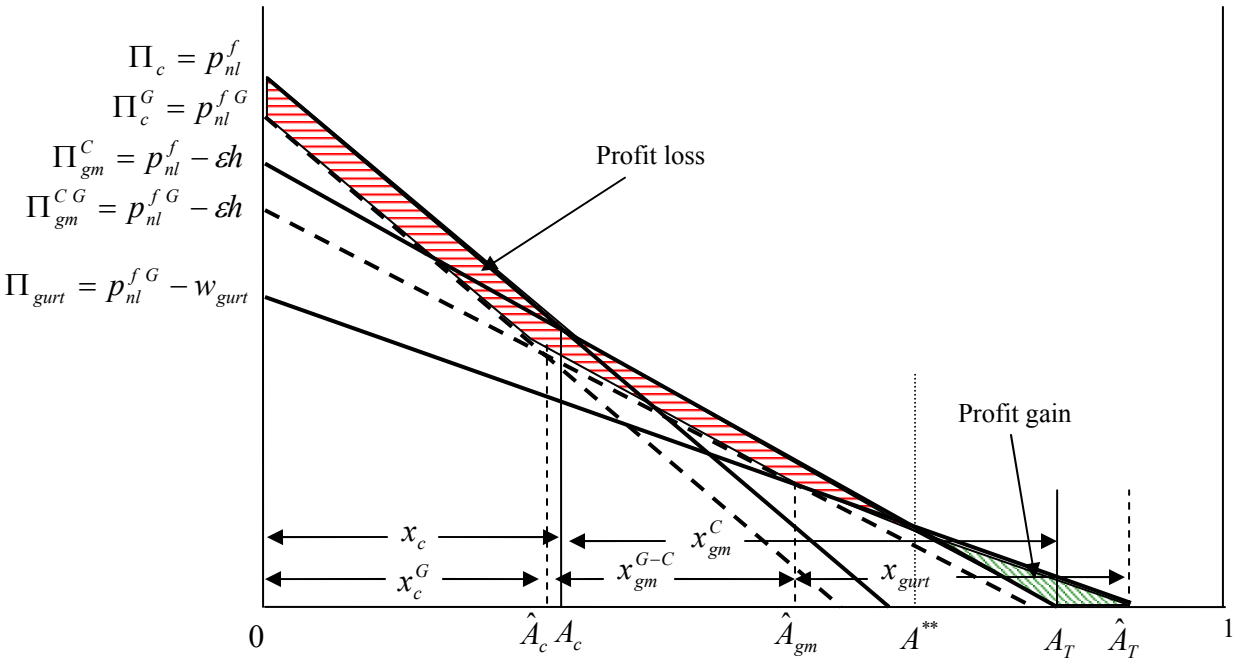
Panel (i): Case I, II_A and II_B - welfare gains and losses when $w_{gm}^G > w_{gm}$, $x_{nl}^G > x_{nl}$ (i.e. $\hat{A}_T > A_T$) and $p_{nl}^G < p_{nl}$.



