THREE ESSAYS IN INTERNATIONAL TRADE

SPS AGREEMENT VIOLATION AND CONCERNS

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ABSTRACT

This dissertation covers three topics of importance for international trade policy. It consists of three independent essays in the area of trade in biotechnology and regionalization of a disease outbreak.

Essay one, through utilization of the Global Trade Analysis Project (GTAP), contributes to the literature by providing a global measurement on the effect that the expanding genetically modified (GM) pipeline has on international trade given the constraint of asynchronous regulations for a new GM event among countries. The model measures the effect of the GM global pipeline on international trade flows between countries, and the effect on trade flows between countries given the unintended presence of GM events in the export of non-GM crops. These measurements are achieved through the development of five simulations for the following agriculture goods: maize, soybeans, canola, wheat and rice. The simulation results indicate that asynchronicity does affect trade flows on a global level. However, society is better off overall with additional GM events on the market, even when asynchronicity is present and large, as the increase in trade flow is greater from the new GM events than the reduction in trade flow caused by asynchronicity.

Essay two, through the application of a real options model, evaluates the investment risk for a biotechnology firm that aspires to enter a highly regulated European Union (EU) market for genetically modified products. The regulatory (political) risk is captured as uncertainty that can influence the optimal decision of the investment firm. The findings in this thesis indicate that the presence of political factors in the EU decision process for approving new GM varieties

influences the exporter's decision who wants to export a safe GM product into the EU market. As result exporter postpones their decision to enter the EU market into the future and reduces the level of sunk cost they are willing to invest to enter the market. However, continually postponing the investment into the future can lead to the investment never occurring. The final outcome is that the presence of political factors in the decision approval process slows the growth of the biotechnology industry and constrains the accessibility of this technology for developing countries.

Essay three, through an application of a partial equilibrium model, analyses the regionalization concept accounting for the incentive for commercial and casual smuggling. The essay evaluates the model with the risk of being caught and the risk of not being caught. If there is no risk of being caught the incentive to smuggle will exist as long as the price minus the smuggling costs in the non-infected area exceeds that of the infected area. If we consider the risk of being caught and fined by the governing authorities, then the incentive to smuggle will depend on the probability of being caught. The higher the probability of being caught the lower the incentive for smuggling will be, given the losses in revenue in the non-infected market and the additional cost of being fined. Casual smuggling depends on the distance the consumer has to travel to the low priced region, the cost of transportation and the easiness of avoiding the authorities. Two policies were discussed in this essay: price support, and enforcement and punishment that were applied to commercial smuggling with and without risk, and to casual smuggling. Price support was evaluated as a more appropriate policy as it is difficult to estimate the appropriate level of enforcement and punishment under that type of policy that would bring smuggling to zero.

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CHAPTER 1

Introduction

This dissertation investigates three topics in international trade policy. Each essay examines a different global issue in international trade through empirical measurement, economic modeling or policy analysis. In the last decade the application of biotechnology in agriculture has evolved as a global issue. The use of biotech in agriculture has produced a number of genetically modified products (GM) and it was estimated that commercially available GM events would reach 219 by the end of 2020 (Parisi et al., 2016). However, legislation regarding GM events is made at the individual country level and, therefore, can vary between countries and regions around the world. This fragmented approval process can disrupt trade flows as a result of what is termed "asynchronous approval". "Asynchronous approval" of GM events creates challenges between exporting and importing countries given that international shipments of a particular GM or non-GM agricultural commodity may contain unauthorized material leading to costly trade disruptions.

Two international trade trends: the expanding GM global pipeline for new events and; the difficulties of perfect segregation among GM and non-GM products in the global trade system form the basis of the research questions in the first essay. The research questions addressed in this essay measures the effect of the increasing GM global pipeline on international trade flows between countries and measures the effect on trade flows between countries given the unintended presence of GM events in the export of non-GM crops. This essay investigates, tabulates and measures these disruptions through the trade flows of key crops where modern agricultural technology is widely utilized: maize, soybeans and rapeseed.

The measurements were conducted through utilization of the Global Trade Analysis Project (GTAP). The motivation behind the GTAP model is to provide an instrument that is able to capture the behavior of the economy and the changes for that economy when external shocks are applied, while remaining consistent with economic theory. Five simulations were developed with the GTAP program in order to answer research questions specified in Chapter 2. The simulation results indicate that asynchronicity does affect trade flows on a global level. However, society is better off overall with more GM events on the market, even when asynchronicity is present and large since the increase in trade flow is larger as a result of the new GM events than the reduction in the trade flow caused by asynchronicity.

The second explores the biotechnology issue from an international trade point of view including the investment in technology. Application of a real options model evaluates the investment risk for a biotechnology firm that aspires to enter a highly regulated market for genetically modified products. The model developed in this essay is used to evaluate the additional risks arising from policy measures in the European Union (EU). More specifically, the theoretical model analyses the decision approval process of a GM event in the EU, the EU's inconsistency with multilateral trade agreements and how this type of regulatory structure can be defined as political risk that can influence the investment decisions of firms intending to bring GM products to the EU market. The regulatory (political) risk is captured as uncertainty that can influence the optimal decision of the investment firm. Hence each additional step of the approval process for GM products gradually increases the uncertainty and postpones the investment decision into the future. However, the postponement of the investment and the increasing uncertainty causes the

investor's acceptable level of irreversible costs to decrease. This leads to a situation where over time the level of investment may be reduced.

Biotechnology is an important agricultural technology that can increase global food production in an environmentally sustainable manner. Thus, regulation inefficiencies, as in the EU where decision making is based on political factors and not scientific evidence, divert investment from the market and slow the growth of the biotechnology industry. Furthermore, it complicates the accessibility of this technology for developing countries which are most likely to benefit from the technology given the food security challenges they face.

The concept of regionalization under the World Trade Organization (WTO) has become of growing importance in international agricultural markets and if appropriately implemented can lead to significant economic and trade benefits. The concept of the regionalization means that if a disease outbreak occurs that can be controlled and localized to a specific area within the country, then constraints on international trade need only apply to products originating from the infected area, thereby allowing the uninfected area of the country or countries in question to continue exporting (Loppacher et al., 2006). Without regionalization, a disease outbreak in an exporting country allows importing countries to deny market access to all of a country's products even if there are regions of the country that are disease free. However, a large number of countries have experienced difficulty in having their disease free region(s) recognized by importing countries.

Essay three examines the concept of regionalization under the WTO and analyses the reasons why implementation of this facet of trade law has thus far failed. Price disparity between two

regions in an exporting country creates an incentive to smuggle and is one reason why the implementation of the regionalization concept has failed. Through economic evaluation, essay three determines the appropriate mode to implement the regionalization concept. This research, through application of a partial equilibrium model, analyses the regionalization concept accounting for the incentive to smuggle. Finally, a policy is designed to remove the appeal of smuggling from the infected area to the non-infected area as a result of a disease outbreak.

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CHAPTER 2

The Impact of the Global Pipeline for New Genetically Modified Organisms on International Trade – A General Equilibrium Approach

2.1 Introduction

Modern biotechnology is the latest stage in the development of evolving plant breeding technologies; part of the "new information economy". It involves the use of known genetically controlled traits combined with the technical ability to alter the expression of those traits, which provides enhancements to the biological organisms thereby reducing the constraints imposed by the natural environment (Gaisford et al., 2001).

The use of biotechnology (biotech) in agriculture has produced a number of genetically modified organisms (GMOs) and the products derived from them are known as genetically modified (GM) products. GM crops were first commercialised in 1996 in five countries, by 2015 the global area of GM crop cultivation had increased to over 179.7 million hectares in 28 countries (James, 2015). Major GM crops under cultivation include soybean, maize, cotton, and rapeseed [1](canola) with global acreages of 92.1 million, 53.7 million, 24 million, and 8.6 million hectares respectively (James, 2015). The rapid adoption of GM technology is a result of the benefits bestowed upon producers through increased yields, reduced production costs leading to potential profit increases, and increasing the sustainability of agriculture through reduced chemical use

[1] As discussed in Smyth and Phillips (2015) there is a significant difference between canola and rapeseed. Canola applies GM technology in the production while rapeseed represents the non-GM varieties. In this essay, the term rapeseed is used because canola production is included under the rapeseed production dataset in the Global Analysis Trade Project (GTAP) program.

over the long run. It is these benefits that have produced billions of dollars of economic gain every year (Kalaitzandonakes, 2011).

Before a GM product is authorized and commercialized, it must go through extensive detailed tests and regulatory scrutiny to ensure human, animal and environment safety (Konduru, 2008). However, legislation regarding GMO decisions is made at the individual country level and, therefore, can vary between countries and regions around the world. The main difference in GMO regulations among various countries is whether the decision making process is based on scientific risk assessment or whether science has an informative role while other criteria play a more important role in the decision making process such as social-economic factors[2]. Further, countries that have not put in place GMO legislation have been known to ban imports, cultivation, and commercialization of GMOs. Banning GMOs creates considerable differences in the number of GM "events" that are authorized in various countries. Even when authorization is an available option, the length of the authorization period varies considerably among countries. Typically, without domestic authorization, imports of GM products cannot take place.

Country specific legislation and regulatory processes create international trade difficulties from the point of view that a particular GM event may have completed the licensing process in some countries, be part way through the process in other countries, not yet submitted for approval in other countries, and lastly in others the regulatory approval will not be sought and, hence, granted because the process is perceived to be prohibitively expensive or the rates of approval perceived to be too low. This fragmented approval process can leave trade flows disrupted as the

[2] Described in Isaac, (2007) as the Social Rationality Approach in the Risk Analysis Framework.

result of what is termed "asynchronous approval". "Asynchronous approval" of GM events creates problems between exporting and importing countries given that a particular GM or non-GM agricultural commodity traded may contain unauthorized material leading to costly trade disruptions[3] (Kalaitzandonakes, 2011). Unauthorized material in agricultural commodities is commonly referred to as "Low Level Presence" (LLP). Kalaitzandonakes (2011) defines LLP as the accidental presence of small amounts of biotechnology events that have undergone a full safety assessment and have received regulatory approve in one or more countries but are still unauthorized in others. The acceptable level of LLP is not harmonized among countries, thus countries have various LLP threshold levels[4].

