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Market and Welfare Effects of the Introduction of Second-Generation, Consumer-Oriented Genetically Modified Products in the European Union

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بسم الله الرحمن الرحيم

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List of abbreviations

BSE: Bovine Spongiform Encephalopathy

DNA: Deoxyribonucleic acid

EU: European Union

EC: European Commission

EEC: European Economic Community

GM: Genetically Modified

GMOs: Genetically Modified Organisms

GMP: Genetically Modified Product

NGOs: Non Governmental Organizations

UK: United Kingdom

UN: United Nations

US: United States

WHO: World Health Organization

WTP: Willingness To Pay

WTO: World Trade Organization

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Abstract

This thesis builds on the literature on the economic effects of the second-generation, consumer-oriented GM products by analyzing the market and welfare impacts of the introduction of these new products in markets that, like the EU, mandate the segregation and labeling of the first-generation, producer-oriented GM products. In particular, this study seeks to determine the effects of these consumer-oriented GM products on the markets of conventional, GM and organic products, and the welfare of consumers and agricultural producers.

To determine the market and welfare effects of the second-generation, consumer-oriented GM products, the study compares and contrasts the equilibrium quantities, prices, and (consumer and producer) welfare before and after the introduction of the new GMPs. In deriving the different equilibria, the thesis explicitly accounts for the empirically relevant differences in consumer preferences for conventional, GM and organic products as well as for differences in the returns associated with the production of these products. The models developed allow for both vertical and horizontal product differentiation and facilitate the estimation of consumer and producer welfare in a theory-consistent and tractable manner.

Our analysis indicates that the market effects of the introduction of the second-generation GMPs in countries that mandate the labeling of their first-generation counterparts are similar to the effects in markets that treat GM and conventional products as substantially equivalent and do not require the segregation and labeling of GM products. While a country's labeling policy on GMOs does not affect the market effects of the second-generation GM products, it *does* affect the effect of these products on producer and consumer welfare. In this context, the results of this thesis should be of interest to policy makers, academics, and all participants in the GM, conventional and organic food supply channels.

Introduction

One of the most intriguing attributes of modern industrial society is its approach to nutrition. Humanity has moved from subsistence economies, where eating was a matter of survival, to economies characterized by increasing consumer demands for greater variety of food products and dietary excesses that have led to a spate of, so-called, diseases of civilization: cardiovascular disease, obesity, diabetes and certain types of cancer. Technological progress has resulted in the appearance of new concepts such as genetically modified organisms

(GMOs), nutraceuticals, functional products and dietary supplements which have influenced the consumer view of, and perceptions about food.

The list of important types of food products included in our diet has lately been expanded to include the genetically modified (GM) products. Despite their important agronomic benefits to agricultural producers (e.g., increased yields and/or reduced input costs), GM products have been facing increasing consumer opposition. Fears related to potential health and environmental effects of genetic modification as well as moral and philosophical concerns have consistently been cited as the driving forces behind the expressed consumer aversion to GM products. This consumer opposition varies significantly between countries and so does the countries' regulatory response to products of biotechnology (Giannakas and Fulton, 2002). For instance, while the United States of America (US), the world leader in GM production, treats biotech products as substantially equivalent to their conventional counterparts and does not require their segregation and labeling, the European Union (EU) has instituted a mandatory labeling regime that is regarded as the strictest in the world.

Consumer opposition to GMOs is the strongest in the EU where, intriguingly, consumer confidence in the food safety and inspection systems is among the lowest in the developed world. This lack of trust is thought to originate, at least in part, from recent series of food safety scares like the Bovine Spongiform Encephalopathy (BSE, also known as the Mad Cow Disease) incidents in the United Kingdom (UK), the Foot and Mouth disease, and the dioxin contamination of poultry in Belgium. While the EU appears to have made food safety a top priority through its new integrated "farm to fork" food safety approach, restoration of consumer confidence should be expected to, at best, be gradual. This is particularly important for GM products where the lack of conclusive scientific evidence on their long-term health and environmental impacts introduces an element of uncertainty, which, when combined with a low confidence in the food safety and inspection systems, can rationalize the, often viewed as irrational, consumer fears.

Apparently, the focus of the first-generation GM products on conferring agronomic benefits to producers (while providing no perceived advantages to consumers) did little to promote the market acceptance of these products. Consumer opposition to GM products is expected to decrease (even if by a tiny bit) with the introduction of second-generation GM products, however. Many of these new GM products are close to their commercialization stage and focus on providing direct consumer benefits by enhancing the quality of a product. Important examples of these consumer-oriented, second-generation GM products include the vitamin A enriched golden rice and high-oleic soybeans (Giannakas and Yiannaka, 2008, 2006).

Giannakas and Yiannaka (2008) have developed a methodological framework of heterogeneous consumers and producers to analyze the market and welfare impacts of the introduction of these consumer-oriented, GM products into the food system of countries that, like the US, do not require segregation and labeling of the first-generation, producer-oriented GM products. The objective of this thesis is to determine the market and welfare effects of the introduction of these new GM products in markets that, like the EU, mandate the labeling (and segregation) of the first-generation GM products. In particular, this thesis seeks to determine the effects of the introduction of the second-generation, consumer-oriented GM products on the markets of organic, conventional, and GM food products and to identify the winners and the losers from their introduction into the agro-food system. To our knowledge, this study represents the first attempt to systematically analyze the economic effects of the introduction of consumer-oriented GM products in markets that, like the EU, have a mandatory labeling regime governing the products of biotechnology.

To analyze these market and welfare impacts of the new consumer-oriented GM products, our analysis extends and adapts the Giannakas and Yiannaka (2008) framework of analysis to account for the fact that, in the markets considered in this study, the current first-generation GM products are required to be segregated and labeled as such. It is important to emphasize that this is a meaningful extension of the literature on this issue as the presence (or absence) of a labeling regime for the first-generation GM products has been shown to have significant effects on equilibrium prices, quantities and the welfare of the interest groups involved (Giannakas and Fulton, 2002; Fulton and Giannakas, 2004; Lapan and Moschini, 2004; Lence and Heyes, 2005; Veyssiere and Giannakas, 2006). In addition to providing important new insights on the likely economic impacts of the new consumer-oriented GM products, our study can provide an explanation for the position on agricultural biotechnology of the relevant European interest groups involved.

The rest of this thesis is structured as follows. Chapter (1) presents background information on the adoption of GMOs, the consumer attitudes towards these organisms, and their regulation around the world. Chapter (2) derives and presents the market conditions before the introduction of second-generation, consumer-oriented GM products, whereas chapter (3) deals with the market conditions after the introduction of these new GM products. Chapter (4) determines the market and welfares effects of the introduction of the second-generation, consumer-oriented GM products. Chapter (5) summarizes and concludes the thesis.

CHAPTER 1

Adoption, Acceptance and Regulation of GM Products

Before delving into the analysis of the market and welfare effects of the introduction of consumer-oriented, second-generation GM products into the food system, it is useful to provide some background information on the adoption, consumer attitudes and regulation of GMOs around the world.

1.1. Adoption of biotech crops around the world

The first GM seeds were planted in the US for commercial use in 1996. Ten years later, GM crops were grown on 102 million hectares worldwide (see Figure 1.1). Between 2005 and 2006 the land devoted to the production of GM crops increased by 13%; an area nearly the size of France and Germany combined. The US is the major GM producing country accounting for half of the total GM cultivations in 2006.

According to the International Service for the Acquisition of Agro-biotech Applications (ISAAA), 10.3 million farmers in 22 countries grew GM soy, maize, rape and cotton in 2006. GM papaya, alfalfa, squash and rice were also cultivated on smaller areas. The 22 countries growing biotech crops included 11 developing countries and 11 industrial countries – namely, in order of acreage devoted to GM crops, USA, Argentina, Brazil, Canada, India, China, Paraguay, South Africa, Uruguay, Philippines, Australia, Romania, Mexico, Spain, Colombia, France, Iran, Honduras, Czech Republic, Portugal, Germany, and Slovakia. Notably, the eight largest producers grew more than 1 million hectares each (James, 2006).

The global market value of biotech crops in 2006 was $6.15 billion representing 16% of the $38.5 billion global crop production market and 21% of the $30 billion global commercial seed market. Soybeans and maize accounted for 44% and 39% of the global market value of biotech crops, respectively, while cotton and canola accounted, respectively, for 14% and 3% of it.

1.2. Adoption of GM crops in the EU

Even though GM crops accounted for less than 1% of the EU maize cultivation area in 2006, the adoption of Bt maize (which is the only GM crop that has been grown in the EU) is increasing. Spain has been the main GM producer in the EU accounting for 87% of the 62,000 hectares devoted to GM maize in 2006 (James, 2006). In 2007, this GM crop was grown on a total of almost 110,000 hectares in Spain, France, Portugal, Czech Republic and Germany (Table 1.1).

Table 1.1: GM maize production (ha) in the EU

	GM maize (ha)	
	2006	**2007**
Spain	54,000	75,000
France	500	20,000
Czech Republic	1,290	2,650
Portugal	1,250	5,000
Germany	950	3,000

Source: http://www.gmo-compass.org/eng/agri_biotechnology/gmo_planting/191.eu_growing_area.html

After years of an effective EU moratorium to GM crops, the cultivation of GM plants is now legally possible in all EU countries as the new EU legislative framework for the approval of GM feeds and foods has been enacted in the entire EU. Nevertheless, by use of various national regulations and decrees, the cultivation of GM plants has been limited in some member states such as Germany, Austria and Hungary. Since such regulations must, by law, be based on scientifically sound knowledge, the EU Commission has taken legal action against the national policies of these states. Legislation concerning GMOs will be further discussed later in this chapter.

1.3. Consumer attitudes towards GM products

As mentioned earlier, while the world-wide adoption of biotech crops has been increasing rapidly, consumers in general, and European ones in particular, have been opposing the development of GM plants and animals as well as their use in food production. Consumer opposition to biotech products has been expressed mainly through opinion surveys even though a more extreme expression of sentiments has also occurred. A case in point is the destruction of 50% of the total GMO field trials in France in 2003 (see *www.Biomatnet.org/publications/2024con.pdf*).

It is becoming more and more apparent that consumer choice regarding novel foods is not driven only by prices and economic status, but also by ethics and emotions. While consumers are aware of benefits like enhanced pest resistance and increased yields (case of first-generation GM foods) and improved nutrition or new products (case of second-generation GM foods), they are also concerned about potential adverse effects on human health and the environment. Obviously, consumer concerns about GMOs affect their behavior as well as the behavior of food suppliers and retailers.

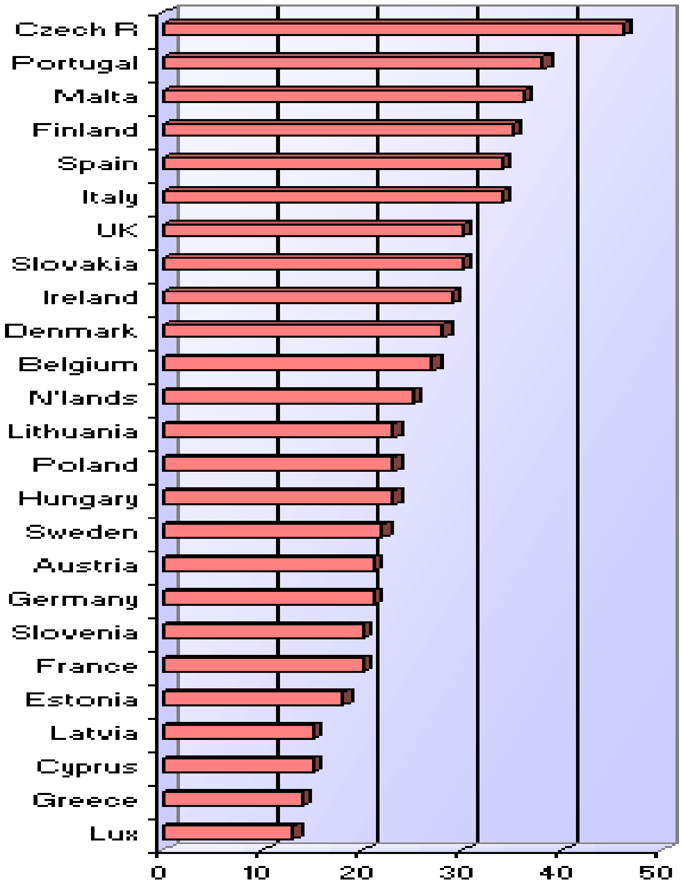
Overall, the reasons that have periodically been provided for the European consumer aversion to GMOs include (see *saasinc.org/Tulsa2004/TulsaPresentations/ SAAS_Hoban.ppt*):

- Biotechnology arrived to the EU market on the heels of mad-cow disease and other food safety problems
- EU consumers have realized no direct benefits from the first generation of GMOs
- There are concerns about the long-term effects on the environment and human health
- Europeans resent "Americanization" in all its forms, but particularly when it comes to food (e.g., McDonalds)

In addition to affecting the behavior of processors and retailers of the relevant food supply channels, consumer opposition to GMOs is viewed as a key determinant of the regulatory response to products of biotechnology. Both the EU moratorium on GMOs and the introduction of strict labeling and traceability requirements in 2004 have used the consumer reaction and "right to know" as their basis and justification. Note that, due to genetic modification being a credence process attribute, labeling is the single most important means of identifying these products (Giannakas and Fulton, 2002).