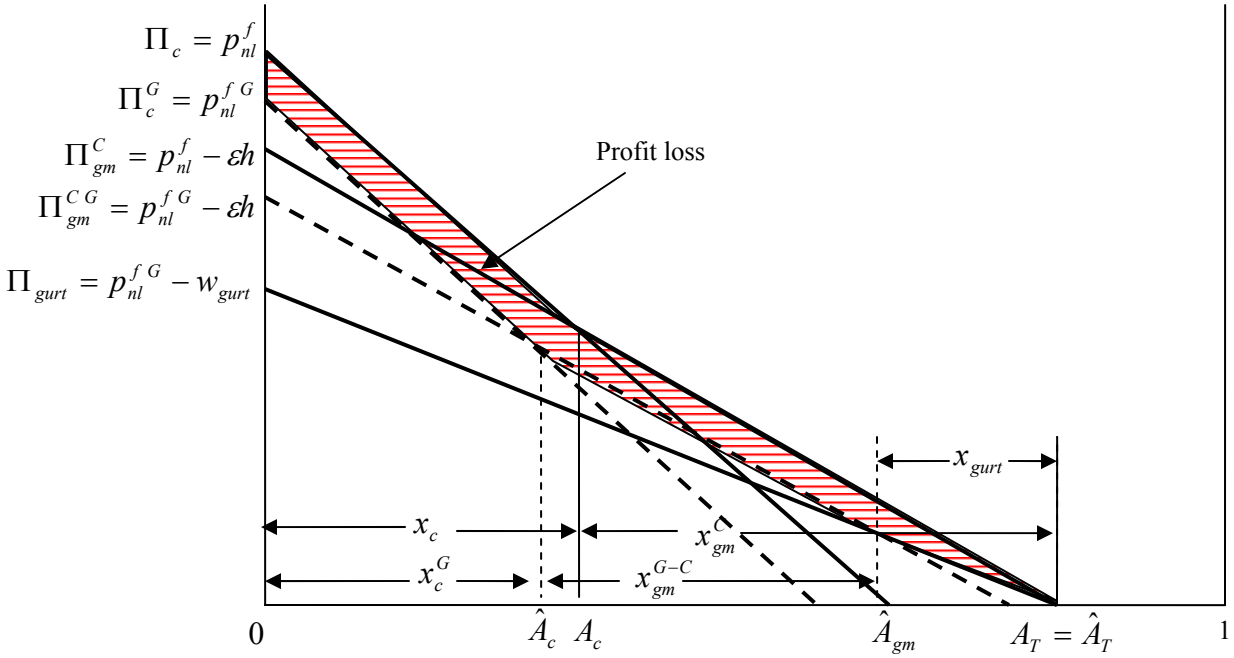
Panel (ii): Case II_A - welfare losses when $w_{gm}^G = w_{gm}$, $x_{nl}^G = x_{nl}$ (i.e. $\hat{A}_T = A_T$) and $p_{nl}^G < p_{nl}$.



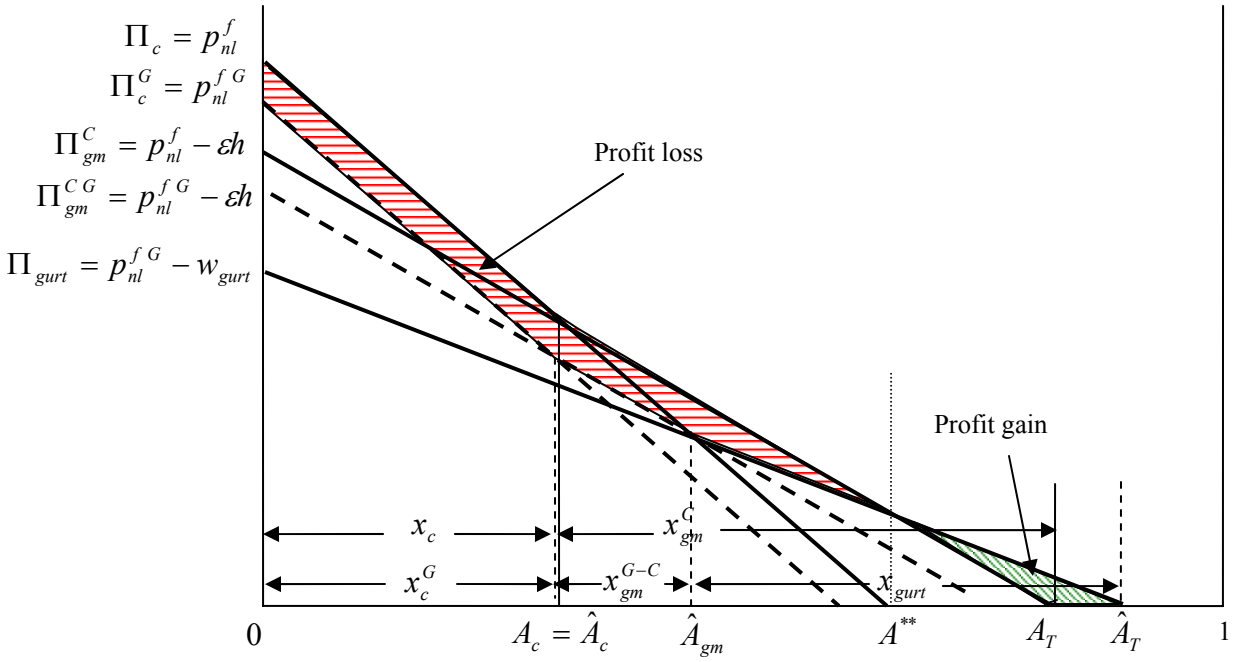
Panel (iii): Case II_A and II_B - welfare losses when $w_{gm}^G < w_{gm}$, $x_{nl}^G < x_{nl}$ (i.e. $\hat{A}_T < A_T$) and $p_{nl}^G < p_{nl}$.