Perfect segregation of approved GM events and conventional products from unapproved GM events is difficult in the global agriculture commodity trade system (Konduru, 2008). Thus, the private sector has had to make substantial investments to segregate GM products from non-GM to maintain market access (Phillips et al., 2006). However, Dayananda (2011) states that during seed production, cultivation, harvest, transport, or processing the opportunity for technically unavoidable presence of non-authorized GMOs in conventional or other GM food may occur within the exporting country. The parallel existence of GM and non-GM raise the issue of co-mingling in the international trade of non-GM products (Kerr and Hobbs, 2012). According to Kerr and Hobbs (2012) the co-mingling of non-GM products can take two forms: 1) co-mingling of non-GM product shipments with unauthorized GM product belonging to the same crop group,

[3] Discussed in section 2.2.1

[4] Under EU legislation there are two categories of unapproved GM events (Kerr and Hobbs, 2012). The first refers to the LLP where the GM event has been approved in one or more countries but not in the importing country (Kerr and Hobbs, 2012). The second refers to the adventitious presence (AP) where the GM event has not been approved in any country (Kerr and Hobbs, 2012).

e.g. co-mingling of non-GM corn shipments with a GM corn event; 2) co-mingling of non-GM product shipments with unauthorized GM products belonging to a different group of products, e.g. co-mingling of non-GM corn shipments with a GM soya event[5].

While the problems created by asynchronous approvals have, until now, been seen as one-off events, the potential for a significant increase in co-mingling issues exists as the global pipeline for GM crops is expanding rapidly. Currently there are 49 GM events commercially available that are cultivated worldwide and this number was expected to rise to 96 GM events by 2020 (Parisi et al., 2016). Firms engaged in exporting face increased risk from LLP and thus, the possibility of trade disruptions occurring more frequently. These two international trade trends: the growing GM global pipeline; and the difficulties of perfect segregation among GM and non-GM products in the global trade system form the basis for the following research questions. The research questions addressed in this essay will be to measure the effect of the increasing GM global pipeline on international trade flows between specified countries; and measure the effect on trade flows between specified countries given the unintended presence of GM events in the export of non-GM crops.

2.2 The GM Pipeline and Trade Consequences

The wide acceptance of GM crops creates incentives for developers of GM products to invest in new GM varietal traits that perform better than the existing one, are more suitable for specific markets, and incorporate product quality characteristics that consumers demand. Currently, GM events are primarily developed by private firms located in the US, but a trend is evolving where

[5] The latter form of co-mingling is also known as cross-co-mingling

by novel GM events are developed by national technology providers, particularly in Asia and Latin America. These national Asian and Latin America developers will design GM events for domestic markets. Another progressing trend is the stacking of multiple GM traits in varietal crop development. These innovative GM events can already be found in the pipeline and will be in the process of commercialization in the coming years. Thus, the GM pipeline can be described as the global status of GM crops that are either currently in commercial use, authorized, in the regulatory process, or in the latter stage of development.

The research of Stein and Rodriguez-Cerezo (2009a) offers the most complete overview of the global pipeline of GMOs through 2015. Stein and Rodriguez-Cerezo (2009a) grouped new GM events into a number of pipeline categories based on the current stage of development. They use the following four pipeline categories:

- Commercial crop: commercialized GM events currently marketed in at least one country worldwide.
- Commercial pipeline: GM event authorized in at least one country but not yet commercialized. The commercialization depends only on the decision of the developer.
- Regulatory pipeline: GM events already within the regulatory process for approval to be marketed in at least one country.
- Advanced R&D pipeline: GM events in the last stage of development, such as large scale multi-location field trials to generate data for the authorization dossier.

According to Stein and Rodriguez-Cerezo (2010), by the end of 2015 the number of individual GM events will have increased to 124 from 33 in 2008. Table 2.1 lists the worldwide GM events, by pipeline and crop type.

Table 2. 1: GM events in the pipeline worldwide, by crop type

Crop	Commercial	Commercial pipeline	Regulatory pipeline	Advanced development	Total by 2015
Soybeans	1	2	4	10	17
Maize	9	3	5	7	24
Rapeseed	4	0	1	5	10
Cotton	12	1	5	9	27
Rice	0	1	4	10	15
Potatoes	0	0	3	5	8
Other crops	7	0	2	14	23
All crops	33	7	24	61	124

Source: Stein and Rodriguez-Cerezo (2010)

In Table 2.2, the traits category lists future novel crop composition traits (product quality) that will become available in the market. The targeted compounds for novel traits include the proportion of fatty acids, starch content, beta-carotene, and enzymes. Crops varieties that are resistant to viruses and tolerant to abiotic stress, caused by drought, high salinity, and soil acidity will become important features. Current dominant traits – those for insect resistance and herbicide tolerance – will continue to lead pipeline development (Stein and Rodriguez-Cerezo, 2010).

Table 2. 2: GM events in the pipeline worldwide, by trait category

Trait Category	Commercial	Commercial pipeline	Regulatory pipeline	Advanced development	Total by 2015
Insect resistance	21	2	11	25	59
Herbicide tolerance	11	5	4	13	33
Product quality	2	1	5	12	20
Virus resistance	5	0	2	3	10
Abiotic stress tolerance	0	0	1	6	7
Other	0	0	2	11	13

Source: Dunwell (2010)

Currently private North American firms are the major developers of GM events, however in the coming years both public and private entities will participate in the development of new GM events, with more developers originating from regions in Asia, mainly China and India. New products from Asia will be developed for domestic consumption and not for export markets. This will increase the problems associated with asynchronous approval and unintended presence of GM events in the shipment of non-GM crops because wide ranging approval around the world will not be sought. Table 2.3 lists worldwide GM events in the pipeline by region of origin.

Table 2. 3: GM events in the pipeline worldwide, by region of origin

Developer country	Commercial	Commercial pipeline	Regulatory pipeline	Advanced development	Total by 2015
United States and Europe	24	7	10	26	67
Asia	9	0	11	34	54
Latin America	0	0	2	1	3

Source: Stein and Rodriguez-Cerezo (2010)

Presently, soybean, maize, cotton, and rapeseed are the four major crops covering 99% of worldwide cultivation of GM varieties. Soybean leads with 51%, followed by maize with 30%,

cotton with 13.4%, and rapeseed with 4.8% (James 2015). James (2015) estimated that 83% of the global soybean area is cultivated as GM. For maize, cotton, and rapeseed these proportions are 29%, 75%, and 24% respectively (James, 2015). Cotton as a GM product raises less of an issue in the international trade environment because it is used as input in products that are not for human or animal consumption. Therefore, using corn, soybean, and rapeseed to evaluate the GM pipeline and the effect these crops have on trade flows is reasonable given that they cover 84% of worldwide GM cultivation. Stein and Rodriguez-Cerezo (2009a) forecast that the majority of GM events that would be approved by 2015 will be for previously approved GM crops that are cultivated worldwide.

Stein and Rodriguez-Cerezo (2009b) developed a dataset for each GM event and its position in the GM pipeline till the end of 2015. Tables 2.4, 2.5, 2.6, and 2.7 present the GM events and their position within the GM pipeline through the end of 2015 according to Stein and Rodriguez-Cerezo (2009a). Stein and Rodriguez-Cerezo's analysis was completed in 2008, since then certain crop events have shifted between pipeline categories. For example: Soybean MON89788 (Roundup Ready 2) and A2704-12 (Liberty Link) have moved from the commercial pipeline to a commercial crop. Soybean CV 127 (Imi) has moved from the regulatory pipeline to the commercial pipeline; and MON87769 (Omega-3) has moved from the advanced R&D pipeline to the commercial pipeline.

For simplicity, the 2008 dataset by Stein and Rodriguez-Cerezo (2009b) will be utilized as it provides a good fit with the GTAP[6] dataset that employs 2007 as the base year. This essay only covers the individual GM events available through the end of 2015. Stacking events are not considered as the current literature does not provide a thorough review of future names and numbers for these events. A theoretical estimation is only available for maize as provided by Stein and Rodriguez-Cerezo (2009a, 2010) in which they suggest approximately 12,962 possibilities. If stacked maize events are to be considered in GTAP, each event would be incorporated as a separate sector, increasing the number of sectors to a point that it is simply too high for an accurate analysis utilizing CGE modeling.

Table 2. 4: Commercial GM crops

Type of crop	Developer	Product name	Event name
Soybean	Monsanto	Roundup Ready	MON 40-30-2
Maize	Monsanto	YieldGard Corn Borer	MON810
	Monsanto	Roundup Ready Corn2	NK603
	Monsanto	YieldGard Rootworm	MON863
	Monsanto	Yield Gard VT	MON88017
	Dow AgroSciences and Pioneer Hi-Bred	Herculex I	1507
	Dow AgroSciences and Pioneer Hi-Bred	Herculex RW	59122
	Syngenta	Agrisure CB	Bt11
	Syngenta	Agrisure GT	GA21
	Syngenta	Agrisure RW	MIR604
Rapeseed	Monsanto	Roundup Ready	GT73
	Bayer CropScience	LibertyLink	T45
	Bayer CropScience	InVigor	MS8 xRF3

Source: Stein, A.J. and E. Rodríguez-Cerezo (2009a)

[6] Global Trade Analysis Project (GTAP) consists of a large region and sector database that can be analysed through the application of a computable general equilibrium (CGE) model. A more detailed description of GTAP and CGE is provided in section 2.3.1.