While the majority of European consumers remains skeptical about GMOs, the share of those who are optimistic about the prospects of biotechnology has been increasing in recent years. Also on the rise appears to be the consumer confidence on the EU's regulatory oversight of GMOs. Figure 1.1 summarizes the level of consumer support to GMOs in the EU in 2006.

Figure 1.1: EU member states' support for GM food (percent)



Source: http://www.gmo-compass.org/eng/news/stories/227.eurobarometer_europeans_biotechnology.html

1.4. International regulation of GM products

In the last decade, international trade in agricultural commodities and processed foods has been significantly increased. This increase was accompanied by economic trade restrictions, tariffs and safety standards. Regarding the GM products, they have been subject to various import approval procedures, bans, labeling and traceability requirements. Whereas import approval is a direct measure affecting market access, labeling and traceability indirectly affects trade through the imposition of the cost of implementation to exporters of GM crops. In addition, marketing regulations can affect the demand for GM versus non-GM crops; for example, it has been argued that GM food labels can act as perceived hazard warnings and reduce demand for these crops despite their approval from food safety authorities (Gruère, 2006).

Governments worldwide regulate foods with three objectives (Potter and Hotchkiss, 1995). The first is to ensure the security and wholesomeness of the food supply. The second is to prevent economic fraud. The third is to inform consumers about the nutritional content prior to the purchase and use of food products. Food is required to be labeled honestly and its package not to be deceptive. In the case of GM food, such responsibility rests on the food industry and the government which are supposed to cooperate over proper labeling and honest presentation of novel foods. Even though these regulatory objectives appear to be pretty common around the world, the regulation of GM food varies widely across countries (see Table 2). Nowhere is the difference in the regulatory approach to GM foods greater than between the EU and the US.

As mentioned in the introduction of this thesis, the EU regulations have established stringent approval, labeling and traceability requirements on food produced or derived from GM ingredients based mainly on the "precautionary principle" and consumers' "right to know." In contrast, the US regulatory approach is based on differences in the end product, and, viewing the producer-oriented, first-generation GM products as "substantially equivalent" to their conventional counterparts, includes voluntary labeling guidelines for GM food (Fulton and Giannakas, 2004). Consequently, many novel foods in the US are not subject to special regulation and are not being segregated from conventional food products. This regulatory approach can cause problems to American products exported to places like the EU, Australia, Japan and South Korea where labeling is mandatory.

It is interesting to note that, while some major producing countries like Canada and Argentina have policies mirroring those of the US, a number of countries have progressively moved their approval and labeling regulations to resemble those of the EU. These countries do so in order to either facilitate trade with the EU (e.g., Switzerland), or help their case for accession to the EU (e.g., Croatia). While the aforementioned countries are among those with a well-defined regulatory approach to GMOs, there is a large number of, mainly developing, countries that are currently lacking a regulatory framework governing the approval and marketing of GM products.

Table 1.2: Regulatory approaches to GM products around the world

	Food safety approval regulations	Labeling regulations	Specificity	Countries
Group 1	Process based mandatory	Stringent, mandatory, includes derived products	Traceability requirements, 0.9% threshold	**EU, East Europe**
Group 2	Process based mandatory	Stringent, mandatory, includes derived products	No traceability, low threshold	Brazil, China, Russia, Switzerland, Norway
Group 3	Process based mandatory	"Pragmatic" mandatory	Many labeling exceptions	Australia, Japan, Korea, Saudi Arabia, Thailand
Group 4	Substantial equivalence, mandatory (US: voluntary consultation)	Voluntary for substantial equivalent food	5% threshold level for labeling	**US**, Canada, Argentina, South Africa, Taiwan
Group 5	Mandatory (in place or pending)	Mandatory, introduced but not implemented	"Pragmatic" labeling requirements	Indonesia, Malaysia, Mexico, Philippines, Vietnam,
Group 6	Mandatory (in place or pending)	Intention to require labeling	Slow regulatory process	India, Kenya
Group 7	Considering mandatory	No clear position	Slow regulatory process	Bangladesh, most African countries
Group 8	No	No clear position	GM free	A few African countries (Zimbabwe, Zambia)

Source: Gruère (2006).

Despite the significant differences in the approaches to the regulation of GM products around the world, there have been some important harmonization efforts related to the research, trade, and use of GM crops in the context of (Nuffield Council on Bioethics 2003):

- The World Trade Organization (WTO) which aims to control barriers to international trade. It is there that the US and a number of other countries have challenged the EU on the authorization of GM crops.
- The Codex Alimentarius which is a set of international codes of practice, guidelines and recommendations pertaining to food labeling and food safety and is recognized as a reference standard of food safety in the Sanitary and Phytosanitary Agreement of the WTO.
- The Cartagena Protocol on Biosafety introduced in January 2000 under the Convention on Biological Diversity (CBD), which is a multilateral agreement covering the trans-boundary movement of living modified organizations (LMOs) that might have an adverse effect on biological diversity.

1.5. GM product regulation in the EU

As mentioned previously, the development and commercialization of novel foods derived from GMOs have caused serious concerns and intense debates around the world. Although there has been no scientific evidence of actual or potential harm from GM food, many consumers in the EU and elsewhere remain skeptical about genetic engineering. The regulatory framework for GM products in the EU is based on the proposition that these products are not harmful or that any harm they may cause is as slight as to be generally acceptable. Consumers have demanded their right to make informed consumption decisions, however, which, due to the credence nature of genetic modification, resulted in the introduction of mandatory labeling and segregation of GM and non-GM food products. Following below is a listing and short description of the EU directives and regulations governing food and feed products derived from GM crops.

- Directive 90/219/EEC, introduced in 1990, on the contained use of GMOs for the purpose of protecting human health and the environment.
- Directive 90/220/EEC, entered into force in 1991, on the deliberate release of GMOs into the environment (Official Journal of the European Communities - 8.5.90 - Page No L 117/15). This proposal includes the labeling of the product that may contain or may consist of GMOs. The indication could be included on a label or in an accompanying document.

- Regulation 258/97, introduced in 1997, was entitled the Novel Foods Regulation and applied to new food products including GMOs. It defined approval procedures requiring proof that any GM food is safe for human consumption.
- Regulations 1813/97 and 1139/98 required the labeling of food products containing approved GM soybeans and GM corn.
- Regulation 49/2000 introduced mandatory labeling of GM food and GM ingredients at the 1% level.
- Regulation 50/2000 extended the labeling requirements to food ingredients containing GM additives and flavorings.
- Directive 2000/13/EC of the European Parliament and of the Council of March 20, 2000 on the approximation of the laws of the Member States relating to the labeling, presentation and advertising of foodstuffs. The Directive applies to pre-packaged foodstuffs to be delivered to the final consumer or to restaurants, hospitals, canteens and other similar mass caterers (see http://europa.eu/scadplus/leg/en/lvb/l21090.htm). It does not apply to products intended for export outside the Community. According to this directive, the labeling, presentation and advertising of foodstuffs should not:
    - Mislead the consumer as to the foodstuff's characteristics or effects.
    - Attribute to a foodstuff (except for natural mineral waters and foodstuffs intended for special diets, which are covered by specific Community provisions) properties for the prevention, treatment or cure of a human illness. The labeling of foodstuffs must include the name under which the product is sold, list of ingredients, quantity or categories of ingredients expressed as a percentage, allergens, foods containing meat, net quantity, and date of minimum durability.
- Directive 2001/18/EC, introduced in October 2002, stressed the deliberate release of GMOs into the environment and repealed Council Directive 90/220/EEC. It introduced measures to ensure the regulation of GMOs that would meet the demands of EU regulators and consumers including (García, 2006):
    - Principles for environmental risk assessment – According to this directive, if a company wishes to market a GMO, it must first submit an application to the relevant national authority of the EU member state. The application has to take into account direct and indirect effects on human health and the environment which may arise from placing the product in the market. If no objections are

noted from EU states, approval is granted and the product can be marketed throughout the EU.

  - Mandatory information for the public.
  - Requirement for member states to ensure labeling and traceability at all stages of the supply channel.

- Regulation 1829/2003 took effect on April 18, 2004 and established procedures for evaluating potential risks from GM food as well as rules on labeling of GM food and feed.
- Regulation 1830/2003 of the European Parliament and the Council of September 22, 2003, concerned the traceability and labeling of GMOs and the traceability of food and feed products produced from GMOs and amended Directive 2001/18/EC. This regulation covers all foodstuffs produced from GMOs and stipulates that traceability will be required throughout the food chain with two main objectives (http://europa.eu/ scadplus/leg/en/lvb/l21170.htm):
  - To inform consumers through the mandatory labeling of GM products whether for human or animal consumption.
  - To guarantee a "safety net" based on the traceability of these products at all stages of production and placing on the market.

Approvals are now granted for a period of 10 years, and are renewable. There is a 0 percent threshold for unapproved GM crops. Labeling is extended to animal feed, food sold by caterers, and food derived from GM ingredients even if the end product has no significant traces of transgenic DNA or proteins. One major addition is the traceability requirements for GM and non-GM food: any food potentially containing GM material has to be tracked all the way from the farm to the consumer. This requires food companies to keep track of all shipments and to conduct DNA or protein tests at different stages of the supply chain. There is no labeling requirement for products such as meat, milk or eggs produced from animals fed with GM feed. The purity threshold for the labeling of a product is 0.9% - i.e., a product containing more (less) than 0.9% of GM material has (does not have to) be labeled as “GM.”

It is important to note that the new labeling and traceability regulation was introduced to force member states to end the *de facto* 4-year moratorium on new GM crops and to respond to the pressure imposed by the US and other countries when they launched a WTO dispute on the moratorium. Many argue, however, that the mandatory labeling requirements have become the new *de facto* trade barrier for targeted “food” products. In addition, although the labeling policy does facilitate informed consumer decisions, it also introduces high control and segregation costs and has the potential to worsen consumer fears of the risks associated with the production and consumption of GM products.

After discussing the adoption, consumer attitudes, and regulation of GM products around the world, we focus next on the main objective of this thesis – namely, the determination of the market and welfare effects of the introduction of the new, second-generation, consumer-oriented GM products in a market that, like the EU, mandates the labeling of the first-generation, producer-oriented GM products. How are the markets of conventional, organic and first-generation GM products going to be affected by the introduction of the new GM products? Who will gain and who will lose from the introduction of the second-generation GM products in the market? The answer to these questions is the focus of the rest of this thesis.

CHAPTER 2

Market Conditions Before the Introduction of Second-Generation, Consumer-Oriented GM Products

This chapter focuses on the consumer and producer choices, decisions and welfare as well as on the market outcome prior to the introduction of the new GM products. Before delving into the formal analysis of economic behavior and outcomes, it would be useful to present some key characteristics of the products considered in this study.

2.1. The Model

2.1.1. Product and consumer characteristics

A useful and quite meaningful taxonomy of products that are close but imperfect substitutes is the one between vertically and horizontally differentiated products. Vertically differentiated products are those that are uniformly quality ranked by consumers. If those products were sold at the same price, all consumers would buy the product with the highest perceived level of quality. Horizontally differentiated products, on the other hand, are those that are not uniformly utility ranked by consumers. If those products were offered at the same price, they would all enjoy a positive market share.

To capture the expressed consumer preferences for GM, conventional and organic products appearing in numerous consumer studies around the world (Lusk et al., 2005), we follow Giannakas and Yiannaka (2008) and model these products as vertically differentiated ones with consumers differing in their intensity of preference for quality (Giannakas and Fulton, 2002; Bonnisseau and Lahmandi-Ayed, 2006). Organic products are considered the high quality products followed by the conventional and first-generation GMPs. Even though the conventional, GM and organic products in our study differ in their (credence) process attributes (i.e., the process through which they have been produced), they share the same observable physical characteristics (e.g., same appearance).

To capture these elements, consider a consumer that has the choice between three versions of a product available in the market: a conventional product, a first-generation GM labeled product, and a certified organic product. Assuming that the consumer spends a small fraction of his expenditure on the goods in question, his utility function can be written as follows:

$U_{fgm} = U - p^c_{fgm} - \gamma \alpha$: if a unit of first-generation GM product is consumed

$U_c = U - p^c_c - \delta \alpha$: if a unit of conventional product is consumed

$U_0 = U - p^c_o + \beta \alpha$: if a unit of organic product is consumed

where:

- U_c, U_{fgm} and U_o are the utilities associated with the unit consumption of conventional, first-generation GM, and organic products, respectively.
- The parameter *U* is a per unit base level of utility derived from the observable physical characteristics of these products. It is assumed that *U* exceeds the prices of the different products and is common to all consumers.