Panel (iv): Case II_B - welfare gains and losses when $w_{gm}^G < w_{gm}$, $x_{nl}^G > x_{nl}$ (i.e. $\hat{A}_T > A_T$) and $p_{nl}^G < p_{nl}$.



Panel (v): Case II_A and II_B - welfare gains and losses when $w_{gm}^G < w_{gm}$, $x_{nl}^G = x_{nl}$ (i.e. $\hat{A}_T = A_T$) and $p_{nl}^G < p_{nl}$.



Panel (vi): Case II_B - welfare losses and gains when $w_{gm}^G = w_{gm}$, $x_{nl}^G > x_{nl}$ (i.e. $\hat{A}_T > A_T$) and $p_{nl}^G < p_{nl}$.

Figure 14. Changes in producer welfare when $p_{nl}^G < p_{nl}$ due to the introduction of GURTs.

Under case III, when $w_{gm}^{G} > w_{gm}$ and $x_{nl}^{G} = x_{nl}$, there is an increase in the equilibrium price of the non-labeled product due to the introduction of GURTs, $p_{nl}^{G} > p_{nl}$. Figure 15, panel (i), depicts the changes in the profits of producers, when $p_{nl}^{f\,G} > p_{nl}^{f}$ and thus, $p_{nl}^{f\,G} - \varepsilon h > p_{nl}^{f} - \varepsilon h$, $w_{gm}^{G} > w_{gm}$ and thus, the slopes of the profit curve of the GM product are such that $\delta + w_{gm}^{G} - \varepsilon h > \delta + w_{gm} - \varepsilon h$, and $x_{nl}^{G} = x_{nl}$, i.e., $\hat{A}_T = A_T$. From the graph we see that, under the above conditions, producers find it more optimal to increase the production of the conventional product, reduce the production of the GM product and start producing the GURTs product. The producers who are located at $[0, A_c)$, $(\hat{A}_c, \hat{A}_{gm})$ and $(\hat{A}_T, 1]$ do not switch their production and keep producing the conventional, the GM and the alternative products, respectively. The producers who find it optimal to switch their production after the introduction of GURTs are the producers who are located at $(A_c, \hat{A}_c)$ who switch from producing the now relatively more expensive GM product to producing the relatively less expensive conventional product and the producers who are located at $(\hat{A}_{gm}, A_T)$ who produce the GM products under the status quo but after the introduction of GURTs find it more profitable to produce the GURTs product.

When comparing the profits levels the producers receive before and after the introduction of GURTs we notice that after the introduction of GURTs some producers experience an increase in their profits, others a decrease in their profits and some are not affected. Specifically, the producers located at $[0, \hat{A}_c)$ who are those producing the conventional product experience an increase in their profits, while those located at $(\hat{A}_c, \hat{A}_T)$ who are those producing the GM and the GURTs products experience a decrease

in their profits. Obviously, the producers located at $\left(\hat{A}_T, 1\right]$ who produce the alternative product do not experience any changes in their profits due to the introduction of GURTs.