Table 2. 5: Commercial pipeline for GM crops

Type of crop	Developer	Product name	Event name
Soybean	Monsanto	Roundup Ready 2	MON 89788
	Bayer CropScience	LibertyLink	A2704-12
	Bayer CropScience	LibertyLink	A5547-127
	Pioneer Hi-Bred	Optimum GAT	356043
Maize	Monsanto	YieldGard VT PRO	MON89034
	Monsanto	High lysine	LY038
	Syngenta	n/a[7]	3272

Source: Stein, A.J. and E. Rodríguez-Cerezo (2009a)

Table 2. 6: Regulatory pipeline for GM crops

Type of crop	Developer	Product name	Event name
Soybean	Monsanto	Roundup Ready	MON 40-30-2
	BASF Plant Science and Embrapa	Imi	CV127
	n/a(China)	n/a	Gna
Maize	Syngenta	AgrisureViptera	MIR162
	Pioneer Hi-Bred	Optimum GAT	98140
	n/a(China)	n/a	Cry1A
	n/a(China)	n/a	n/a
	n/a(China)	n/a	n/a
Rapeseed	n/a(China)	n/a	n/a

Source: Stein, A.J. and E. Rodríguez-Cerezo (2009a)

Table 2. 7: Advanced R&D pipeline for GM crops

Type of crop	Developer	Product name	Event name
Soybean	Syngenta	n/a	n/a
	Syngenta	n/a	n/a
	Monsanto	Omega-3	MON87769
	Monsanto	n/a	n/a
	Monsanto	n/a	n/a
	Monsanto	Vistive III	MON87754
	Dow AgroSciences	DHT	n/a
	Bayer CropScience	n/a	n/a
	Bayer CropScience	n/a	n/a
Maize	Syngenta	n/a	n/a
	Pioneer Hi-Bred	Optimum AcreMax 1	n/a
	Monsanto	n/a	MON87754

[7] n/a- Not available

	Monsanto and BASF	n/a	MON87460
	Dow AgroSciences	DHT	n/a
	n/a(India)	n/a	Cry1Ac+cp4epsp4
	BASF Plant Science	NutriDense	n/a
Rapeseed	Bayer CropScience	n/a	n/a
	Bayer CropScience	n/a	n/a
	Bayer CropScience	n/a	n/a
	BASF Plant Science	n/a	n/a
	BASF Plant Science	n/a	n/a

Source: Stein, A.J. and E. Rodríguez-Cerezo (2009a)

2.2.1 Trade Consequences in the Supply Chain of non-GM Crops as a Result of Asynchronous Approval of GM Events

Soybeans, maize, and rapeseed are raw commodities where the primary use is inputs in the feed, food, and drink industries. Appendix A-Figure 2.A.1 lists the wide spectrum of food industries where soybeans, maize, and rapeseed are used as inputs. Since the value of these crops is low compared to the final products in which they are typically inputs infers that transport and storage must often be organized in bulk in order for operational and transaction costs to be kept low.

The current supply chain structure in which these crops are traded creates several possibilities for impurities or co-mingling. It is common practice in food safety regulations to allow a minimum presence of unintended materials like dirt, weed seeds, and mycotoxins in crop shipments (Backus et al. 2008). However, this may not always be the case regarding the unintended presence of traces of an unapproved GM event in the non-GM crops (whether crops where no GM approvals have been made or crops where GM varieties have been commercialized). For example, the EU has a zero tolerance level for unapproved GM events in the shipments of crops. Thus, the case of asynchronous approval of GM varieties and differing thresholds for LLP among countries can lead to important impediments to trade. These can include returning,

relocation, or destroying cargos of non-GM varieties at the importing country's port as a result of the unintended presence of GM traits. Also, with the growing number of GM events being licensed or within a particular stage of the pipeline, the probability of non-GM crops becoming co-mingled with GM traits is increasing.

Exporters of soybeans, maize, and rapeseed have taken specific measures when shipping to importing countries in order to maintain their market access. These measures are in place to ensure that shipments of conventional crops are not mingled with traces of GM varieties that are not approved by the importing country. These measures are taken as a system to ensure "identity preservation" (IP) (Backus et al., 2008). As defined by Backus et al. (2008), IP is a system of crop or raw material management which preserves the identity of the source or nature of the materials. The size of the IP cost is determined by several factors, including the size of the market, the specific crop, and the level of tolerance in the importing country. The Literature on IP cost is diverse, covering estimates of IP cost for a particular year, specific part of the supply chain, location, or a specific crop (Kalaitzandonakes and Kaufman, 2010). Backus et al. (2008) state that even with the existence of IP systems, it is very difficult to prevent traces of GMOs in export shipments. Hence, IP measures will be more difficult, costly, and prone to failure when new GM events are introduced and accepted as new GM events increase the potential for co-mingling with non-GM exports and for non-GM varieties of crops where GM varieties have been commercialized.

The trade consequences, costs, and economic losses as result of unintended presence of GM traits in non-GM crops have been investigated by a number of authors (Backus et al., 2008;

Brookes, 2008; Nowicki, 2010; Dayananda, 2011). These studies have focused on co-mingling in the face of the EU's zero tolerance for unapproved GM events as the majority of comingled shipment incidents resulting from unapproved GM events have occurred in the EU. During the period 1997-2010, there were 223 cases of non-GM crops co-mingled with unauthorized GM events worldwide, and from these cases 147 incidents occurred in the EU (Viju et al., 2011).

Brooks (2008) calculated the cost to the EU rice sector as a result of presence of unapproved GM herbicide tolerance rice (LL601) in shipments from the US since 2006. The LL601 event was not approved by the US government at that time, but was used in field trails in Louisiana and Arkansas between 1998 and 2001. However, LL601 did find its way into the conventional crop supply and was detected in exports to the EU, resulting in trade disruptions. The trade disruption was lengthy and import volumes into the EU in 2007 were 95% lower than in 2006. The calculated average costs with an LLP of zero tolerance for unapproved GMOs at the company level (rice miller) range between 3.5 million euro and 7.4 million euro. At the industry level trade disruption costs reached between 52 million euro and 111 million euro in early 2008. This trade disruption also resulted in numerous lawsuits valued at US$750 million against Bayer CropScience, the developer of LL601 (Smyth and Phillips, 2015). Brooks (2008) also estimated that for the EU soybean sector that these costs would be much higher, at the company level costs could be between 82 million euro and 156 million euro and at the at the industry level could reach between 492 million euro and 936 million euro.

Backus et al. (2008) review several cases where unauthorized GMOs have been detected in shipments, even in the presence of an IP system on the exporting side. For example, between

April 2007 and March 2008 the EU placed a temporary import ban for Argentinian maize as a result of shipments being co-mingled by an unauthorized maize event (GA-21). Even with the Argentinian government's segregation efforts, the presence of GA-21 seeds in maize shipments could not be completely eliminated. This import ban resulted in a premium increase for non-GM maize of USD 30-50 per tonne. Previous to the EU import ban the non-GM maize premium was USD 50 per tonne before April 2007 and increased to USD 80-100 per tonne between April 2007 and March 2008 representing an increase in cost for purchasers in the EU.

In these two cases the IP system was not stringent, but a stringent IP system does not guarantee unintended presence. Backus et al. (2008) explain a case of unintended presence for GM maize event DAS-59122-7 (Herculex Root Worm Corn) took place when an applied stringent IP system was in place. In this case an Action Plan was implemented with the goal to apply measures that would prevent an unapproved GM event in maize products destined for export to the EU through monitoring measures at each barge loading point for corn gluten feed (CGF) and dried distillersgrains (DDG). Unfortunately these measures were not sufficient to prevent the unintended presence GM maize event DAS-59122-7.

Since October 15, 2006 all vessels containing CGF and DDG leaving a US port have certificates that state negative test results for GM maize event DAS-59122-7. In April 2007 at the port of Rotterdam, a Greenpeace biosafety patrol activist was allowed on board a ship containing a maize shipment. The captain allowed the activist to take two samples from the cargo. Greenpeace states their analysis detected the presence of GM event DAS-59122-7 in the CGF shipment. In May 2007 two shipments tested positive for the presence of GM event DAS-59122-

7, of which the DDG shipment indicated contamination up to 23% (Backus et al., 2008). The cost calculated to complete testing for the DAS-59122-7 event was estimated at USD 1 million on an annual basis. As a result, the export of CGF and DDG from US to EU was close to a zero between May and September 2007.

In 2009 the EU market banned the import of Canadian flaxseed due to the detection of GM CDC Triffid Flax (FP967). Seven percent of vessels holds tested positively for CDC Triffid Flax in export shipments (Viju et al., 2011). Dayananda (2011) calculated the cost of this incident for Canada resulted in CAN$7.6 million in export losses to the EU market and CAN$8.3 million in export losses to global markets during 2009/2010. The total cost of testing for Triffid Flax was calculated at CAN$1.3 million and total segregation costs at CAN$4.2 million for export to all countries. However, testing and segregation costs continued for years after this single event happened. Ryan and Smyth (2012) estimate the total cost, including demurrage, quarantine, testing, segregation and other costs, to be CAN$29 million for Canada for the 2009 to 2011 period.

All the above cases reveal the difficulties and associated costs that can arise due to asynchronous approval of GM events and their unintended presence in non-GM shipments. The degree of economic impact depends on each country's response to trade policy regarding GM events, which is specifically based on the LLP level of each country, the testing method at the port of entry, the rejection of imports, and the withdrawal of the products from the importing market. However, the above examples are just a few among the many in the world. A survey by a FAO (2014) reveals that between 2002 and 2013 there were total of 198 cases of adventitious presence

of GM events in conventional crop shipments, and a 138 of these cases were between 2009 and 2013.

The current literature on the global GM pipeline and its economic and trade effect as a result of asynchronous approval of GM events is mostly theoretical and policy focused, for example Backus et al., 2008; Stein and Rodriguez-Cerezo, 2010 and Kalaitzandonakes, 2011. The current research on the empirical measurement of the expanding global GM pipeline is mainly focused on specific regions and crops. However, little work on global quantitative measurement has been completed on the effect the expanding GM pipeline is likely to have on international trade given the constraint of asynchronous regulations for a new GM event among countries.