- p_c^c, p_{fgm}^c and p_o^c represent the consumer prices of conventional, GM, and organic products, respectively. To allow for positive market shares of these products, our analysis focuses on the case where $p_o^c > p_c^c > p_{fgm}^c$.[1]

- The characteristic α captures the difference in consumer preferences for the different products. It takes values between 0 and 1 and consumers are assumed to be uniformly distributed between the polar values of α.
- The parameter β is a non-negative utility enhancement factor associated with the consumption of the organic product while the parameters γ and δ are non-negative utility discount factors associated with the consumption of conventional and GM products, respectively. In this context, $(\gamma-\delta)\alpha$ denotes the aversion to GM products of the consumer with differentiating attribute α. For simplicity and without loss of generality, in the remaining of this study δ is normalized to 0.
- $U-\gamma\alpha$, $U-\delta\alpha$ and $U+\beta\alpha$ represent the consumer willingness to pay (WTP) for a unit of first-generation, conventional and organic products respectively. Subtracting the relevant prices from these WTP values provides an estimate of the consumer surplus associated with the consumption of these products.

[1] The condition $p_o^c > p_c^c > p_{fgm}^c$ is a necessary condition for the co-existence of the three products in a market. As pointed out by Giannakas and Fulton (2002), there are two reasons why the GM products will be priced lower than their conventional counterparts. First, mandatory labeling means increased marketing and segregation costs that can cause consumer prices to rise. The majority of these costs are incurred in the non-GM product chain, which, in turn, implies that the consumer of conventional products faces a greater price. Second, it is assumed that the GM technology generates production cost savings at the farm level. Some of the cost savings may be transmitted to the consumer of the first-generation GM products.

2.1.2. Producer characteristics

Under a mandatory labeling regime, producers of a product have the choice of producing the conventional, the GM, or the organic version of it. Producers differ in the returns they receive from the different products due to differences in geography, education, experience, management skills, technology adopted etc. (Fulton and Giannakas, 2004). Let $A \in [0,1]$ be the attribute that differentiates producers. The net returns function of the producer with attribute A is then:

$\Pi_{fgm} = p^{f}_{fgm} - (w_{fgm} + dA)$: if a unit of first-generation GM product is produced

$\Pi_{c} = p^{f}_{c} - (w_{c} + cA)$: if a unit of conventional product is produced

$\Pi_{o} = p^{f}_{o} - (w_{o} + bA)$: if a unit of organic product is produced

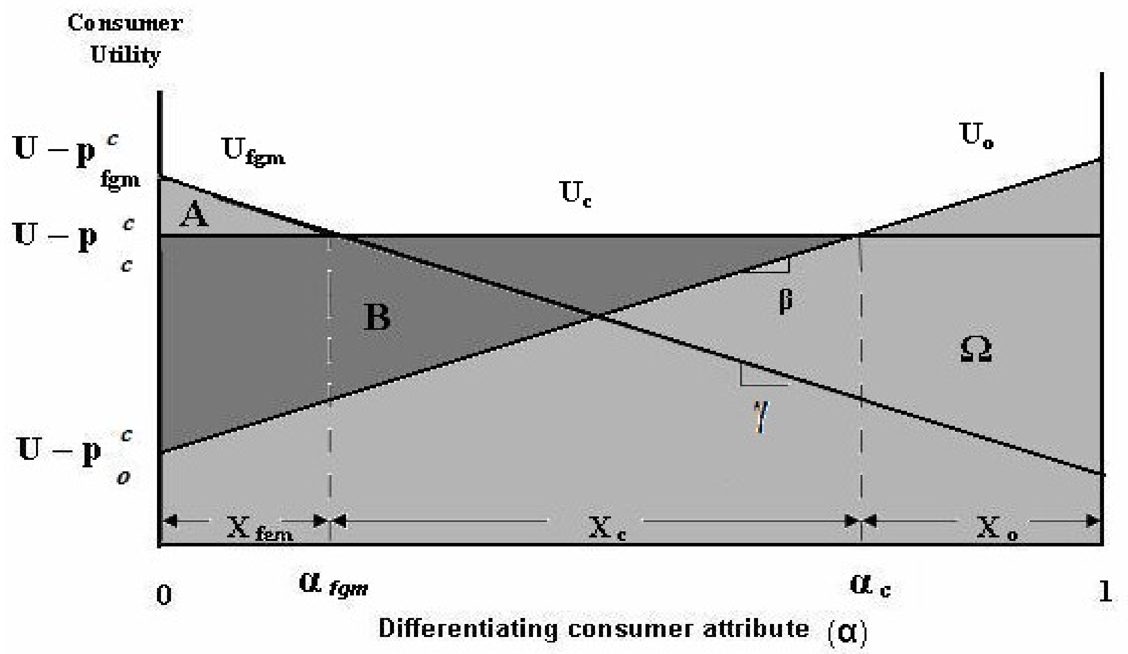
where:

- Π_i ($i \in \{fgm, c, o\}$) are the net returns resulting from the production of product *i*.
- p^{f}_{i} is the farm price of product *i*.
- w_i is the base cost of production (reflecting costs not affected by the individual producer) of product *i*.
- The parameters *d*, c and b are the cost enhancement factors associated with the production of the three products. To capture the increased costs associated with organic food production, we assume that $b > c$, while to capture the producer orientation of the first-generation GM products, we assume that $c > d$ with $(c - d)A$ capturing the agronomic benefits of the GM technology for the producer with differentiating attribute A.

2.2. Consumer decisions and welfare before the introduction of the new GMPs

A consumer's purchasing decision is determined by comparing the utilities derived from the products involved. Figure 2.1 illustrates the decisions and welfare of consumers when the prices and preference parameters are such that the conventional, organic and first-generation GM products enjoy positive market shares. The upward sloping curve graphs the consumer utility when the organic product is consumed, while the downward sloping line shows the utility when the first-generation GM product is consumed for different values of the differentiating attribute α.

Figure 2.1: Consumer decisions and welfare before the introduction of the new GM products



The intersection of two utility curves determines the level of the differentiating attribute that corresponds to the indifferent consumer. In particular, the consumer with differentiating attribute $\alpha_{fgm} : U_c = U_{fgm} \Rightarrow \alpha_{fgm} = (p^c_c - p^c_{fgm}) / \gamma$ is indifferent between consuming a unit of the conventional and a unit of the GM product as the utility associated with their consumption is the same. Similarly, the consumer with differentiating attribute $\alpha_c : U_c = U_o \Rightarrow \alpha_c = (p^c_o - p^c_c) / \beta$ is indifferent between consuming a unit of conventional and a unit of the organic product. Consumers located to the left of α_{fgm} prefer the GM products, consumers with $\alpha_{fgm} < \alpha < \alpha_c$ prefer the conventional product, and consumers with $\alpha > \alpha_c$ prefer the organic product. Normalizing the mass of consumer to one, the consumer demands for the three products are:

$$X^D_{fgm} = \alpha_{fgm} = (p^c_c - p^c_{fgm}) / \gamma \qquad (1)$$

$$X^D_c = \alpha_c - \alpha_{fgm} = \left[\lambda p^c_o - (\lambda + \beta) p^c_c + \beta p^c_{fgm}\right] / \beta \ \lambda \qquad (2)$$

$$X^D_o = 1 - \alpha_c = (\beta - p^c_o + p^c_c) / \beta \qquad (3)$$

- **Consumer surplus**

Consumer surplus (defined as the difference between the consumers' willingness to pay and the price they actually pay for their product of choice) is given by the area under the effective net utility curve in Figure 2.1 and equals:

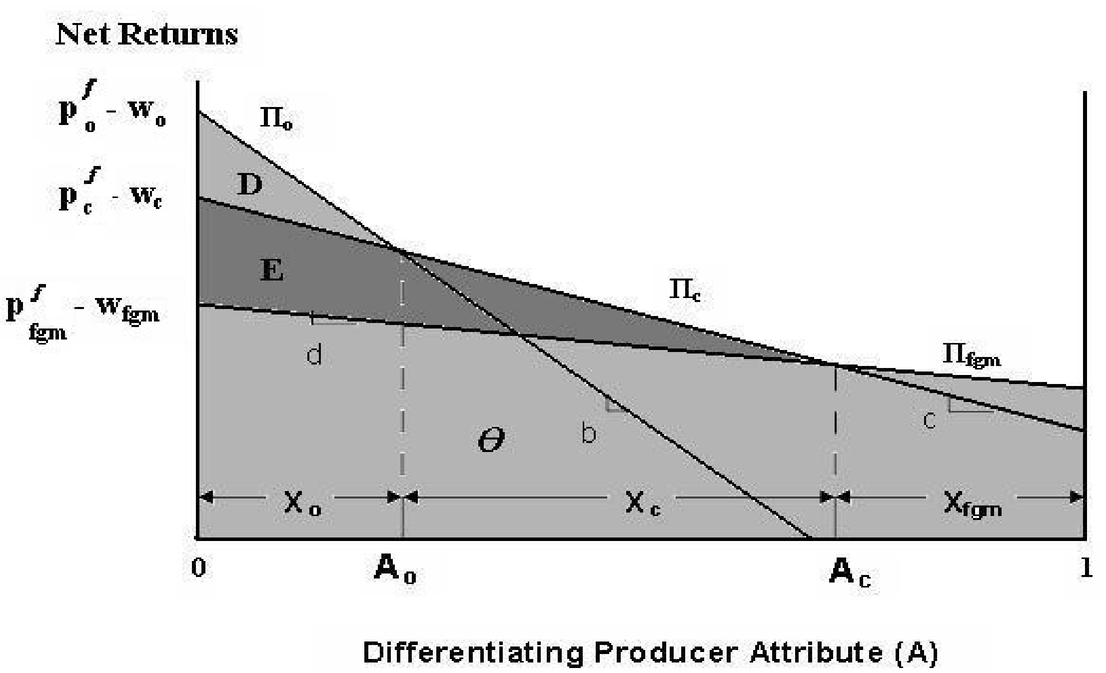
$$CS = \int_{o}^{\alpha_{fgm}} U_{fgm} d\alpha + \int_{\alpha_{fgm}}^{\alpha_c} U_c d\alpha + \int_{\alpha_c}^{1} U_o d\alpha = A + B + \Omega$$

$$\Rightarrow CS = (p_c^c - p_{fgm}^c)^2 / 2\lambda + (p_o^c - p_c^c)^2 / 2\beta + U - p_o^c + \beta / 2 \qquad (4)$$

2.3. Producer decisions and welfare before the introduction of the new GMPs

A farmer's production decision is determined by comparing the net returns associated with the production of first-generation GM, conventional and organic products. The figure 2.2 below graphs the relevant net returns when the prices and agronomic parameters are such that the three products enjoy positive market shares.

Figure 2.2: Producer decisions and welfare before the introduction of the new GM products



The intersection of two net return curves determines the level of the differentiating attribute that corresponds to the indifferent producer. In particular, the producer with differentiating attribute $A_o : \Pi_c = \Pi_o \Rightarrow A_o = (p_o^f - p_c^f - w_o + w_c)/(b-c)$ is indifferent between producing a unit of conventional and a unit of organic product as the net returns from the production of these products are the same. Similarly, the producer with differentiating attribute $A_c : \Pi_{fgm} = \Pi_c \Rightarrow A_c = (p_c^f - p_{fgm}^f - w_c + w_{fgm})/(c-d)$ is indifferent between the conventional and the first-generation GM product. Producers with differentiating attribute $A \in [0, A_o]$ produce the organic product, producers with $A \in (A_o, A_c]$ produce the conventional product and producers with $A \in (A_c, 1]$ produce the GM product. The supply functions of the three products are then:

$$X_o^S = A_o = (p_o^f - p_c^f - w_o + w_c)/(b-c) \qquad (5)$$

$$X_c^S = A_c - A_o = [(c(p_o^f + p_{fgm}^f + w_o - w_{fgm}) + d(p_o^f + p_c^f - w_o + w_c) + b(p_c^f - p_{fgm}^f - w_c + w_{fgm})]/(c-d)(b-c)$$

(6)

$$X_{fgm}^S = 1 - A_c = 1 - (p_c^f - w_c - p_{fgm}^f + w_{fgm})/(b-c) \qquad (7)$$

- **Producer welfare**

Aggregate producer welfare is given by the shaded area underneath the effective net returns curve in Figure 2.2 and equals to:

$$PW = \int_0^{A_o} \Pi_o \, da + \int_{A_o}^{A_c} \Pi_c \, dA + \int_{A_c}^{1} \Pi_{fgm} = D + E + \Theta \Rightarrow$$

$$PW = (p_o^f - p_c^f - w_o + w_c)^2 / 2(b-c) + (p_c^f - p_{fgm}^f - w_c + w_{fgm})^2 / 2(c-d) + p_{fgm}^f - w_{fgm} - d/2 \qquad (8)$$

2.4. Market Outcome before the introduction of the new GMPs

After having determined the demand and supply functions for the different products, this section will determine the market outcome prior to the introduction of the second-generation GM products by simultaneously solving the relevant demand and supply equations derived previously and summarized in Table 2.1. The parameter $mm_i = p_i^c - p_i^f$ is the marketing margin in the supply channel of product *i* (where $i \in \{c, o, fgm\}$).