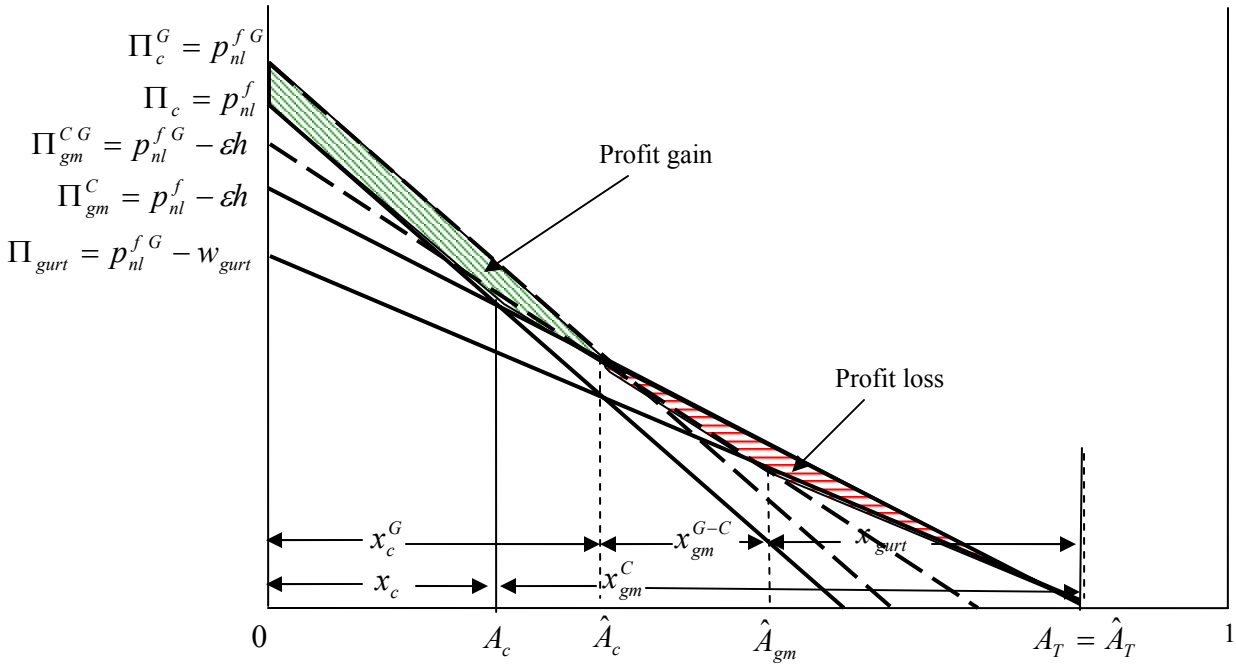
The intuition behind this outcome is that those producers who save seed relatively more (i.e., those located closer to zero), gain after GURTs are introduced due to the higher price they receive for their product in the market (conventional producers). Those producers who save seed relatively less (i.e., those located closer to one) loose after GURTs are introduced, even though they receive a higher price for their product, due to the higher GM seed price (GM producers) and their inability to save seed (GURTs producers). Note that, the lower A value GURTs producers loose more than higher A value GURTs producers.

Under case III, when $w_{gm}^{G} > w_{gm}$ and $x_{nl}^{G} > x_{nl}$, there is an increase in the equilibrium price of the non-labeled product due to the introduction of GURTs, $p_{nl}^{G} > p_{nl}$. Figure 15, panel (i), depicts the changes in the profits of producers, when $p_{nl}^{f\,G} > p_{nl}^{f}$ and thus, $p_{nl}^{f\,G} - \varepsilon h > p_{nl}^{f} - \varepsilon h$, $w_{gm}^{G} > w_{gm}$ and thus, the slopes of the profit curve of the GM product are such that $\delta + w_{gm}^{G} - \varepsilon h > \delta + w_{gm} - \varepsilon h$, and $x_{nl}^{G} > x_{nl}$, i.e., $\hat{A}_T > A_T$. From the graph we see that, under the above conditions, producers find it optimal to increase the production of the conventional product, reduce the production of the GM and the alternative products and start producing the GURTs product. The producers who are located at $[0, A_c)$, $\left(\hat{A}_c, \hat{A}_{gm}\right)$ and $\left(\hat{A}_T, 1\right]$ do not switch their production and keep producing the conventional, the GM and the alternative products, respectively. The producers who find it optimal to switch their production after the introduction of GURTs are the producers who are located at $\left(A_c, \hat{A}_c\right)$ who switch from producing the now