2.3 Quantitative Approach in Defining the Effect the GM Pipeline has on International Trade

To answer the research questions regarding measuring the trade flow of GM and non-GM crops between countries, given the unintended presence of GM events in the shipment of crops in parallel with the expanding global GM pipeline, involves a quantitative analysis of an applied economy-wide model with specifications regarding trade relations between economies. A computable general equilibrium (CGE) model is an applied multi-sector, multi-region, economy-wide model that computes a system of equations describing the motivation and behavior of all the agents in the economy and the linkages among them. CGE produces numerical and precise answers that are theoretically consistent. The Global Trade Analysis project (GTAP) is a commonly used CGE model accepted by trade researches due to its large regional and sectorial

database. GTAP allows the impact of trade policies to be quantified through trade flows or welfare changes on a global level.

2.3.1 Previous Literature Evaluating the GMO global impact with GTAP model

There is limited literature that has used GTAP to estimate the global impact of GM products. Earlier studies by Nielsen and Anderson (2001) use the whole sector of cereal grains and oilseeds for the countries accepting GM technology. They distinguish GM technology from conventional by applying a 5% Hicks-neutral technology shift, meaning the productivity growth encompasses the whole sector. Research by Anderson et al. (2001) is a continuation of Nielsen and Anderson (2001) where they estimated the economic global effects of GMOs, however, the difference from the previous study is that GM cotton and rice were added to the analysis. The key conclusion of this paper is the capacity that the Western Europe ban on GMOs has had on reducing global welfare. A more detailed segregation of the sector was completed by Jackson and Anderson (2003), where for the first time the cereal grains and oilseeds sectors were segregated into GM and non-GM sectors. Jackson and Anderson (2003) also attempted to incorporate consumer resistance of GM products in the EU by placing a low elasticity of substitution between GM and non-GM crops.

The analysis completed by Jensen (2009) is a step forward as some policy-relevant limitations for the adoption of GM food products in the EU was considered. Among the policy limitations considered was the lack of approval of GM food crops in the EU. In this research, GM productivity advancement is modeled as a reduction in input costs. The results indicated that the EU benefits on the consumption side as a result of the spillover effects from import of GM

products. In addition, the benefit would be even higher if the EU decided to cultivate GM products. Philippidis (2010) completed a more sophisticated GTAP analysis exploring the impact of the zero tolerance policy for unapproved GMO imports on EU livestock, meat and dairy sectors. His model considers the common agricultural policy (CAP) in the EU along with biofuels. The import ban is modeled by a reduction in consumer utility corresponding to a specific imported product. The results indicate an alarming impact on EU livestock production, specifically on the swine and poultry sectors that are highly dependent on soy as a feed input. Economic and environmental impacts related to the elimination of GMO events for three major crops, corn, soybeans and cotton in the US was completed by Taheripour et al. (2015). Their findings estimate that the price of corn could increase as much as 28%, while soybean prices could increase 22%.

2.3.2 Structure of the Global Trade Analysis Project, GTAP

GTAP, based at Purdue University in the US, started in 1992 as a project with the goal to lower the costs of entry barriers for researchers conducting analysis in international trade issues with applications of the global CGE framework (Hertel, 2013). GTAP encompassed a growing global network of researchers conducting quantitative analysis of international policy issues (GTAP, 2014).

GTAP has two major components, the GTAP database and the GTAP model. The GTAP database underlies the GTAP Model and GEMPACK(General Equilibrium Modelling Package) software allows manipulation of the dataset and implementation of the GTAP model.

2.3.2.1 GTAP Database

GTAP 8, the database version, covers 129 countries (Appendix B-Table 2.B.1), 57 sectors (Appendix B-Table 2.B.2), and 5 factors (land, skilled labour, unskilled labour, capital, and natural resources) with benchmark years 2004 and 2007 (GTAP, 2014). The GTAP database registers global annual flows of goods and services for the world economy in the benchmark years. The database consists of detailed bilateral trade, transport, protection matrices, and individual country/ regional input-output economic database that accounts for inter-sectorial linkages within regions (Narayanan et al., 2012).

The following two types of data are used in creating the GTAP database, the regional input-output (I-O) tables and data from international organizations. The regional (I-O) tables are collected by individual researches sourced from national published input-output tables. Several international trade organizations are used, the United Nations Comtrade, Eurostat, World Bank Development Indicators, International Trade Center MAcMap system, International Monetary Fund's Government Finance Statistic and International Energy Agency for collecting merchandise trade data, service trade data, macroeconomic data, tariff data, income and factor taxes and energy data respectively. The inconsistency of merchandise and service trade data reported by two countries is reconciled by applying the Gehlhar[8] method (Harslett, 2013). The trade data is collected at the HS6-digit level[9]. The database is operationalized in a standard

[8] Gehlhar approach determines the reliability of each country as reporter of information

[9] Harmonized Commodity Description and Coding Systems (HS) is an international classification for products. It classifies products using a six-digit code. The first two digits define a product in more broad categories and each additional digit of the code defines the products into a more detailed division. It is used on an international level for the purpose of countries to classify products on a common base when engaged in international trade.

modeling framework with the potential for modification and extension (Narayanan et al., 2012), and the unit of value in the database is in millions of US dollars.

To solve the GTAP model in computable form the data has to be arranged in a social accounting matrix (SAM). SAM is a square matrix in which each row and column is called an account. SAM describes the inter-industry and inter-activity transactions (value flows) within an economy at the regional, national, or international level for the benchmark period (Wing, 2004). In the SAM matrix the income of all agents in the economy (households, government, producers, investors, and rest of the world) is recorded in the appropriate row and the expenditures are recorded in the appropriate column. Thus, each cell element shows the payment from a column account to a row account. The dimensions of a SAM are diverse for CGE models and depend on the number of industries, factors of production, and households. Figure 2.B.1 in Appendix B displays a common SAM structure for GTAP models. The SAM table must balance, which means each column total must be equal to the corresponding row total. For example, the aggregate demand must equal aggregate supply. Balancing the SAM matrix establishes the accounting identities to build the CGE model and data boundaries. Figure 2.B.2 (Appendix B) lists the accounting identities that establish the trade data boundaries in SAM and the global GTAP model.

The GTAP database uses three categories of pricing: agent, market, and world. The agent and market prices differ depending whether the commodity is domestic or imported. The calculation of market and agent pricing is shown below in Table 2.8.

Table 2. 8: GTAP database pricing

Imported commodities Market prices = World prices + Trade and transport margins + import duties Agent prices = Market prices + sales and purchase taxes
Domestic commodities World prices = Market prices - export taxes (exported domestic commodity) Agent prices = Market prices + sales and purchase taxes

Source: Fjellheim (2011)

2.3.2.2 Overview of the GTAP Model and Institutions

The standard GTAP Model is a static multi-region, multi-sector, CGE model where consumers and producers are model under neoclassical theory. Consumers maximize their utility subject to a budget constraint and producers maximize their profit subject to a technology constraint. The behavior of the agent in the economy is based on the following assumptions: perfect competition, constant returns to scale, full labour market employment, and that domestic goods and imports are treated as heterogeneous goods.

The intuition behind the GTAP model is to represent an instrument that is able to capture the behavior of the economy and the changes of that economy when external shocks are applied, while remaining consistent with economic theory. The global GTAP model equations and parameters are derived from the SAM account identities presented in Section 2.3.1.1; which includes the functional forms of agent behavior, and the market clearing conditions for general equilibrium.

Figure 2.1 presents a simple overview of value flows in the GTAP model. The behavior of the agents in the GTAP model's demand and supply system is represented with multiple levels or

nest functions. The starting point in the demand side is regional households, which represents the country specific whole income of the economy.

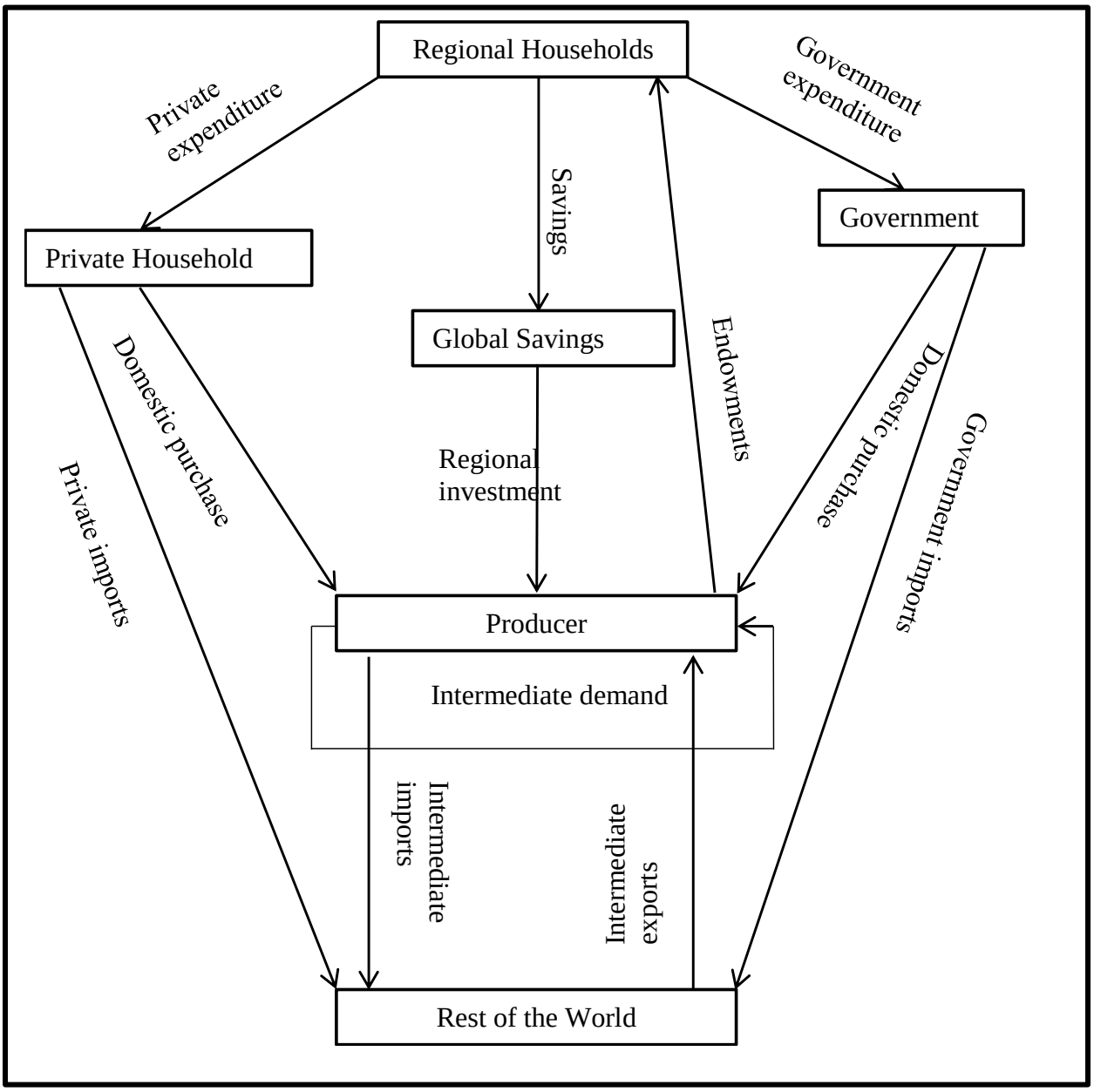

Figure 2. 1: Value flow between the institutions in the GTAP model for a multi-region open economy
Source: Brockkmeier (2001)