Table 2.1: Product demands and supplies before the introduction of the new GMPs

Product version	Product demands	Product supplies
First-Generation GM	$X^D_{fgm} = (p^c_c - p^c_{fgm})/\gamma$ (1)	$X^S_{fgm} = 1 - (p^f_c - w_c - p^f_{fgm} + w_{fgm})/(c-d)$ (7)
Conventional	$X^D_c = [\gamma p^c_o - (\gamma+\beta) p^c_c + \beta p^c_{fgm}]/\beta\gamma$ (2)	$X^S_c = [c(p^f_o + p^f_{fgm} + w_o - w_{fgm}) + d(p^f_o - p^f_c - w_o + w_c) + b(p^f_c - p^f_{fgm} - w_c + w_{fgm})]/(c-d)(b-c)$ (6)
Organic	$X^D_o = (\beta - p^c_o + p^c_c)/\beta$ (3)	$X^S_o = (p^f_o - p^f_c - w_o + w_c)/(b-c)$ (5)

In particular, by equating equations (1) and (7), the equilibrium quantity for the first-generation of GM product is derived as:

$$X^*_{fgm} = (c - d - mm_{fgm} - w_{fgm} + mm_c + w_c)/(c - d + \gamma) \qquad (9)$$

The smaller the marketing margin of the first-generation of GM products, their base cost of production, and the consumer aversion to these products, or/and the greater the agronomic benefits from GM production, the marketing margin and the cost of producing the conventional products, the greater the market share of the first-generation GM products.

By equating equations (3) and (5), the equilibrium quantity of the organic product is given by:

$$X^*_o = (\beta - mm_o - w_o + mm_c + w_c)/(b - c + \beta) \qquad (10)$$

The smaller the marketing margin and the base costs of producing the organic product, or/and the greater the consumer preference for the organic product, the marketing margin and the cost of producing the conventional product, the greater the market share of the organic product.

The equilibrium quantity of the conventional product is then:

$$X^*_c = 1 - (X^*_{fgm} + X^*_o)$$

$$X^*_c = [(b - c + \beta)(\gamma + w_{fgm} + mm_{fgm}) - (c - d + \gamma)(\beta - mm_o - w_o) - (\gamma + \beta + b - d)(mm_c + w_c)]/(b - c + \beta)(c - d + \gamma$$

(11)

The smaller the marketing margin, the production costs of the conventional product and/or the agronomic benefits from producing transgenic products, or/and the larger the marketing margins and the costs of producing the first-generation GM and organic products, the larger the market share of the conventional products.

Using equations (1), (9), (3) and (10), the equilibrium price premia paid for conventional and organic products are, respectively:

$$p_c^c - p_{fgm}^c = \gamma(c - d - mm_{fgm} - w_{fgm} + mm_c + w_c)/(c - d + \gamma) \qquad (12)$$

$$p_o^c - p_c^c = \beta(b - c + mm_o + w_o - mm_c - w_c) - (b - c + \beta) \qquad (13)$$

From those two equations, it can be inferred that the equilibrium price premium paid for the conventional products increases with a raise in the marketing margin of the conventional products or/and a drop in the marketing margin of the first-generation GM products. On the other hand, the equilibrium price premium paid for the organic products goes up with an increase in the marketing margin of the organic products or/and a fall in the marketing margin of the conventional products.

CHAPTER 3

Market Conditions After the Introduction of Second-Generation, Consumer-Oriented GM Products

The first-generation of GM products focused on the provision of agronomic benefits to agricultural producers (such as herbicide tolerance, insect resistance and viral resistance) as well as on environmental benefits from reduced herbicide and insecticide use, and reduced agricultural tillage leading to soil erosion (Bertheau and Davison, 2006). The second-generation of GM products aims at offering benefits to consumers, such as enhanced nutritional value and functional characteristics that reduce the risk of diseases.

To date, GM techniques have been utilized to alter nutritional profiles by: increasing the content of vitamins, minerals and other micronutrients, modifying fats and oils, altering the starch and sugar content, altering the protein/amino acid profile, reducing levels of anti-nutritional/allergy factors and flavor enhancements (Dibb and Mayer, 2000). The famous example of second-generation GM products is the rice with enhanced levels of beta-carotene (the precursor of vitamin A) and iron. This, so-called, 'golden rice', developed by Swiss researchers, has been promoted as a means of addressing the problems of vitamin A deficiency in developing countries.

The new GM foods are also known as health-enhancing foods, enriching products, or friendly GM products. This new food category, positioned between medicine and conventional foods, has attracted the attention of consumers, market researchers, public health policy makers, and the food industry and is expected to receive a more positive reaction than their first-generation, producer-oriented counterparts.

This change in consumer attitudes towards GM food was captured by Li et al. (2002) who found that the Chinese consumers in their sample were willing to pay, on average, a 38% premium for golden rice. Similarly, Boccaletti and Moro (2000) reported a decrease in the percentage of Italian consumers who refuse to buy GM food products, from 17% to 12%, when the GM products had enhanced nutritional and organoleptic characteristics, and longer shelf life. The same tendency was reported in Colombia, where the willingness to buy a food product increased significantly when GM products contained a characteristic desired by consumers, such as enhanced nutrition and taste (Pachico and Wolf, 2002).

In this chapter, we seek to determine the equilibrium conditions after the introduction of the new, consumer-oriented GMPs (new GMPs, hereafter) in markets that, like the EU, mandate the labeling of the first-generation, producer-oriented GM products.

3.1. The Model

With the introduction of the new GM products, the consumer has an additional option available and his utility function becomes:

$U_{sgm} = U + (V + \theta\alpha) - p^{c}_{sgm} - \zeta c$: if a unit of second-generation GMP is consumed

$U'_{fgm} = U - p'^{c}_{fgm} - \gamma\alpha$: if a unit of first-generation GMP is consumed

$U'_{c} = U - p'^{c}_{c}$: if a unit of conventional product is consumed

$U'_{o} = U - p'^{c}_{o} + \beta\alpha$: if a unit of organic product is consumed

where U_{sgm} is the utility associated with the unit consumption of the new GMP; p^{c}_{sgm} is the consumer price of the new GMP; and $V + \theta\alpha$ is the value consumers place on the new quality-enhancing attribute of the new product (e.g., vitamin A in 'golden rice'). This value increases with *α* indicating that consumers that value high quality the most (i.e., consumers with higher values of *α*) place a greater value on the quality enhancement embedded in the new GMP. All other variables are as defined previously.

Similar to consumers, the introduction of the new GM products offers another option to agricultural producers who now face the choice between the second-generation GM, first-generation GM, conventional and organic products. The net returns function of the producer with differentiating attribute A becomes:

$\Pi_{sgm} = p^{f}_{sgm} - (w_{sgm} + dA)$: if a unit of second-generation GM product is produced

$\Pi_{fgm} = p'^{f}_{fgm} - (w_{fgm} + dA)$: if a unit of first-generation GM product is produced

$\Pi_{c} = p'^{f}_{c} - (w_{c} + cA)$: if a unit of conventional product is produced

$\Pi_{o} = p'^{f}_{o} - (w_{o} + bA)$: if a unit of organic product is produced

where: $\prod_{sgm}$ are the net returns associated with the production of the second-generation GM product, p^{f}_{sgm} is the farm price of the new GMP, and w_{sgm} is the base cost of production of the new GMP. All other variables are as previously defined.

Since we assume that both generations of GM products share the same agronomic characteristics, the cost enhancement factor associated with their production is the same. In such a case, for producers to adopt the new GM products, the net returns associated with the production of these products have to exceed the net returns associated with the production of their first-generation counterparts, i.e., $p^{f}_{sgm} - w_{sgm} > p'^{f}_{fgm} - w_{fgm}$. It should be noted, however, that this, necessary for the adoption of the second-generation GMPs, condition, is also a sufficient condition for driving the first-generation GMPs out of the market.

Result 1. *The introduction of second-generation, consumer-oriented GM products that share the same agronomic characteristics with their first-generation, producer-oriented counterparts drives the first-generation GM products out of the market.*

This result is consistent with the findings of Giannakas and Yiannaka (2008) on the market and welfare effects of the introduction of the new GM products in a market that, like the US, does not require segregation and labeling of the first-generation GM products. An important implication of this similarity is that, no matter if the first-generation GM products are required to be labeled or not, the introduction of their second-generation counterparts that share the same agronomic characteristics will drive them out of the market.

When the condition that results in the successful entry of the new GMPs is met, the consumer choice is reduced to that between the new GMPs, the conventional and the organic products. Setting $\gamma = \theta + \zeta$, the consumer utility function becomes:

$U_{sgm} = U + V - p^{c}_{sgm} - \gamma \alpha$: if a unit of second-generation GM product is consumed

$U_{c} = U - p'^{c}_{c}$: if a unit of conventional product is consumed

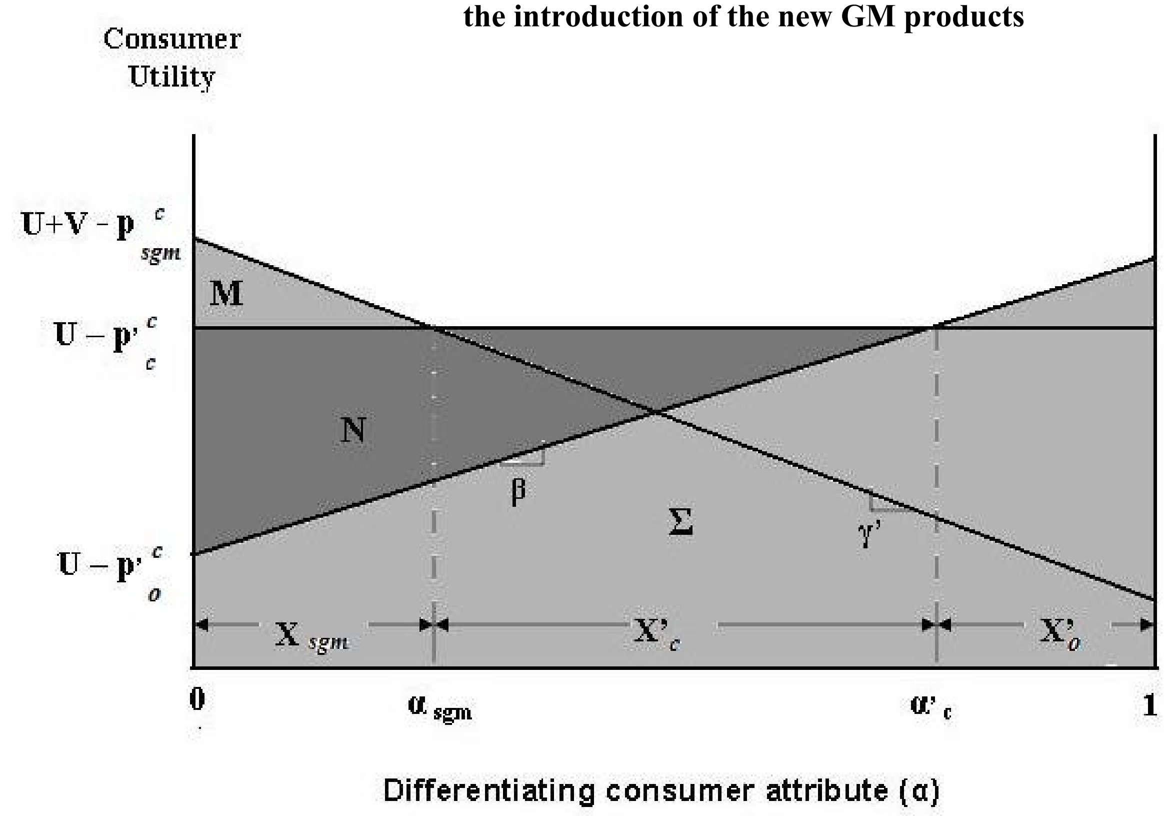
$U_{o} = U - p'^{c}_{o} + \beta\alpha$: if a unit of organic product is consumed

In addition to driving the first-generation GMPs out of the market, the introduction of the new GMPs can be shown to change the nature of the relationship between the GM products and their conventional and organic counterparts from vertical to horizontal product differentiation. This finding also appears in Giannakas and Yiannaka (2008) and its proof can be found in the appendix.

3.2. Consumer decisions and welfare after the introduction of the new GMP

Figure 3.1 illustrates the decisions and welfare of consumers in the presence of the second-generation GM products. The upward sloping curve graphs utility levels when the organic product is consumed, while the downward sloping line depicts the utility when the second-generation of GM product is consumed for different levels of the differentiating attribute *α*. By finding the indifferent consumer, located at the intersection of two utility curves, we can determine the consumer demand for each product.