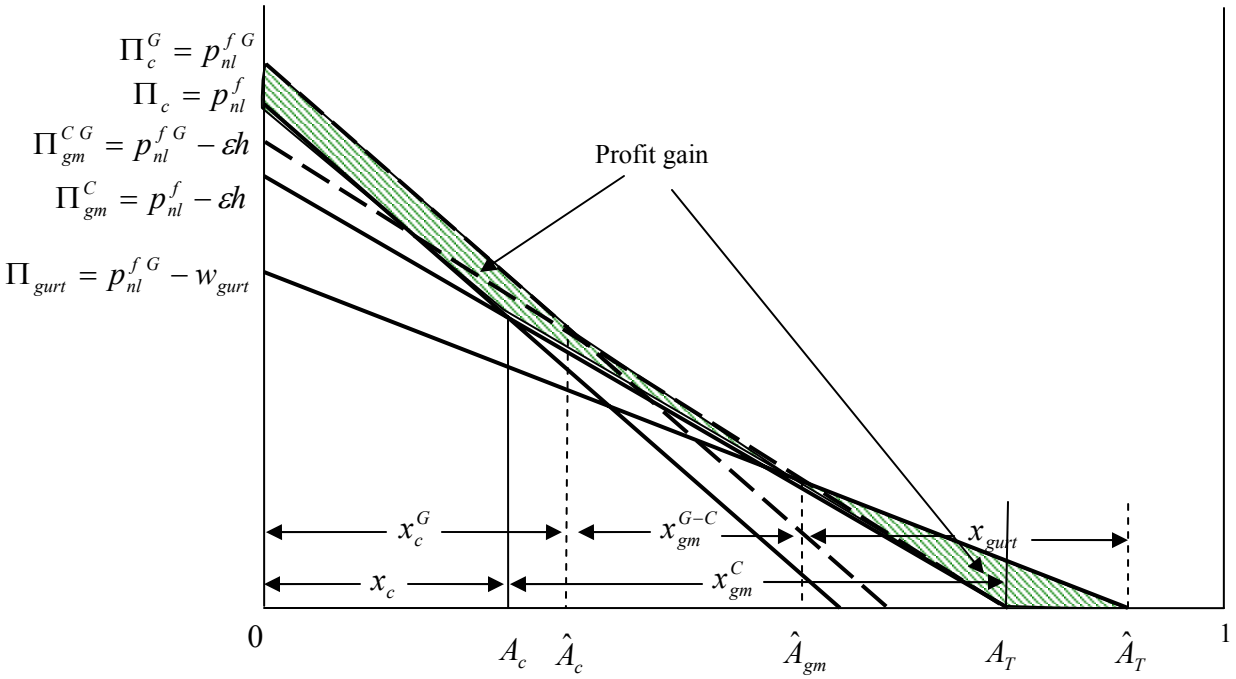
relatively more expensive GM product to producing the relatively less expensive conventional product; the producers who are located at $\left(\hat{A}_{gm}, A_T\right)$ who decide not to produce the now relatively more expensive GM products and switch to the production of the GURTs products; and the producers who are located at $\left(\hat{A}_{gm}, A_T\right)$ who produce the alternative products under the status quo but after the introduction of GURTs find it more profitable to produce the GURTs.

When comparing the profits levels the producers receive before and after the introduction of GURTs we notice that all producers who produce the non-labeled product (producers located at $\left[0, \hat{A}_T\right)$) experience an increase in their profits due to the introduction of GURTs. The intuition behind this outcome is that losses in profits due to the increase in the prices of the GM seed (for producers who find it optimal to keep producing the GM product) or due to the inability to save and reuse seed (for producer who find it optimal to adopt GURTs) are lower than gains in profits due to the higher product price. The graph in Figure 15, panel (ii), depicts the case when all producers gain. By allowing the slope of the GM curve to be steeper one can get the outcome where some GM producers do not experience any change in their profits.

As was mentioned before, the analysis is conducted under the assumption that producers are uniformly distributed between zero and one, i.e., $A \in [0, 1]$. If the distribution of producers between A values is skewed, the magnitude of the welfare effects depends on the skewness of the distribution. For instance, in Figure 15, panel (i), if relatively more producers save large percentage of their seed (are closer to zero) it is more likely that the introduction of GURTs will result in welfare gains rather than in welfare losses.



Panel (i): Case III - welfare gains and losses when $w_{gm}^G > w_{gm}$, $x_{nl}^G = x_{nl}$ (i.e. $\hat{A}_T = A_T$) and $p_{nl}^G > p_{nl}$.