Regional household income uses an aggregate Cobb-Douglass utility function to allocate income into three forms of final demand: private household expenditures (PRIVEXP), Savings (SAVE), and government expenditures (GOVEXP). The three types of final demand in the GTAP model have a fixed share of the total regional income, therefore, a change in regional income causes an equivalent change in private expenditures, government expenditures, and savings. Lastly, each agent in the open economy cannot spend more than what they receive as income.

The private household regional income is received as value paid by the producers for the use of factor endowments. The primary factor endowment consists of land, skilled labour, unskilled labour, capital, and natural resources in the GTAP model.

The private households and government spend income on domestic and imported commodities. The private household preference in each country is modeled by constant difference elasticity expenditure functions (CDE) that consider the non-homothetic (differences in income) nature of the final consumption. Governmental behaviour is modeled by a Cobb-Douglas utility function. Thus, the nesting structure of aggregate consumption function for individual *i* can be shown in the form:

$$C_i = f\left[P_i, g\left(C_{m_1} \ldots\ldots C_{m_m}, d(D_i M_i), G_i, h\left(C_{m_1} \ldots\ldots C_{m_m}, k(D_i M_i)\right), S_i\right]\right. \quad (1)$$

Total consumption C_i is represented by a top level nested Cobb-Douglas function aggregating the private consumption P_i, government consumption G_i and the savings S_i by the individual *i*. The bundle of commodities $Cm_1 \ldots . Cm_m$ consumed by the private household P_i is aggregate by a CDE

function, and the bundle of commodities $Cm_1 \ldots Cm_m$ consumed by the government G_i is aggregated by a Cobb-Douglas function representing the second level of nesting. In addition to the consumption of bundled commodities by private households and the government, the third level of nesting allows the households and government to decide whether the commodity will be domestic D_i or imported M_i. Savings are fully spent on investment which is a fixed proportion from regional income. The function *f, g, d, h, k* represent the various levels of nesting functions. The consumption nested structure is presented in Figure 2.2.

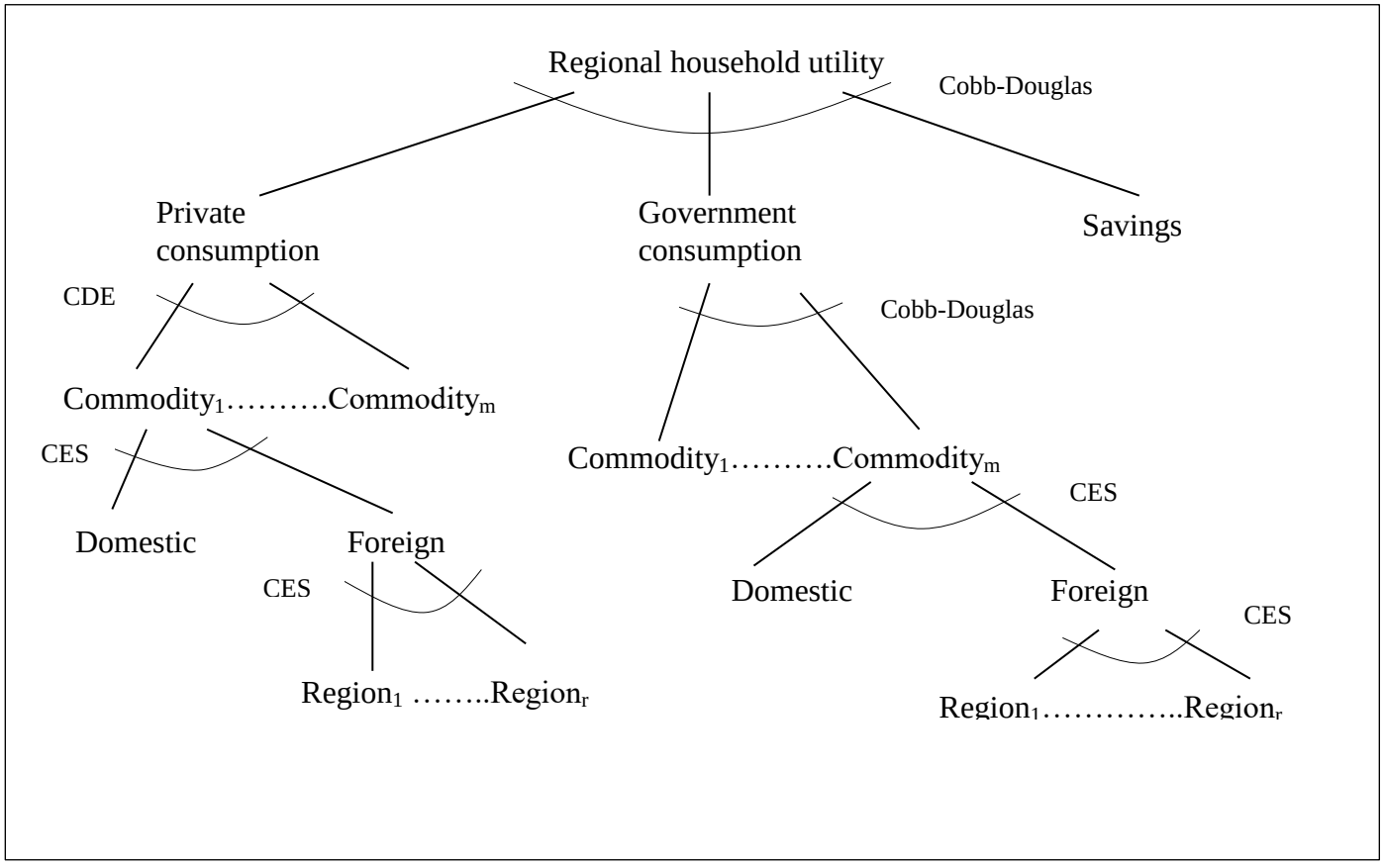

Figure 2. 2: Consumption nesting structure in the GTAP model
Source: modified from Burfisher, (2011)

The production side of the model assumes perfect competition and constant returns to scale for production technology. The perfect competition assumption, or zero profit assumption, indicates that the revenue of the producer is determined by the management of producer costs. Constant returns to scale indicate that a percentage change in the price of any output commodity will equal the weighted sum of the percentage change in input prices. In the GTAP model, producers receive income from selling their output to private households, the government, intermediate inputs to other producers, and exports to the Rest of the World.

Production technology is represented by a nested production function, indicating that producers are making decisions in several independent steps. Each sector produces a single output by combining the value added by the factor endowments with the intermediate inputs in fixed proportions through the Leontief function. The output production *Qo* represents the top level of the nested production function. The value added Qv_A nests the five factor endowments (skilled labour *Ls*, unskilled labour *Lu*, capital *K*, natural resources *R* and land *P*) through the constant elasticity of substitution function (CES). The intermediate inputs *Qf*, which can be imported *Qfm* or domestic *Qfd*, are combined through the CES function. Hence, the nested production function for sector *j* can be shown as:

$$Q_{o_j} = f\left[Q_{VA_j}, g\left(L_{S_j}, L_{U_j}, K_j, R_j, P_j\right), Q_{f_j}, h\left(Q_{fd_j}, Q_{fm_j}\right)\right] \quad (2)$$

Where the functions *f*, *g*, and *h* represent the various levels of the nested functions.

Figure 2.3 represents the production technology of the GTAP model. On each level of the production tree there is a variable for implementing technological change (*ao*, *ava*, *af*) resulting from value added savings, intermediate input savings, or overall Hicks-neutral savings. Thus, there is a possibility for substitution between inputs from the same level as result of a change in prices, but there is no possibility of substitution between inputs from different levels of the nested function as a result of a change in prices. For example, the demand for intermediate inputs is determined by the change in prices of intermediate inputs but this is independent from the change in prices for a factor endowment.