Figure 3.1: Consumer decisions and welfare after the introduction of the new GM products



Specifically, the intersection of the utility curves associated with the consumption of the new GM and conventional products determines the consumer with differentiating characteristic $\alpha_{sgm}: U_{sgm} = U'_c \Rightarrow \alpha_{sgm} = (V - p^c_{sgm} + p'^c_c)/\gamma'$ who is indifferent between the new GMP and the conventional product. Similarly, the consumer with differentiating characteristic $\alpha'_c: U'_c = U'_o \Rightarrow \alpha'_c = (p'^c_o - p'^c_c)/\beta$ is indifferent between the conventional and organic products. Consumers located to the left of α_{sgm} prefer the new GMP, consumers with $\alpha \in (\alpha_{sgm}, \alpha'_c]$ prefer the conventional product, while consumers with $\alpha \in (\alpha'_c, 1]$ prefer the organic. The consumer demands for the second-generation GM, the conventional and the organic products are then, respectively:

$$X^{D}_{sgm} = \alpha_{sgm} = (V - p^{c}_{sgm} + p'^{c}_{c}) / \gamma' \tag{14}$$

$$X'^{D}_{c} = \alpha'_{c} - \alpha_{sgm} = [\gamma' p'^{c}_{o} - (\gamma' + \beta) p'^{c}_{c} - \beta (V - p^{c}_{sgm})] / \beta\gamma' \tag{15}$$

$$X'^{D}_{o} = 1 - \alpha'_{c} = (\beta - p'^{c}_{o} + p'^{c}_{c}) / \beta \tag{16}$$

Aggregate consumer surplus is given by the shaded area underneath the effective utility curve in Figure 3.1 and equals:

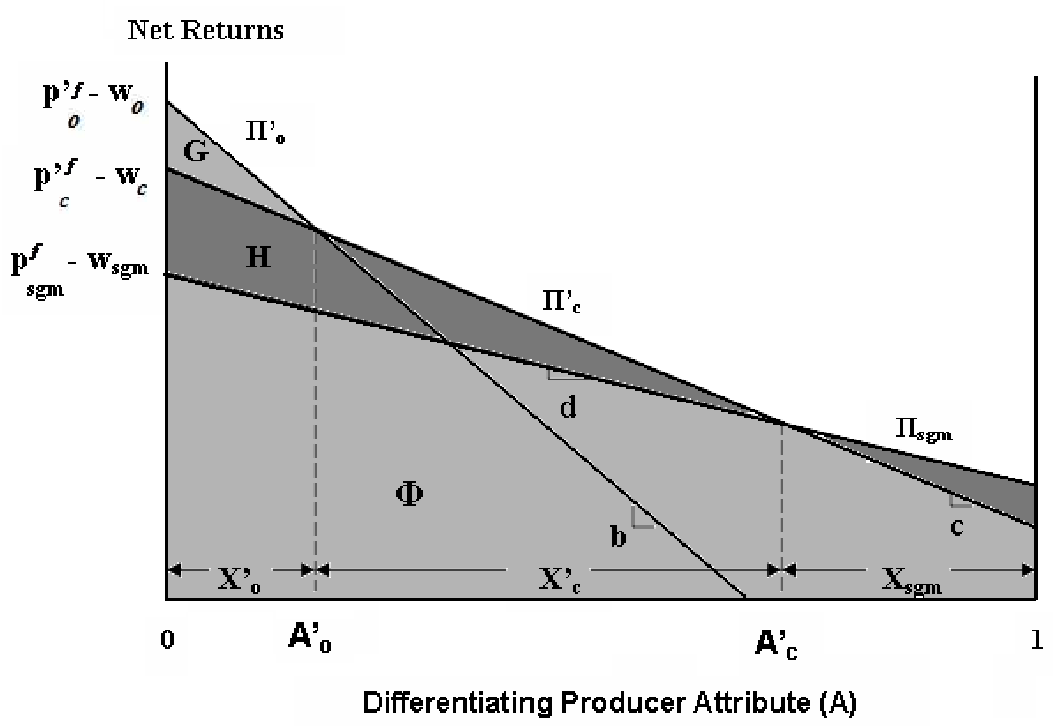
$$CS' = \int_{0}^{\alpha_{sgm}} U_{sgm} d\alpha + \int_{\alpha_{sgm}}^{\alpha'_{c}} U'_{c} d\alpha + \int_{\alpha'_{c}}^{1} U'_{o} d\alpha = M + N + \Sigma \Rightarrow$$

$$CS' = (V - p^{c}_{sgm} + p'^{c}_{c})^{2} / 2\gamma' + (p'^{c}_{o} - p'^{c}_{c})^{2} / 2\beta + (U - p'^{c}_{o} + \beta / 2) \tag{17}$$

3.3. Producer decisions and welfare after the introduction of the new GMP

A farmer's production decision is determined by comparing the net returns associated with the production of the different products. Figure 3.2 graphs the producer decisions and welfare when the prices and agronomic parameters are such that all products enjoy positive market shares.

Figure 3.2.: Producer decisions and welfare after the introduction of the new GM products



Producers with differentiating attribute $A \in [0, A'_0]$ find it optimal to produce organic products as the returns generated from their production exceed those generated by the other alternatives. Producers with $A \in [A'_0, A'_c]$ produce the conventional product and producers with $A \in [A'_c, 1]$ find it optimal to produce the new GMP. The supply functions of the three products are given by:

$$X'^S_o = A'_o = (p'^f_o - p'^f_c - w_o + w_c)/(b-c)$$

$$X'^S_c = A'_c - A'_o = (p'^f_c - p^f_{sgm} - w_c + w_{sgm})/(c-d) - (p'^f_o - p'^f_c - w_o + w_c)/(b-c)$$

(18)

$$= [c(p^f_{sgm} - p'^f_o - w_{sgm} + w_o) + d(p'^f_o - p'^f_c - w_o + w_c) + b(p'^f_c - p^f_{sgm} - w_c + w_{sgm})]/(c-d)(b-d)$$

(19)

$$X'^S_{sgm} = 1 - A'_c = 1 - (p'^f_c - p^f_{sgm} - w_c + w_{sgm})/(c-d)$$

(20)

Aggregate producer welfare is given by the shaded area underneath the effective net returns curve in Figure 3.2 and equals:

$$PW' = \int_0^{A'_o} \Pi_o dA + \int_{A'_o}^{A'_c} \Pi_c \, dA + \int_{A'_c}^{1} \Pi_{sgm} \, dA = G + H + \Phi \Rightarrow$$

$$PW' = (p'^f_o - p'^f_c - w_o + w_c)^2 / 2(b-c) + (p'^f_c - p'^f_{sgm} - w_c + w_{sgm})^2 / 2(c-d) + p^f_{sgm} - w_{sgm} - d/2$$

(21)

3.4. Market outcome after the introduction of the new GMP

When the three product versions (conventional, second-generation GM and organic) co-exist in the market, their equilibrium quantities are derived by equating the relevant product demands and supplies summarized in table 3.1 below.

Table 3.1: Product demands and supplies after the introduction of the new GMPs

Product version	Product demands	Product supplies
Second-Generation GM	$X^D_{sgm} = (V - p^c_{sgm} + p'^c_c)/\gamma'$ (14)	$X^S_{sgm} = 1 - (p'^f_c - p^f_{sgm} - w_c + w_{sgm})/(c-d)$ (20)
Conventional	$X'^D_c = [\delta p'^c_o - (\gamma'+\beta) p'^c_c - \beta(V - p^c_{sgm})]/\beta\gamma'$ (15)	$X'^S_c = [c(p^f_{sgm} - p'^f_o - w_{sgm} + w_o) + d(p'^f_o - p'^f_c - w_o + w_c) + b(p'^f_c - p^f_{sgm} - w_c + w_{sgm})]/(c-d)(b-d)$ (19)
Organic	$X'^D_o = (\beta - p'^c_o + p'^c_c)/\beta$ (16)	$X'^S_o = (p'^f_o - p'^f_c - w_o + w_c)/(b-c)$ (18)

Specifically, by equating equations (14) and (20), the equilibrium quantity of second-generation GM products is given by:

$$X^*_{sgm} = (V - mm_{sgm} - w_{sgm} + mm'_c + w_c + c - d)/(c - d + \gamma') \qquad (22)$$

Based on equation (22), for X^*_{sgm} to be positive, the base consumer valuation of the quality enhancement of the new GMP, V, has to be greater than a critical value V^* where

$$V^* = mm_{sgm} + w_{sgm} - mm'_c - w_c - c + d$$

The greater the consumer valuation V, the agronomic benefits from GM production, the marketing margin and cost of producing the conventional products, the greater the market share of the new GM products. On the other hand, the market acceptance of the new GMPs falls with the cost of production, the marketing margin and the consumer aversion to these products.

When $V > V^*$, the equilibrium quantities of organic and conventional products are, respectively:

$$X'^{*}_{o} = (\beta - mm'_{o} - w_{o} + mm'_{c} + w_{c})/(\beta + b - c) \tag{23}$$

$$X'^{*}_{c} = [(b - c + \beta)(\gamma' - V + mm_{sgm} + w_{sgm}) - (c - d + \gamma')(\beta - mm'_{o} - w_{o}) - (\gamma' + b - d + \beta)(mm'_{c} + w_{c})]/(b - c + \beta)(\tag{24}$$

The smaller the marketing margin and cost of producing the organic products, or/and the greater the consumer preference for organic products, the marketing margin and cost of producing the conventional products, the greater the market share of the organic products.

Using equations (22) and (14), the price premium enjoyed by the new GMP can be determined as follows:

$$p^{c}_{sgm} - p'^{c}_{c} = [V(c - d) - \gamma'(c - d + mm'_{c} + w_{c} - mm_{sgm} - w_{sgm})]/(c - d + \gamma') \tag{25}$$

while from equations (23) and (16), the price premium enjoyed by the organic product in the presence of the second-generation GMP is given by:

$$p'^{c}_{o} - p'^{c}_{c} = \beta(b - c + mm_{o} + w_{o} - mm_{c} - w_{c})/(b - c + \beta) \tag{26}$$

In analyzing the effects of the introduction of the new GM products into the market, it is important to point out that the co-existence of the new GMP with its organic and conventional counterparts holds for values of V that are greater than V^{*} but less than V^{**} where

$$V^{**} = [(b - c + \beta)(mm_{sgm} + w_{sgm} + \gamma') + (c - d + \gamma')(mm'_{o} + w_{o} - \beta) - (b - d + \beta + \gamma')(mm'_{c} + w_{c})]/(b - c + \beta)$$

If V exceeds V^{**}, then equation (24) suggests that the introduction of the new GMP drives the conventional product out of the market. The next chapter will present all possible scenarios on the effects of the new GM product on the markets for first-generation GM, conventional and organic food products.

CHAPTER 4

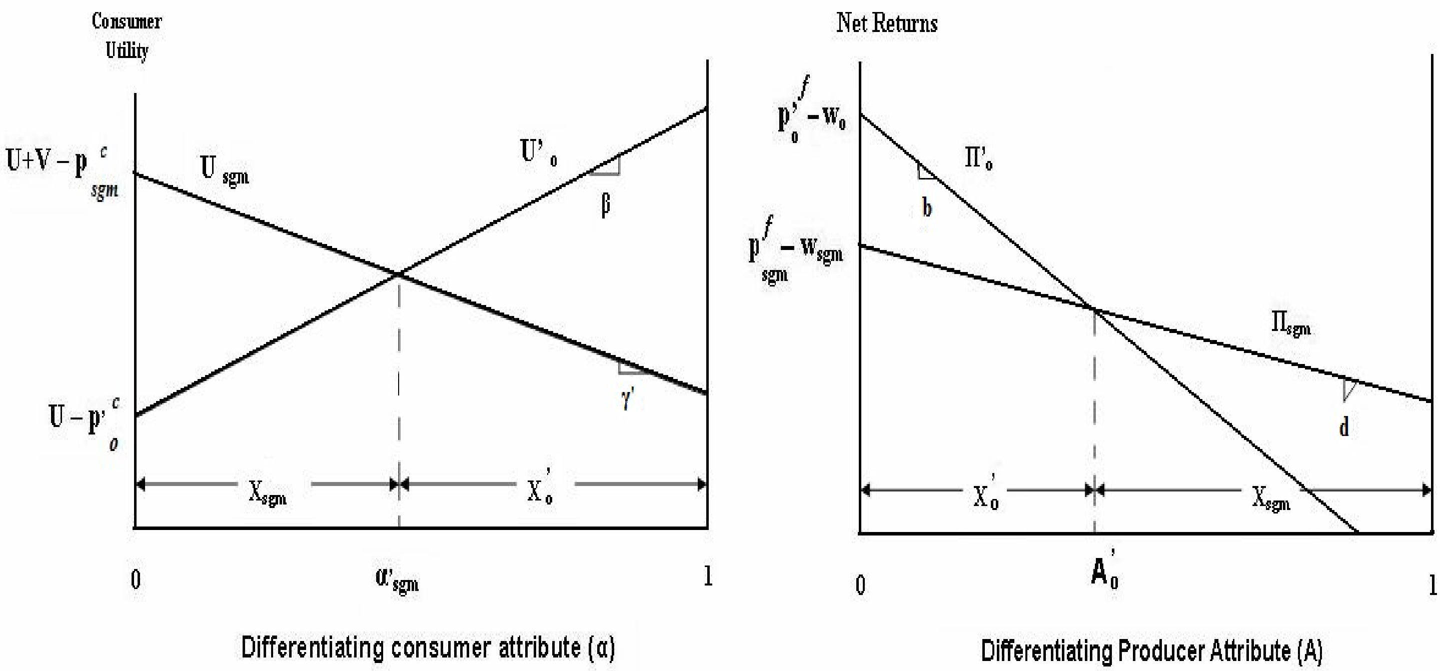
Market and Welfare Effects of the Introduction of Second-Generation, Consumer-Oriented GM Products

4.1. Market effects of the introduction of the new GM products

As mentioned previously, the number and type of products available to consumers after the introduction of the new GMP depends on the value consumers place on the quality-enhancing attribute of the new GMP. So, when V is below the critical value V^*, the new technology is deemed ineffective as there is no producer that will find it optimal to adopt this technology (and produce the new GMP). Thus, for X^*_{sgm} to be positive, V has to be greater then V^*.