Panel (ii): Case III - welfare gains when $w_{gm}^G > w_{gm}$, $x_{nl}^G > x_{nl}$ (i.e. $\hat{A}_T > A_T$) and $p_{nl}^G > p_{nl}$

Figure 15. Changes in Producer Welfare $p_{nl}^G > p_{nl}$ due to the Introduction of GURTs.

To summarize the main findings of this section, under Case I, all consumers who purchase the non-labeled product and some producers who produce the GURTs product and have relatively high A values (i.e., low dependency on saving seed) experience an increase in their welfare due to the introduction of GURTs. However, the producers of the conventional and GM products and those who produce the GURTs product but have relatively lower A values experience a decrease in their welfare due to the introduction of GURTs.

Under case II, with the large price decrease of the non-labeled product after GURTs are introduced all consumers who purchase the non-labeled product experience an increase in their welfare, while with the small price decrease only the consumers with only low c values (i.e., low levels of aversion to interventions in the production process) benefit from the introduction of GURTs. Under case II, the only producers who may benefit from the introduction of GURTs are those who find it optimal to produce the GURTs product and have relatively high A values; the rest experience a decrease in their welfare due to the introduction of GURTs.

Finally, under case III, when the increase in the equilibrium price of the non-labeled product is large, all consumers experience a decrease in their welfare due to the introduction of GURTs, while when the increase is relatively small, the consumers with low c values loose and those with high c values benefit (i.e., with low and high levels of aversion to interventions in the production process, respectively) from the introduction of GURTs. Under case III, the producers producing the conventional product experience an increase in their welfare due to the introduction of GURTs. The producers producing the GM product benefit (loose) due to the introduction of GURTs, when the increase in the

product price is greater (lower) than the increase in the cost of producing the GM product. Finally, the producers of the GURTs product benefit (loose) due to the introduction of GURTs, when producing the GURTs product is relatively more (not much more) cost effective than producing the GM product.

3.3 The Incentives of the Innovating Firm

The market outcome analysis in section 2.3 and the subsequent welfare analysis in sections 3.1 and 3.2 has been conducted assuming different pricing strategies for the innovating firm. Different outcomes have been discussed based on how the monopolist prices her products, i.e., whether she increases, decreases, or keeps unchanged the price of GM seed after she introduces GURTs into the market, as well as the pricing and the agronomic characteristics of the GURTs product that she introduces. Knowing how consumers and producers react to these different strategies (under the different outcomes) the monopolist can decide on the optimal strategy. For instance, the monopolist knows that if consumer aversion to GURTs is relatively high ($\mu > \lambda$), if she increases the price of the GM seed after she introduces GURTs, she might loose market share for the GM and GURTs product (e.g., $\theta + \alpha < \psi$ - case III).

The analysis shows that in most cases (see Figure 14 and Figure 15) the GURTs product captures market share from the GM product and in some cases from the alternative product. For example, in the case depicted in Figure 14, panel (iv), the monopolist knows that when she reduces the price of the GM seed after she introduces the GURTs seed, she can capture producers who, under the status quo, find it optimal to produce the conventional product. At the same time, if the monopolist introduces the GURTs seed at a relatively low price more producers will find it profitable to switch their

production from the GM and the alternative to the GURTs crops, even when their dependency on saving seed is relatively high. In addition, if the monopolist works on increasing the agronomic characteristics of GURTs, $\gamma < \delta$, which will provide the GURTs producers with higher benefits over the GM producers, then the slope of the GURTs product would become flatter, and as it can be seen from Figure 14, panel (iv), the GURTs product will attract more producers from the alternative product sector. As a result, more producers can experience an increase in their welfare due to the introduction of GURTs.

As another example, see the case depicted in Figure 15, panel (ii), where the monopolist knows that when she increases the price of the GM seed after she introduces the GURTs seed, she can loose those producers who, under the status quo, find it optimal to produce the GM product and with the increase of the GM seed price will produce the conventional product instead. At the same time, if the monopolist introduces the GURTs seed at a relatively low price, more producers will find it profitable to switch their production from the GM and the alternative to the GURTs crop, even when their dependency on saving seed is relatively high. In addition, if the monopolist works on increasing the agronomic characteristics of GURTs, then the slope of the GURTs product would become flatter, and as it can be seen from Figure 14, panel (iv), the GURTs product will attract more producers from the alternative product sector. As a result, more producers can experience an increase in their welfare due to the introduction of GURTs.