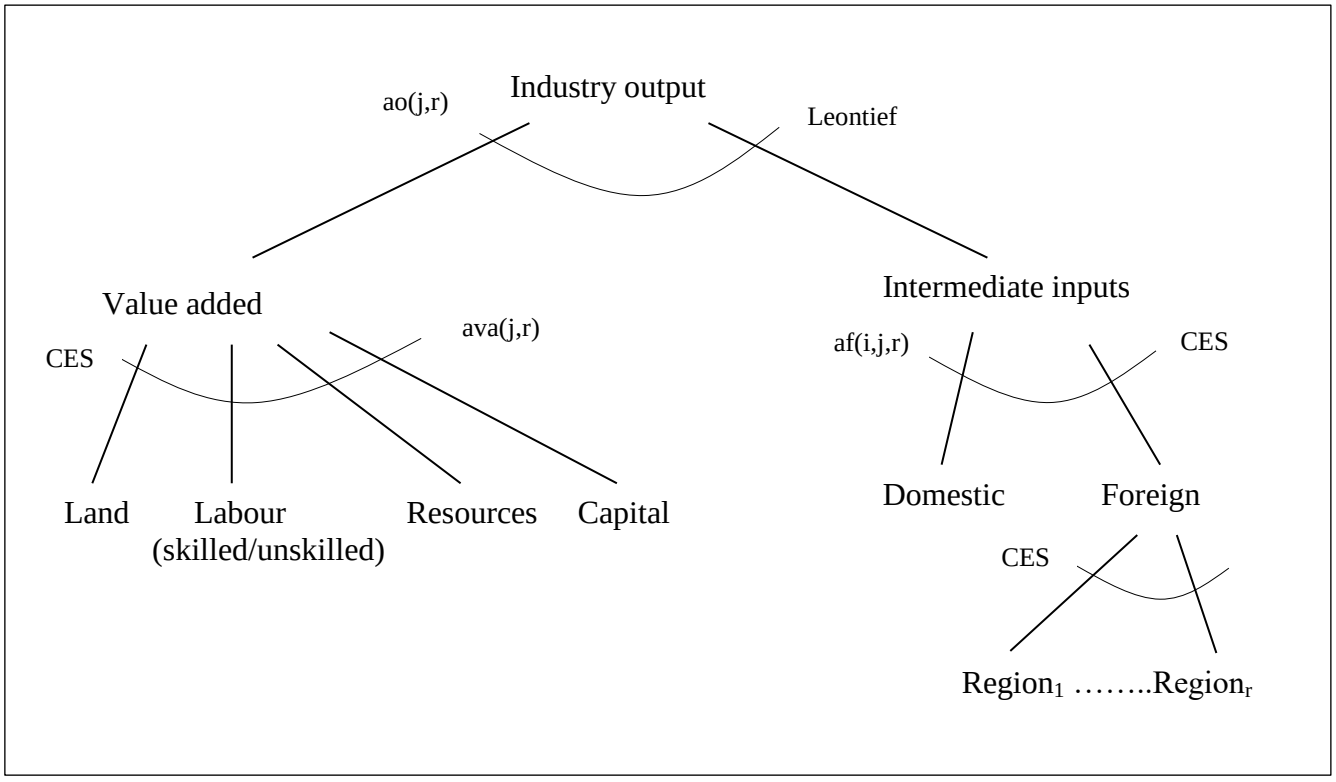

Figure 2. 3: Production nesting structure in the GTAP model
Source: modified from Hertel and Tsigas, (1997)

The Rest of the World represents all other countries in the global economy, and they behave in the same manner as the region of interest described in Figure 2.1. The interaction of the rest of the world with the other agents in the region is monitored through trade flows. Hence, import and export flows can be traced by the type of commodity, specific sector of the economy (agents), and the region of origin and destination.

Modeling of international trade in GTAP is completed using the Armington assumption represented by the CES function. The Armington assumption treats the imported and domestic commodities as imperfect substitutes. Thus imports are distinguish by the country of origin and aggregated at the border into a two-stage nesting process. Thereby, producers and consumers choose first the bundle of commodities, then whether to consume a domestic or imported commodity. If a decision is made to consume an imported commodity then the producer or consumer would choose the region of the import. In Figures 2.2 and 2.3 the trade decision is presented after the foreign sector or the border line for the consumption and production technology respectively.

The two stage nested trade function applied in the GTAP model:

$$C_i = f\left[D_i, g\left(M_{i_1} \ldots . M_{i_r}\right)\right] \tag{3}$$

The function *f* represents the top level nested function, determining the mixture of domestic D_i and imported M_i for product C_i. The lower level nested function *g* determines the region of import (1…*r*). Both functions have CES elasticity. Considering that the Armington assumption

in (3) is present in both the producers' production and consumers' consumption decisions in equations (1) and (2), then we can describe (3) in more detail:

$$C_i =$$

$$f\left[P_i, g\left(C_{m_1} \dots C_{m_m}, d\left(D_i, l\left(M_{i_1} \dots M_{i_r}\right)\right)\right), G_i, h\left(C_{m_1} \dots C_{m_m}, k\left(D_i, n\left(M_{i_1} \dots M_{i_r}\right)\right)\right), S_i\right] \quad (4)$$

$$Q_{o_j} = f\left[Q_{VA_j}, g\left(L_{S_j}, L_{U_j}, K_j, R_j, P_j\right), Q_{f_j}, h\left(Q_{fd_j}, d\left(Q_{fm_{j1}} \dots Q_{fm_{jr}}\right)\right)\right] \quad (5)$$

There are two global sectors in the GTAP model, global banking and global transportation. The global banking sector maintains the balance between global savings and global investment through macroeconomic closure. The global transportation sector accounts for the difference between FOB export values and CIF import values on a global level.

The modeling process consists of modeling variables, coefficients, and parameters. The variables in the database are defined in terms of value, such as the value of imports/exports from the source region to the destination region. Value terms are calculated by the quantity and price variables. Price and quantity are endogenous variables that result in the database variables being updated by the value terms once the model is solved. The value terms in the GTAP database are defined in an agent's market and world price levels. The difference between the value of the agents' prices and the market prices defines the taxes or subsidies. The difference between the terms of value for exports and imports at market and world prices defines border interventions (tariffs, quotas, etc). The use of taxes and border interventions in forming the agent, market, and world prices is outlined in Figure 2.4 using an example of output value. Various taxes, subsidies,

and border interventions describe policy variables in the GTAP model, which provides linkages between market prices at various levels (Lotze, 1998). There are also various slack variables in the GTAP model that are used to change model closure, for example changing an endogenous variable for an exogenous variable.

Domestic market in region "r"	Value of output at agents' prices +Output taxes/subsidies =Value of output at market price =>Domestic sales, exports, and transportation
	Value of exports at market prices +Export taxes/subsidies
World market	=Value of export at world prices (fob) +Value of international transportation =Value of imports at world prices (cif)
Domestic market at region "s"	+Import taxes/subsidies =Value of imports at market prices
	=>Import purchase of private households, government and firms

Figure 2. 4: Taxes and border interventions effect on forming agent, market, and world prices
Source: Lotze, (1998)

The GTAP model brings flexibility through the closure option, which allows for the differentiation of variables into endogenous and exogenous classes. In the standard model endogenous variables include prices, quantities of non-endowment commodities, and regional income. Exogenous variables include policy, technical change, population, land, labour, and capital. Only exogenous variables, one per model simulation, can be shocked. However, if shocking an endogenous variable is of interest there is an option to swap an endogenous variable for an exogenous variable. Behavioral parameter equations for all factors can also be modified within the model. Lastly, model output includes a matrix of bilateral trade flows by sector and region, private and governmental consumption, regional welfare, and a variety of summary variables (Narayanan et al., 2012).

2.3.3 Extensions to the GTAP Model and Database

The structure of GTAP version 8 is broad, allowing 57 commodities and 129 regions to be linked. To meet the research specifications of this essay both the GTAP data and model requires modification.

The first step of the modification is to aggregate the regions and sectors[10]. Region aggregation is completed by grouping the largest exporters and importers by country based on the following three crops: soybean, maize, and rapeseed. The remaining countries are aggregated into one group labeled Rest of the World.

Sector aggregation is completed to simplify the model through aggregation of sectors that are outside of our area of interest into larger concentrated sector clusters for further modification. The aggregated regions and sectors are presented in Table 2.9. This initial aggregation resulted in a total of 14 regions and 17 sectors.

Table 2. 9: Region and sector aggregation in the GTAP model

	Region Aggregation		Sector Aggregation
1	Argentina	1	Rice
2	Australia and New Zealand	2	Wheat
3	Brazil	3	Cereal Grains
4	Canada	4	Vegetables,fruit,nuts
5	China	5	Oil seeds
6	EU28	6	Sugar cane, Sugar beet
7	India	7	Plant-based fibers
8	Japan	8	Crops
9	Mexico	9	Cattle,sheep,goats,horses

[10] For aggregating region and sectors GTAP AGG software is used.

10	Paraguay and Uruguay	10	Animal products
11	Rest of the World	11	Natural Resources
12	Russia	12	Meat: cattle,sheep,goat,horse
13	Ukraine	13	Vegetable oils and fats
14	US	14	Food Products and Beverages
		15	Chemical
		16	Manufacturing
		17	Services

Source: Authors modification of the GTAP database

The next level of data modification is to disaggregate specific sectors. Since soybeans and rapeseed are part of the oil seed sector and maize part of the cereal grain sector, we have to first disaggregate them as a separate sector. Additionally we are also disaggregating the three sectors of interest into GM and non-GM varieties, leading to a total of 23 sectors. Furthermore, the GM varieties are disaggregated into GM events for each stage of the global GM pipeline. Thus, the final outcome will be 72 sectors and 14 regions.

The application of disaggregation and the introduction of new commodities into the existing GTAP database will be completed using "SplitCom" software. SplitCom software is provided by the GTAP network and allows users to disaggregate commodities using shares supplied by the user (Horridge, 2008). The utility of SplitCom is consistent with the SAM matrix, such that the old sector has to equal the new split sectors. For example, cereal grains are a sum of maize and other cereal grain sectors, and the oilseeds sector is a sum of soybeans, rapeseed, and other oilseed sectors.

SplitCom consists of four weight areas that are used in splitting the sectors: trade share, row share, column share, and cross share. Trade share requires data on production, export, and import

values across the region. Row share requires data on the consumption of new products across the agents in the economy. Column share requires information on the cost structure of the new sectors. Cross share requires information on the use of new commodities in the new sectors. However, not all weight shares need to be applied when splitting sectors. Each weight area can be applied based on the available external data. The external data used for splitting sectors within this research is listed in Table 2.10.