The successful entry of the new GMP (occurring when $V > V^*$) comes at the expense of the first-generation GM products that are driven out of the market by their second-generation counterparts. Consumers of the first-generation GMP are not the only ones lured to the new GMP, however. The greater is the consumer valuation of the quality-enhancing attribute of the new GMP, the greater is the share of conventional product consumers that find it optimal to switch to the new GMP. When V exceeds the critical value V^{**}, the introduction of the new GMPs drives both the first-generation GM and the conventional products out of the market. Figure 4.1 depicts the equilibrium consumption and production choices when $V > V^{**}$ and the new GMP co-exists with its organic counterpart.

Figure 4.1: Consumer and producer decisions when $V > V^{**}$



The consumer demands for the two products are, then, given by:

$$X'^{D}_{sgm} = \alpha'_{sgm} = (V - p^{c}_{sgm} + p'^{c}_{o})/(\beta + \gamma')$$

(27)

$$X'^{D}_{o} = 1 - \alpha'_{sgm} = (\beta + \gamma' - V + p^{c}_{sgm} - p'^{c}_{o})/(\beta + \gamma') \qquad (28)$$

and the supplies of these products by:

$$X'^{S}_{o} = A'_{o} = (p'^{f}_{o} - p^{f}_{sgm} - w_{o} + w_{sgm})/(b - d) \qquad (29)$$

$$X'^{S}_{sgm} = 1 - A'_{o} = (b - d - p'^{f}_{o} + p^{f}_{sgm} + w_{o} - w_{sgm})/(b - d)$$

(30)

By equating (27) to (30) and (28) to (29), the equilibrium quantities of second-generation GM and organic products are derived as:

$$X^{*}_{sgm} = (V - mm_{sgm} - w_{sgm} + mm'_{o} + w_{o} + b - d)/(b - d + \beta + \gamma') \qquad (31)$$

$$X'^{*}_{o} = (\beta + \gamma' - mm'_{o} - w_{o} + mm_{sgm} + w_{sgm} - V)]/(b - d + \beta + \gamma') \qquad (32)$$

and the price premium enjoyed by the organic product is:

$$p'^{c}_{o} - p^{c}_{sgm} = [(\beta + \gamma')(mm'_{o} + w_{o} - mm_{sgm} - w_{sgm} + b - d) - V(b - d)]/(b - d + \beta + \gamma')$$

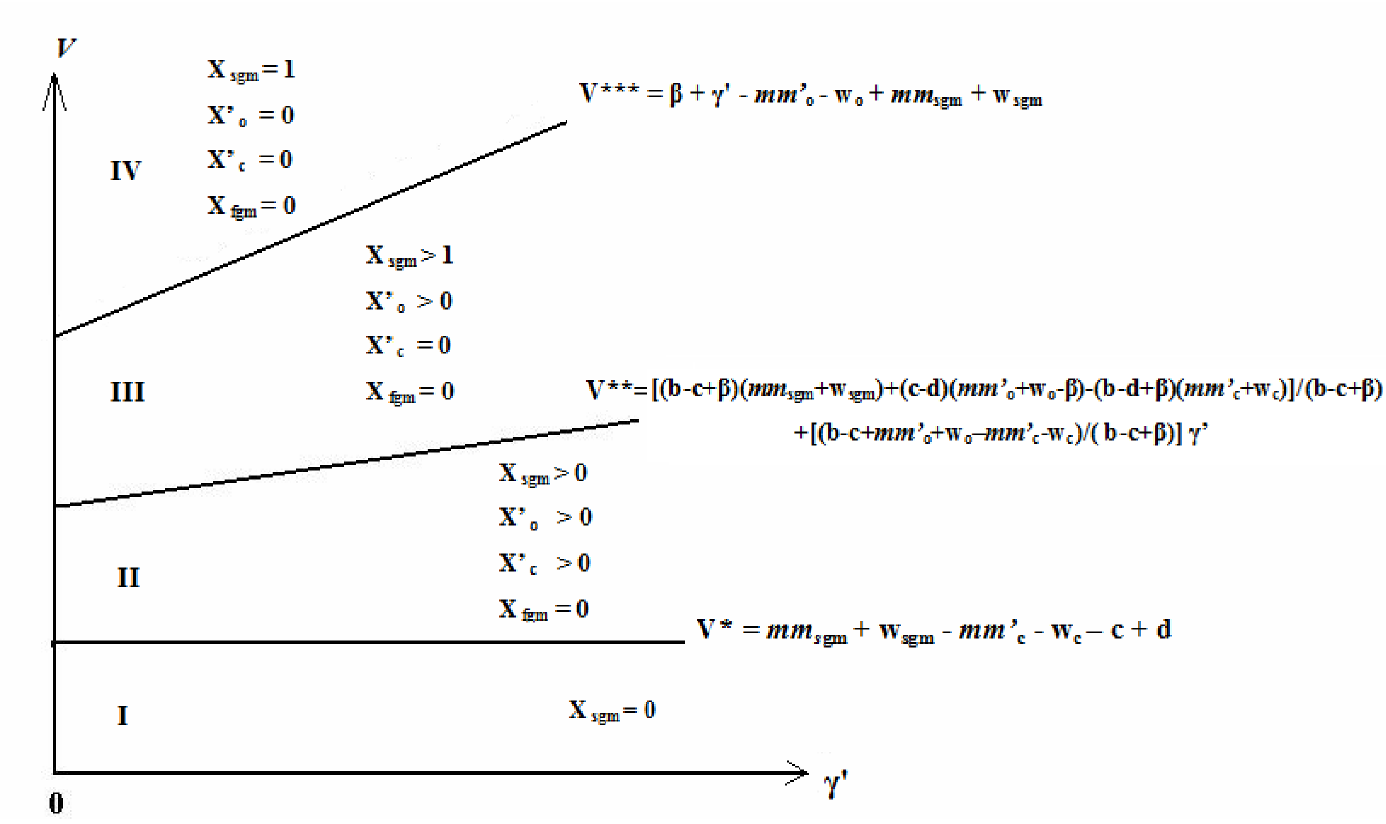
(33)

It is important to note that the greater is the consumer valuation V , the greater is the share of consumers who choose the new GMP over the organic product. Equation (32) indicates that when V exceeds a critical value V^{***} where

$$V^{***} = \beta + \gamma' - mm'_{o} - w_{o} + mm_{sgm} + w_{gm}$$

the introduction of the new GMPs drives all three substitutes (i.e., first-generation GM, conventional and organic) out of the market and becomes the only option available to consumers and producers. Figure 4.2 graphs the consumer valuation of the quality-enhancing attribute of the new GMPs against the consumer aversion to these products and summarizes the market effects of the introduction of the second-generation, consumer-oriented GM products identified in our study.

Figure 4.2: Market effects of the introduction of the new GM products



Before delving into the determination of the welfare effects of the introduction of the second-generation, consumer-oriented GM products into the food system of a country that mandates the labeling of the first-generation GM products, it is important to point out that our results on the market effects of the introduction of the new GMPs are consistent with those of Giannakas and Yiannaka (2008) indicating that the market effects of the new GMPs are not dependent on the labeling regime that governs the first-generation, producer-oriented GM products. Put in a different way, no matter if a country requires the labeling of the first-generation GM products or not, the market effects of the introduction of consumer-oriented GMPs are the same. While the market effects are the same, the next section of this thesis will show that the existence of a mandatory labeling regime governing the first-generation of GM products can affect the welfare implications of the new GM products – their effect on consumers and producers of different products.

4.2. Welfare effects of the introduction of the new GM products

After having identified the market effects of the introduction of consumer-oriented GMPs in a market that, like the EU, mandates the labeling of the first-generation GMPs, we focus next on the other main objective of this thesis – namely, the determination of the welfare effects of the new GMPs. In particular, this section focuses on determining the effect of the introduction of the new GM products on the welfare of consumers and producers of the different products involved.

Relying on the market effects of the new GMPs determined earlier, we discuss changes in prices and, through them, changes in consumer utility and producer net returns under all scenarios involving the entry of new GMPs into the market (i.e., the three scenarios in which the new technology is effective and $X^*_{sgm} > 0$).

Recall that when $V \in [V^*, V^{**}]$, the introduction of the second-generation GM product drives the first-generation GMP out of the market and attracts some consumers of conventional products who switch their consumption to the new GMP. This reduces the demand for conventional product $(X'_c < X_c)$ and, thus, it reduces the equilibrium price of this product $(p'^c_c < p^c_c)$. The reduced p^c_c increases the utility associated with the consumption of the conventional product (i.e., it shifts the utility curve U_c upwards). This increase lures some consumers away from the organic product resulting in reduced demand for, and price of the organic product. The reduced p^c_o causes in turn an increase in the utility associated with the consumption of the organic product (i.e., and shifts the U_o upwards).

In addition to increasing U_c and U_o, the reduced prices of conventional and organic products result in reduced net returns associated with the production of these products. Thus, while the consumers of conventional and organic products gain after the entry of the new

GMPs into the market, the producers of these products lose. Producers of the GM product gain (if they did not they would not have switched their production to the new GMPs), while the effect of the new GMPs on the consumers of the GM product depends on the value of V. If V exceeds the difference in price between the first- and second-generation GMPs (i.e., if $V < p_{sgm}^{c} - p_{fgm}^{c}$), $U_{sgm} > U_{fgm} \forall \alpha$ and all GM consumers benefit from the introduction of the new GMPs. If, on the other hand, $V^{*} < V < p_{sgm}^{c} - p_{fgm}^{c}$ some consumers with low values of the differentiating attribute α lose as the value they place on the quality-enhancing attribute of the new GMP is less that the extra money they have to pay for the new product.

It is important to point out that the findings that (a) some GM consumers may lose and (b) producers of the conventional product always lose after the introduction of the new GMPs are in sharp contrast with the results of Giannakas and Yiannaka (2008) who show that all GM product consumers gain and producers of the conventional product can benefit from the introduction of the new GMPs when those enter in a country that, like the US, does not label its products. This is a very important finding of this paper since, even though the GM market is miniscule in the EU, conventional producers represent at this point the vast majority of agricultural producers in the EU. The reason for the different effect of the new GMPs on the welfare of conventional producers is that, while the exit of the first-generation GMPs (that follows the entry of the new GMPs) results in increased price for the conventional product when conventional and first-generation GM products are marketed together as a non-labeled good, for the reasons discussed earlier, when the new GMPs enter a market that, like the EU, segregates the conventional products from their first-generation counterparts, the price of the conventional product always falls.

The gains in consumer surplus when $V \in [V^{*}, V^{**}]$ and $V > p_{sgm}^{c} - p_{fgm}^{c}$ are given by:

$$\Delta CS = \int_{0}^{\alpha_{fgm}} (U_{sgm} - U_{fgm}) d\alpha + \int_{\alpha_{fgm}}^{\alpha_{sgm}} (U_{sgm} - U_{c}) d\alpha + \int_{\alpha_{sgm}}^{\alpha_{c}} (U'_{c} - U_{c}) + \int_{\alpha_{c}}^{\alpha'_{c}} (U'_{c} - U_{o}) d\alpha + \int_{\alpha'_{c}}^{1} (U'_{o} - U_{o}) d\alpha$$

(34)

and the change in producer welfare is:

$$\Delta PS = \int_{0}^{A'_{0}} (\pi_{0} - \pi'_{0})dA + \int_{A'_{0}}^{A''_{c}} (\pi_{0} - \pi'_{c})dA + \int_{A''_{c}}^{A'_{c}} (\pi_{c} - \pi'_{c})dA + \int_{A'_{c}}^{A_{sgm}} (\pi_{c} - \pi_{sgm})dA + \int_{A_{sgm}}^{A_{c}} (\pi_{sgm} - \pi_{c})dA + \int_{A_{c}}^{1} (\pi_{sgm} - \pi_{fgm})dA \quad (35)$$

The welfare effects of the new GMPs when $V \in [V^{*}, V^{**}]$ and $V > p^{c}_{sgm} - p^{c}_{fgm}$ are depicted in Figure 4.3 while Figure 4.4 graphs the case where $V \in (V^{**}, V^{***}]$.