Therefore, for the monopolist to be able to capture a greater share of the market after she introduces GURTs, she should price the GURTs seed at a relatively low price and/or the GURTs product she introduces should offer greater agronomic benefits than

the GM product.

4. Concluding Remarks

This paper develops an analytical model of heterogeneous consumers and producers to examine the market and welfare effects of the introduction of V-GURTs in the US market. This study is the first to examine the potential impacts of GURTs for the innovator of the technology, the farmers, and the consumers of the final products.

Specifically, the study examines how the agronomic characteristics of GURTs, consumer perceptions and preferences regarding interventions in the production process (i.e., genetic modification) and producer cost structures (e.g., dependence on saving seed) affect the adoption of the technology by producers, the market acceptance of GURTs by consumers and consequently the innovator's incentive to introduce the new technology.

Analytical results show that the market and welfare effects of the introduction of GURTs depend on the level of consumer aversion to interventions in the production process, the production shares of GM and GURTs products in the total production of the non-labeled product, the price of the GM seed after the GURTs product is introduced, the price of the GURTs seed, the agronomic characteristics of the GURTs seed over the GM seed, and the expected penalty producers face when they cheat on their GM licensing agreements.

Specifically, when the GURTs and the GM product production shares in the total production of the non-labeled product stay the same or increase, compared to the GM share under the status quo, the price of the non-labeled product decreases. Under this case, the lower is the price of the non-labeled product, the more likely it is that the introduction of GURTs will lead to welfare gains for consumers with low levels of

aversion to genetic modification and the lower are the welfare losses for consumers with high levels of aversion to genetic modification. For producers with low dependency on saving seed the adoption of the relatively more cost efficient GURTs product will more likely lead to welfare gains despite the decrease in the price of the non-labeled product.

When the GURTs and the GM product production shares in the total production of the non-labeled product decrease, compared to the GM share under the status quo, the price of the non-labeled product increases. This case emerges only when the monopolist increases the price of the GM seed after the GURTs product is introduced. Under this case, the higher is the price of the non-labeled product, the more likely it is that the introduction of GURTs will lead to welfare losses for consumers with low levels of aversion to genetic modification while consumers with high levels of aversion to genetic modification might experience welfare gains (since the likelihood that the non-labeled product is GM or GURTs is smaller under this case). The increase in the price of the non-labeled product leads to welfare gains for producers with high dependency on saving seed while producers with low dependency on saving seed might experience welfare losses due to the increased price of the GM seed.

The results also show that, the greater are the agronomic benefits of the GURTs crop and/or the lower is the price of the GURTs seed, the more likely it is that producers with relatively low dependency on saving seed will find it optimal to switch their production from the conventional and the GM crop to the GURTs crop, and, thus, the more likely it is that the producers with both low and high dependency on saving seed will experience welfare gains.

Finally, the results show that, the lower is consumer aversion to genetic

modification and the lower is the expected penalty producers face when they cheat on their GM licensing agreements, the greater is the incentive of the seed company to introduce the GURTs technology as the greater are the profits that can be captured by the innovating firm.

Overall, the results show that the introduction of GURTs may be welfare-enhancing for all interested groups (consumers, producers and the innovating firm),when consumer aversion to GURTs is relatively low, the agronomic benefits of the GURTs crop are high, and the expected penalty producers face when they cheat on their GM licensing agreements is low.

The above analysis was conducted for a market where there is no mandatory labeling policy (e.g., US market) and under the assumption that a single firm produces the GM seed and develops and introduces the GURTs technology in the market. The framework developed in this study could be extended to examine the market and welfare effects of the introduction of GURTs in countries with labeling regimes, i.e., the EU. The single innovating firm assumption could also be relaxed to examine the market and welfare effects of GURTs in a market where a small number of seed companies produce and introduce the GURTs technology in the market. The examination of the above issues is the focus of future research.

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