Table 2. 10: External data used for splitting sectors

External data applied for splitting in "Split Com"	Source
Area, production, and yield of Corn, Soybeans, and Rapeseed	FAOSTAT (2014)
Trade of Corn, Soybeans, and Rapeseed for all countries	UN Comtrade (2014)
GM crop production and trade	FAO (2014) James, (2011)
GM event approval stage	BIO (2014) Stein and Rodríguez-Cerezo, (2009b)
GM crops productivity effect	Jensen et al., (2009) Brookes, (2008) Alston et al., (2013) Gruere et al., (2007)

Source: Authors application

The new structured database can now be used in the standard GTAP model through the circular flow of income and spending, and the linkages among them, in the economic activities of production, consumption, employment, tax and savings, and trade. Production, consumption, and trade are key economic activities that must be observed when designing the global GM pipeline model.

2.3.3.1 Extension on the Production Side of the GTAP Model

As previously described, each of the three commodities will be segregated by GM and non-GM. The inclusion of GM crops in the model implies that a productivity gain from the adaptation of the new technology should be a key parameter of consideration. There are a number of studies that have used GTAP models for examining the welfare effect of GM technology adoption in a specific region, including that productivity gain is one of the key parameters necessary to fully understand the effect of GM technology (Nielsen and Anderson 2001, Nielsen, et al. 2003, Anderson, et al. 2004, Jensen et al. 2009, Antoine and Gruere 2011). For example, Nielsen, et al. (2003) assume that GM oilseed and GM cereal grain sectors have a 10% higher productivity factor and a 30% chemical cost reduction compared to their non-GM conventional counterparts across all countries.

When applying the efficiency gain of a new technology across regions and sectors, the varying differences amongst those regions and sectors must be acknowledged and accounted for. For example, the license agreements for GM seed in Argentina and Brazil are not enforced, leading to an increase in crop productivity while reducing production costs for farmers (Jensen et al., 2009). In Jensen et al. (2009), we see the application of different assumptions across regions and crops regarding the relative input cost structure of a new technology. Alston et al. (2013) use a global trade model to determine different production cost savings for Roundup Ready Soybeans in seven different countries.

The GM technology productivity gain/loss across regions and crops will be applied in the GTAP model as a productivity shock to the variable implementing technological change. Within the

GTAP model there are multiple variables for technological change, for the purpose of this research the technology variables that will be shocked are the specific intermediate inputs and labour parameters within the production function. The modified production technology tree with the inclusion of the GM global pipeline is presented in Figure 2.5. Hence, the demand for the intermediate inputs for GM and non-GM soybeans, rapeseed, and maize will depend on the prices of the respective GM and non-GM crops through the CES function. Adding this nesting function into the demand for intermediate inputs creates a new structure of the production function where the GM crops and non-GM crops will be selected by the producers based on the lowest price.

The new production function including the GM and non-GM nesting function is as follows:

$$Q_{O_j} = f\left[\begin{array}{c} Q_{VA_j}, g\left(L_{S_j} L_{U_j} K_j R_j P_j\right), h\left(Q_{fd(NoGM)_j}, d\left(Q_{fm(NoGM)_{j1}} \ldots\ldots Q_{fm(NoGM)_{jr}}\right)\right), Q_{fd(GM)_j}, \\ h\left(Q_{fd(GM)_j}, d\left(Q_{fm(GM)_{j1}} \ldots\ldots Q_{fm(GM)_{jr}}\right)\right) \end{array}\right] \quad (6)$$

On the consumer side of the model, the decision on whether to consume a GM or non-GM product will be decided through an additional CES nesting function. Thus the private and government consumers will first decide whether to consume GM or non-GM soybeans, rapeseed, or maize, and then whether the product will be domestic or imported. The purchase decision regarding commodity consumption will depend on the price of the good.

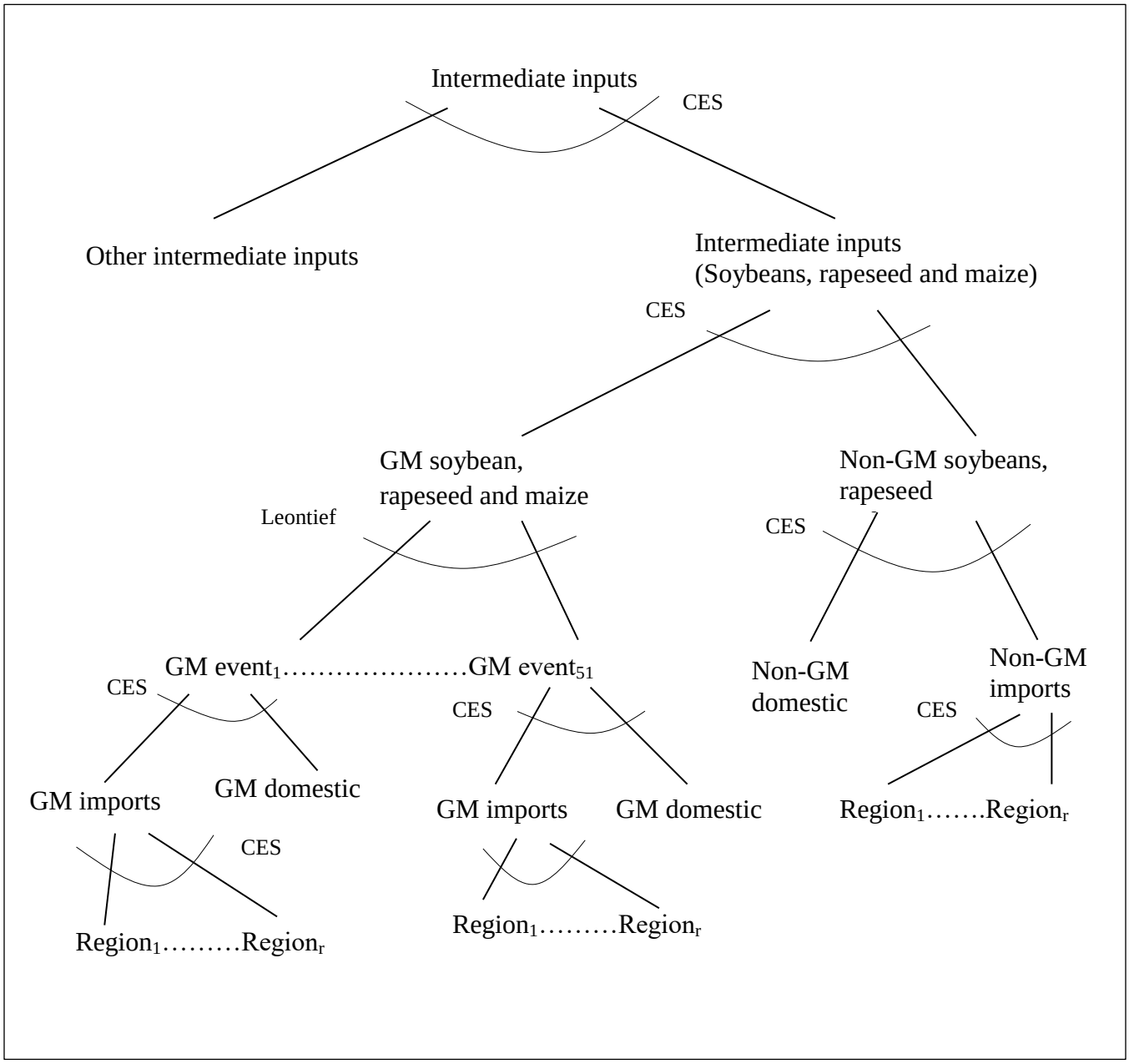

Figure 2. 5: Production technology tree including the global GM pipeline
Source: Authors application

2.3.3.2 Extension on the Trade Side of the GTAP model

The current model design, including the modification of production technology and where the distinction between GM and non-GM products is made based on the lowest prices, will present a

picture of world trade for the commodities without any import constraints for GM events. However, as previously mentioned, the trade of GM commodities is specific because each country has differing regulations and the number of events authorized among countries varies. Therefore, GM events that are not authorized in a specific country or are still contained within the pipeline process will be labelled as having import ban or temporary import ban for that particular product within the model. The standard way of imposing an import ban in GTAP is to fix the import quantity at a specific value, in the case of unauthorized GM events that value will be zero.

Pilippidis (2010) proposed a novel method of designing an import ban, where the ban is constructed by a reduction in consumer utility corresponding to a specific imported product, and this in turn motivates an import reduction. However, in our case the ban on certain GM events arises as a result of regulation delays or asynchronicity among country regulations, and not as a result of consumer acceptance. Therefore, the standard traditional way of imposing an import ban is used.

To modify the model for a specific unapproved GM event in an importing country, the endogenous import quantity variable is swapped with the import tariff. This switch provides an opportunity for import quantities to be controlled by a fixed percentage, and at the same time the import tariff variable will be adjusted by raising the price on that particular import. The rise of the import price is equivalent to the reduction of the import quantity. After switching these two variables, the model is shocked by placing a zero value for the import quantities, which will

create a rise in the import tariff at an equivalent value[11]. This modification allows trade flow amongst countries within the global GM pipeline to be identified.

Measuring the effect of the unintended presence of GM events in the export of non-GM crops on trade flows between countries requires import tariff modifications for the non-GM crops in regions where new GM events are still not approved or contained within the pipeline. As mention in Section 2.2, there are a number of cases where shipments of non-GM crops are co-mingled with traces of unintended GM events and the cost for grain traders can vary between sectors and countries. Backus et al. (2008) states that these costs vary between USD 27 to 90 million, and that costs for testing, demurrage, and destruction of soybean shipments are included in those figures. Viju et al. (2011) revealed that 7 percent of export vessel holds did test positive for CDC triffid flax. Based on these results and to simplify model modifications, it is assumed that export vessels of non-GM crops co-mingled with GM events will vary between 5 and 10 percent.