Recall that when the consumer valuation V exceeds the critical value V^{**}, the introduction of the new GMPs drives the first-generation GM and conventional products out of the market and attracts also some consumers of the organic product. The demand for organic product falls and so does its price. This price reduction benefits the consumers who find it optimal to keep consuming the organic product after the introduction of the new GMP resulting in all consumers gaining from the entry of the second-generation GMPs when $V \in (V^{**}, V^{***}]$. The consumer welfare gains are given by:

$$\Delta CS = \int_0^{\alpha_{fgm}} (U_{sgm} - U_{fgm}) d\alpha + \int_{\alpha_{fgm}}^{\alpha_c} (U_{sgm} - U_c) d\alpha + \int_{\alpha_c}^{\alpha_{sgm}} (U_{sgm} - U_o) d\alpha + \int_{\alpha_{sgm}}^{1} (U'_o - U_o) d\alpha$$
(36)

The reduction in the price of the organic product results in reduced net returns to the organic production and welfare losses for organic producers. On the other hand, the producers of first generation GM and conventional products that find it optimal to switch to the production of the new GMP realize a welfare increase. The change in producer welfare when $V \in (V^{**}, V^{***}]$ is:

$$\Delta PS = \int_0^{A'_o} (\Pi_o - \Pi'_o) dA + \int_{A'_o}^{A_o} (\Pi_o - \Pi_{sgm}) dA + \int_{A_o}^{A_c} (\Pi_{sgm} - \Pi_c) dA + \int_{A_c}^{1} (\Pi_{sgm} - \Pi_{fgm}) dA \quad (37)$$

Finally, when the base consumer valuation of the new GMP exceeds the critical value V^{***}, the introduction of the new GMPs drives all substitute products out of the market. All consumers gain in this case and so do producers of conventional and first-generation GM products that have switched their production to the new GMP. The only losers in this case could be some previous inefficient producers of the organic product (i.e., those with $A \in [0, A'_o]$ in Figure 4.5). The changes in consumer and producer welfare when $V > V^{***}$ are:

$$\Delta CS = \int (U_{sgm} - U_{fgm}) d\alpha + \int_{\alpha_{fgm}}^{\alpha_c} (U_{sgm} - U_c) d\alpha + \int_{\alpha_c}^{1} (U_{sgm} - U_o) d\alpha$$
(38)

$$\Delta PS = \int_0^{A'_o} (\pi_o - \pi_{sgm})dA + \int_{A'_o}^{A_o} (\pi_{sgm} - \pi_o)da + \int_{A_o}^{A_c} (\pi_{sgm} - \pi_c)dA + \int_{A_c}^{1} (\pi_{sgm} - \pi_{fgm})dA \qquad (39)$$

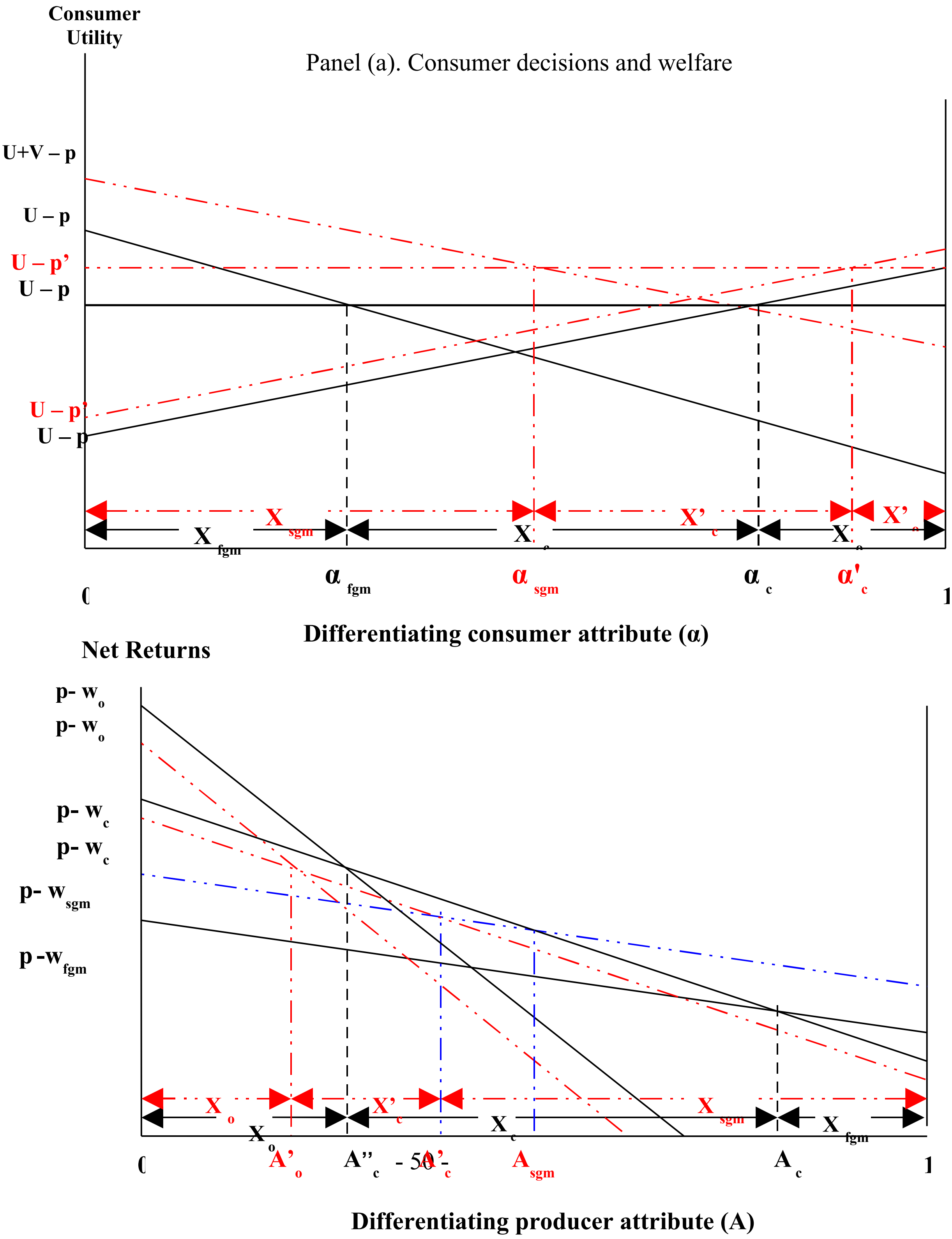
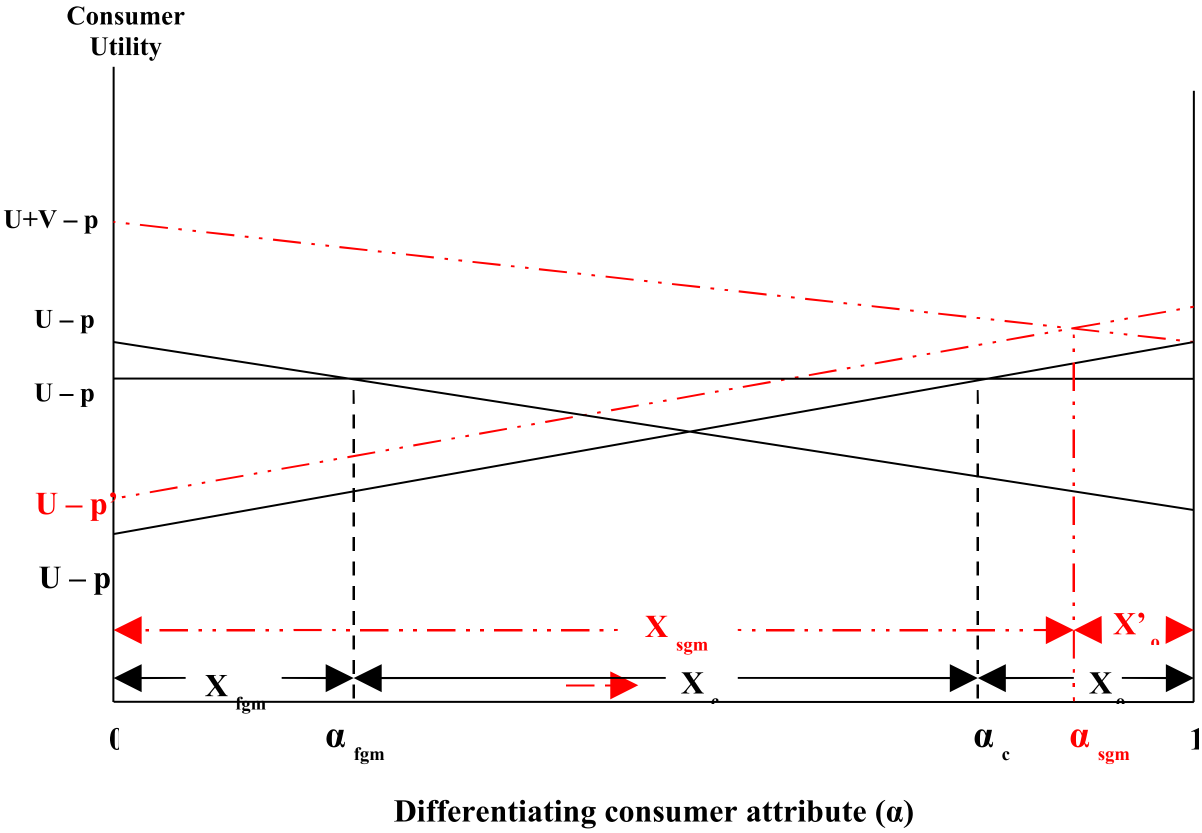


Figure 4.3. Market and welfare effects of the new GM products when *V < *V* < *V*****

Panel (a). Consumer decisions and welfare



Panel (b). Producer decisions and welfare

Figure 4.4. Market and welfare effects of the new GM products when *V* < *V* < *V******

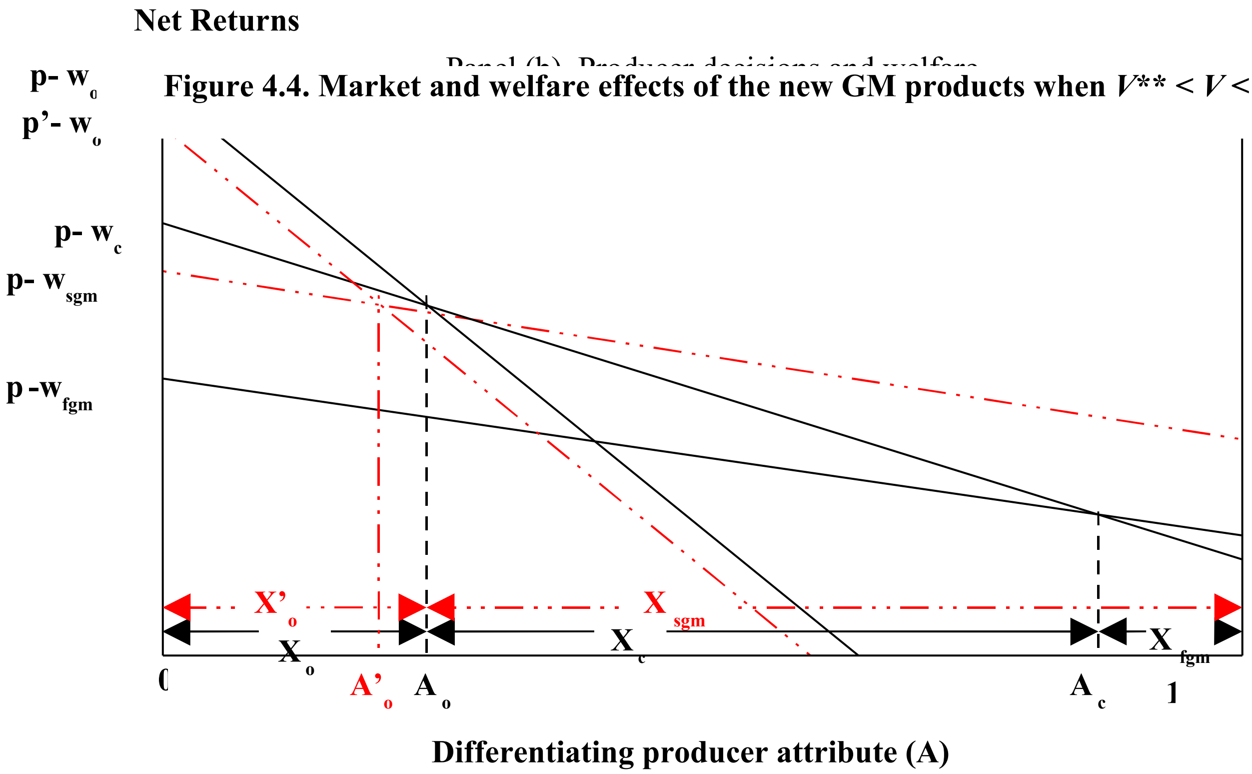


Figure. Market and Welfare Effects of the New GM products when V < V < V****

Figure. Market and Welfare Effects of the New GM products when V < V < V****

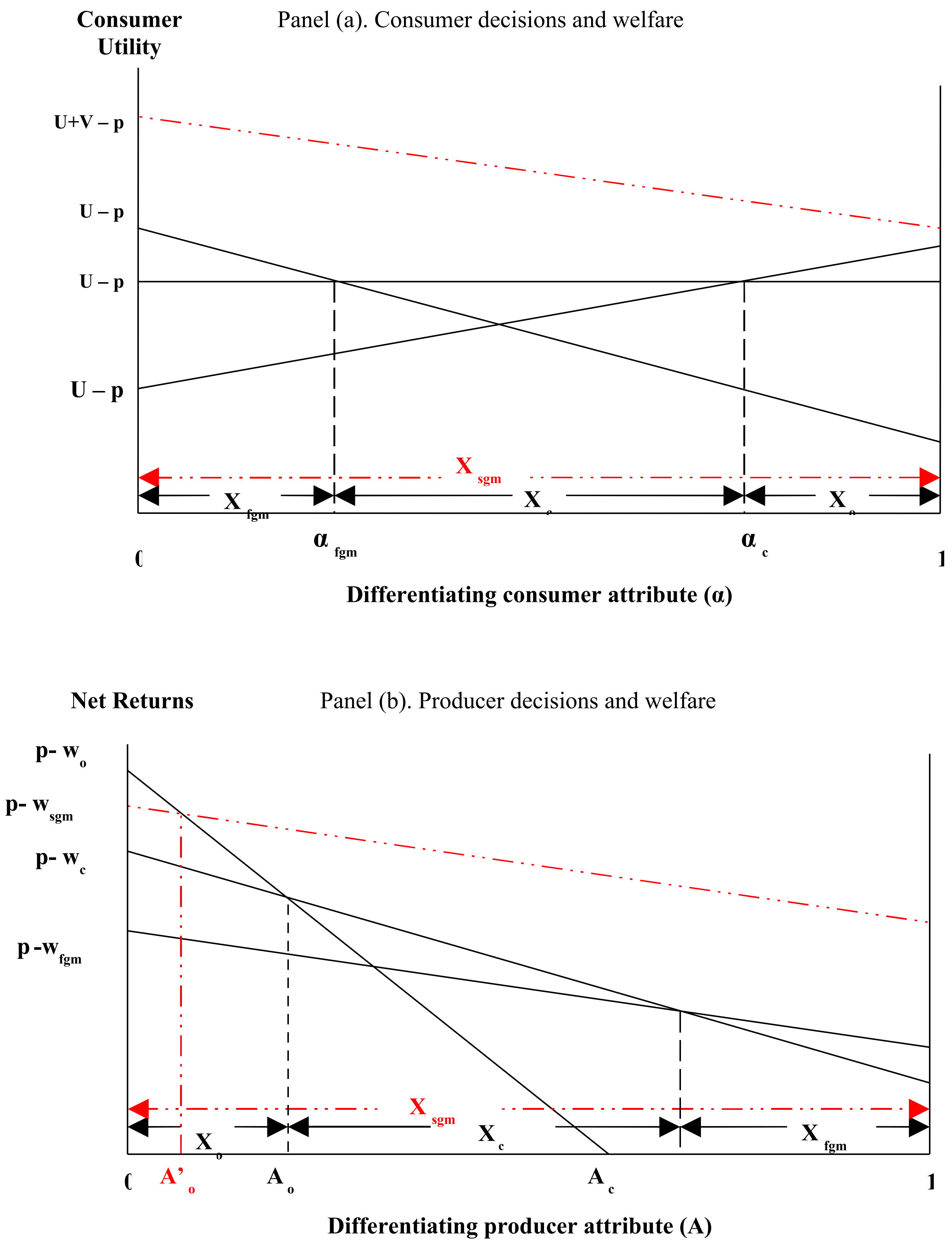


Figure 4.5. Market and welfare effects of the new GM products when *V* > *V****

Figure 4.5. Market and welfare effects of the new GM products when V > V***

CHAPTER 5

Summary and Concluding Remarks

- **Objective and structure**

The objective of this thesis has been to determine the market and welfare effects of the introduction of second-generation, consumer-oriented GM products in a market that, like the EU, mandates the segregation and labeling of the first-generation, producer-oriented GM products. In particular, the study focused on the effect of the second-generation GM products on the markets for conventional, GM and organic products, and the welfare of consumers and producers of these products.

The thesis was structured as follows: chapter 1 presented an overview on the adoption, acceptance and regulation of GM products around the world. The next two chapters developed the theoretical framework and determined the equilibrium conditions and welfare before and after the introduction of the new, consumer-oriented GM products. The following chapter determined then the market and welfare effects of the introduction of the second-generation, consumer-oriented GMPs, that have been the focal point of this thesis.

- **Importance and strengths**

This study represents the first attempt to systematically analyze the economic effects of the next generation of GM products in markets that have a mandatory labeling regime governing the first-generation of producer-oriented GM products.

To analyze the economic impacts of the consumer-oriented GM products, the thesis adapted and extended frontier models of heterogeneous consumers and producers that allow for both vertical and horizontal differentiation of GM, conventional and organic products and facilitate the estimation of consumer and producer welfare in a theory-consistent and tractable manner.

Our analysis reveals important new insights on the likely impacts of the new GM products that should be of interest to academics, policy makers, and all participants in the conventional, GM and organic food supply channels.

- **Results**

A key finding of this thesis is that, no matter the labeling regime governing the first-generation GM products, the market effects of the introduction of the new GMPs are the same. In particular, the introduction of the second-generation, consumer-oriented GMPs:

(a) drives the first-generation, producer-oriented GMPs that share the same agronomic characteristics out of the market

(b) can change the nature of the relationship between the GM products and their conventional and organic counterparts from one of vertical to one of horizontal product differentiation.

The effect of the new GMPs on the markets for conventional, GM and organic products is case-specific and dependent on:

(i) the consumer valuation of the quality-enhancing attribute of the new GMP
(ii) the level of consumer aversion to GMOs
(iii) the strength of consumer preference for organic products
(iv) the production costs and marketing margins in the different supply channels

The greater the consumer valuation of the new GMP, V, the greater the share of consumers attracted to the new product and the lower the market shares of its conventional and organic counterparts.

When V exceeds a critical value V^{**} (determined in this thesis), the new GM product drives out of the market both the first-generation GM and the conventional product and coexists with the organic product. When V is very high (i.e., when it exceeds a critical value V^{***}, also determined in this thesis), then the introduction of the consumer-oriented GMPs drives out all three substitutes (i.e., first-generation GM, conventional and organic products) and dominates the market.

The finding that the labeling policy for the first-generation GMPs does not affect the market effects of the second-generation GMPs is quite important as the presence or absence of labels for the first-generation GMPs has been shown to be a key determinant of market equilibria and welfare in countries with these first-generation GMPs in place.

While the policy on the labeling of the first-generation GMPs does not affect the market effects of the second-generation GMPs, it does affect their welfare implications – i.e., their effect on consumer and producer welfare. In particular, when the new GMPs enter in markets that, like the EU, mandate the labeling of the first-generation GM products and end up co-existing with their conventional and organic counterparts (i.e., when $V \in [V^{*}, V^{**})$), then:

- Producers of GM products and consumers of conventional and organic products gain
- Producers of conventional and organic products lose (due to reduced demands for, and prices of these products)
- Consumers of the GM product may gain or lose depending on their aversion to GMOs, the value they place on the new GMP and the price of this new product.

When $V \in [V^{**}, V^{***})$ and the new GMPs drive the first-generation GM and conventional products out of the market,

- All consumers and those producers that switch to the new GMP gain
- Producers of the organic product lose

Finally, when $V > V^{***}$ and the new GMP dominates the market,

- All consumers and previous producers of GM and conventional products gain
- Some relatively inefficient previous organic producers may lose.

The results that (a) some GM consumers may lose and (b) producers of the conventional product always lose from the introduction of the new GMPs when $V \in [V^{*}, V^{**})$ are in sharp contrast with the results of Giannakas and Yiannaka (2008) who show that all GM product consumers gain and producers of the conventional product can benefit from the introduction of the new GMPs when those enter in a country that, like the US, does not label its products. This is a very important finding of this paper since, even though the GM market is miniscule in the EU, conventional producers represent, at this point, the vast majority of European agricultural producers.

- **Limitations of the study**

This thesis provides important insights on the economic effects of second-generation, consumer-oriented GM products in markets that, like the EU, require the first-generation GM products to be labeled as such. A calibration of our models with real world data and a simulation analysis on the values of the key parameters would provide policy makers and the interest groups involved with valuable insights on the potential magnitude of the market and welfare effects of the second-generation GM products determined in this thesis.

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APPENDIX

This appendix shows how the introduction of the second-generation, consumer-oriented GM products can change the relationship between GM products and their organic and conventional counterparts from vertical to horizontal product differentiation.

A. Only organic and new GM products are available in the market and $p'^c_o = p^c_{sgm}$

When offered at the same price, the organic and second-generation GM products can be horizontally or vertically differentiated depending on the values of the preference parameters. Specifically, when $p'^c_o = p'^c_{sgm}$, $U'_o \geq (\leq) U_{sgm} \Rightarrow V \geq (\leq)(\beta + \gamma)\alpha$.

Case A.1. If $V < (\beta + \gamma)$, the organic products and their second-generation GM counterparts are horizontally differentiated since consumers with differentiating attribute $\alpha \in [0, V/(\beta + \gamma)]$ would buy the new GMPs while consumers with $\alpha \in (V/(\beta + \gamma), 1]$ would prefer the organic.

Case A.2. If $V \geq (\beta + \gamma)$, $U_{sgm} \geq U'_o \ \forall \alpha$ and all consumers would purchase the second-generation GM products. In this case, the GM and organic products are vertically differentiated with the new GM product being the high quality one

B. Only conventional and new GM products are available in the market and $p'^c_c = p^c_{sgm}$

When the second-generation GM products and their conventional counterparts are offered at the same price, $U'_c \geq (<) U_{sgm} \Rightarrow V \geq (<) \gamma \alpha$.

Case B.1. If V<γ', the conventional and second-generation GM products are horizontally differentiated since consumers with differentiating attribute $\alpha \in [0, V/\gamma]$ would buy the new GMP, while consumers with $\alpha \in [V/\gamma, 1]$ would prefer the conventional product.

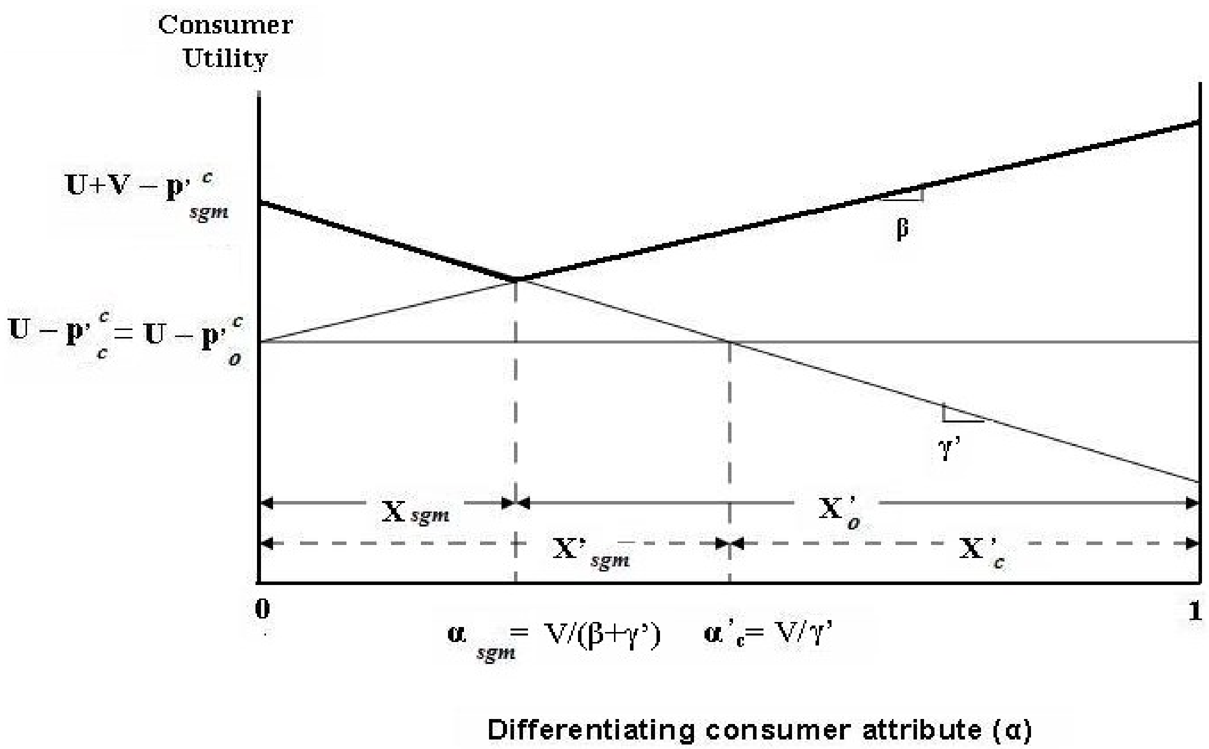
Case B.2. If $V \geq \gamma, U_{sgm} \geq U'_c \ \forall \alpha$ and all consumers would buy the new GM products. In this case, the GM and the conventional products are vertically differentiated with the new GMP being the high quality product.

C. Organic, conventional and new GMPs are available in the market and

$$p'^{c}_{o} = p'^{c}_{c} = p^{c}_{sgm}$$

When the three products co-exist in the market under the same price, a first consequence is that the conventional products are driven out of the market since U'_c lies above U'_o, as shown in figure A.1., due to the vertical differentiation of organic and conventional products. With the conventional products out of the market, the situation is similar to the situation (A) when only the organic and new GM products are available to consumers.

Figure A.1: Consumption decisions after the introduction of the new GM products when $\mathbf{p'^{c}_{o} = p'^{c}_{c} = p^{c}_{sgm}}$



Source: Giannakas and Yiannaka (2008).