The assumption for co-mingling of non-GM vessel crop exports is applied in the same way as modeling an import ban. First the import quantities of the non-GM crops are switched with an import tariff for the same crop, and then imports are exogenously reduced for non-GM crops in specific regions as a result of the unintended presence of GM events in the supply chain. The shock for non-GM crops is then applied simultaneously by reducing import quantities between 5 and 10 percent due to co-mingling of a GM event. Once the results for the base case were

[11] Modeled in a standard way of imposing an import ban in GTAP

obtained, a sensitivity analysis was conducted on the percent of co-mingling and cross co-mingling between GM and non-GM crop shipments.

2.3.4 Model Scenarios

Considering the model modification in the database, production and trade, scenarios are developed in order for the research questions to be answered. The summary of the scenarios is presented in Table 2.11. The structures of the scenarios start with a base scenario, where regulations are synchronized without trade barriers for the commercial GM technology. Each additional scenario considers the previous scenario adding higher level of protection or more GM events commercialization.

Table 2. 11: Scenarios summary

	Commercial crop		**GM pipeline category**		
	Production	Trade barrier	Production	Trade barrier	Contamination of non-GM crops
Scenario1	yes				
Scenario2	yes	yes			
Scenario3	yes	yes	yes		
Scenario4	yes	yes	yes	yes	
Scenario5	yes	yes	yes	yes	yes

Source: Authors application

2.3.4.1 Scenario Description

Scenario 1: Trade flows of approved commercial GM events considering their productivity effect without trade barriers (all countries are synchronized)

Scenario 1 distinguishes between GM and non-GM crop production technology where the main difference is the cost structure of the input. Therefore, only the input cost structure is considered for three main GM crops: maize, soybean, and rapeseed. Efficiency gains of new GM technology vary among regions and sectors, and this variation has been acknowledged and accounted for in this scenario.

Table 2.12 lists the applied assumptions across regions and crops regarding the relative input cost structure. The productivity gain/loss from GM technology across regions and crops are applied as an external shock of the intermediate input chemicals and the value added labour within the production function of the GTAP model.

Table 2. 12: Assumptions About the Relative Cost Share of GM crops Across Regions and Sectors in Percent Value

Crop Type	Parameter	EU-28	US	Argentina	Brazil	Canada	PryUry[12]	Australia	Mexico
GM Maize	Yield	2.1	5	5		5	5		
	Chemicals		-1.5	-5					
	Labour	-5	-5	-5	-15	-5	-5		
GM Soybean	Yield		-0.5						-0.5
	Chemicals		-10	-43	-0.3	-30	-0.3		
	Labour		-10	-7.7	-7.7	-10	-10		
GM Rapeseed	Yield		10.3			10.7		22.11	

Source: Brookes (2008); Alston et al. (2013); Gruere et al. (2007); Jensen et al. 2009

[12] PryUry- Paraguay and Uruguay

Scenario 1 considers only the commercial GM events of maize, soybean, and rapeseed available on the market (see Table 2.13) as presented by Stein and Rodríguez-Cerezo (2009a). The GM cost assumption across regions and sectors from Table 2.12 is applied to the GM events in Table 2.13 based on the crop group they belong to.

Table 2. 13: Commercial GM maize, soybeans and rapeseed

No.	Sectors in the GTAP	Events/Name
1	CGMaize1	MON810
2	CGMaize2	NK603
3	CGMaize3	MON863
4	CGMaize4	MON88017
5	CGMaize5	1507
6	CGMaize6	59122
7	CGMaize7	Bt11
8	CGMaize8	GA21
9	CGMaize9	MIR604
10	CGMSoy	MON 40-3-2
11	CGMRape1	T45 (HCN28)
12	CGMRape2	GT73 (RT73)
13	CGMRape3	MS8
14	CGMRape4	RF3

Source: Authors application

Scenario 1 does not consider GM technology trade barriers between regions, thus the commercial GM crops can be easily traded among regions and all countries are synchronized regarding the regulation of GM crops.

Scenario 2: Scenario one with trade barriers implemented in selected regions where the approved commercial GM events are not approved (non-synchronized)

Scenario 2 builds on scenario 1 with the introduction of trade barriers in regions where the commercial GM events from Table 2.13 are not approved. Table 2.C.1 in Appendix C lists the

commercial GM events for maize, soybean, and rapeseed that are approved or not approved in selected regions according to Stein and Rodríguez-Cerezo (2009b). The implementation of trade barriers on specific GM events for the selected regions is obtained from Table 2.C.1.

Scenario 3: Scenario two plus a 5% adoption rate for GM events currently in the commercial pipeline, regulatory pipeline, and advanced R&D pipeline (all countries are synchronized)

Scenario 3 builds on scenario 2 with a 5% adoption rate of the GM events that are currently in the commercial pipeline, regulatory pipeline, and advanced R&D pipeline according to Stein and Rodríguez-Cerezo (2009a). Table 2.14 categorizes the GM events by commercial, regulatory, and advanced R&D pipelines. No trade barriers exist for the GM events in the three pipelines listed in Table 2.14, thus regulations are synchronized across regions.

The 5 % adoption rate applies to the following countries that are already cultivating GM crops: Argentina, Brazil, Canada, US, Paraguay and Uruguay for GM maize and soybean; and Australia, US, and Canada for GM rapeseed. A 5% adoption rate for GM events that will be specifically developed by China and India for use within their borders has been applied in the model as part of scenario three.

Table 2. 14: GM maize, soybean, and rapeseed events in the commercial, regulatory, and advanced R&D pipelines

No.	Sectors in GTAP	Event/Name	Pipeline Group
1	CoGMaize1	MON89034	Commercial pipeline
2	CoGMaize2	LY038	Commercial pipeline
3	RgGMaize1	3272	Regulatory pipeline
4	RgGMaize2	MIR162	Regulatory pipeline
5	RgGMaize3	n/a(China)	Regulatory pipeline
6	RgGMaize4	98140	Regulatory pipeline
7	RgGMaize5	n/a(China)	Regulatory pipeline

8	RgGMaize6	n/a(China)	Regulatory pipeline
9	RgGMaize7	MON87460	Regulatory pipeline
10	RaDGMaize1	MON87754	Advanced R&D pipeline
11	RaDGMaize2	n/a(Monsanto)	Advanced R&D pipeline
12	RaDGMaize3	n/a(Monsanto)	Advanced R&D pipeline
13	RaDGMaize4	DHT	Advanced R&D pipeline
14	RaDGMaize5	n/a(India)	Advanced R&D pipeline
15	RaDGMaize6	n/a(BASF)	Advanced R&D pipeline
16	CpGMSoy1	A2704-12	Commercial pipeline
17	CpGMSoy2	MON 89788	Commercial pipeline
18	CpGMSoy3	356043	Commercial pipeline
19	CpGMSoy4	A5547-127	Commercial pipeline
20	RgSoy1	305423	Regulatory pipeline
21	RgSoy2	n/a(China)	Regulatory pipeline
22	RaDGMSoy1	CV127	Advanced R&D pipeline
23	RaDGMSoy2	n/a(Syngenta)	Advanced R&D pipeline
24	RaDGMSoy3	MON87769	Advanced R&D pipeline
25	RaDGMSoy4	n/a(Syngenta)	Advanced R&D pipeline
26	RaDGMSoy5	n/a(Monsanto)	Advanced R&D pipeline
27	RaDGMSoy6	n/a(Monsanto)	Advanced R&D pipeline
28	RaDGMSoy7	MON87754	Advanced R&D pipeline
29	RaDGMSoy8	n/a(Bayer)	Advanced R&D pipeline
30	RaDGMSoy9	n/a(Bayer)	Advanced R&D pipeline
31	RaDGMSoy10	n/a(DHT)	Advanced R&D pipeline
32	CPGMRap	CPGMRap	Commercial pipeline
33	RgGMRap	n/a(China)	Regulatory pipeline
34	RaDRape1	n/a(Bayer)	Advanced R&D pipeline
35	RaDRape2	n/a(Bayer)	Advanced R&D pipeline
36	RaDRape3	n/a(Bayer)	Advanced R&D pipeline
37	RaDRape4	n/a(BASF)	Advanced R&D pipeline
38	RaDRape5	n/a(BASF)	Advanced R&D pipeline

Source: Authors application

Scenario 4: Scenario three with trade barriers introduced for upcoming GM events in the three pipelines

Scenario 4 builds on scenario 3 with the introduction of trade barriers in regions where certain GM events in the pipeline are not yet approved. Table 2.C.2 in Appendix C, lists approved and unapproved GM events in the pipeline for selected regions according to Stein and Rodríguez-Cerezo (2009b). Following this, trade barriers on certain GM events in selected countries is

being introduced. However, where data was not available concerning the approved or not approved status of GM events in the pipeline, as marked by n/a in table, the following assumptions were made. GM maize and soybean events were assumed to be approved by Argentina, Brazil, US, Canada, Paraguay and Uruguay, Mexico, Japan, China and Rest of the World. GM rapeseed events were approved by Canada, Australia, US, China, Mexico, Japan, and Rest of the World. The events developed in China and India are approved only within their specific country borders.

Scenario 5: Scenario four with an initial 5% of co-mingling and cross-co-mingling rate of the following non-GM crops: corn, soybean, rapeseed, wheat and rice

Scenario 5 builds on scenario 4 with inclusion of the unintended presence of GM events in the imports of non-GM maize, soybean, rapeseed, wheat and rice in the EU 28. The assumption of a 5% co-mingling level of non-GM vessel crop exports is applied by swapping the bilateral trade flow for maize, soybean, rapeseed, wheat and rice non-GM crops with the import tariff of the same crops. After substituting the variables, the bilateral trade flow is shocked simultaneously by reducing import quantities 5% due to co-mingling with GM event.

2.3.5 Result Description

Variations in trade values are the basis for explaining the results of the five scenarios. Base data showing the global and bilateral trade flows between countries was initially calculated. Next the individual scenario results are compared to the base data and the changes in trade flows between countries are evaluated if either a higher level of protection exists or more GM events are commercialized.

2.3.5.1 Base Data

The base data in Figures 2.6, 2.9 and 2.12 provides an overview of the global aggregate trade of GM and non-GM maze, soya and rapeseed respectively. Figures 2.7, 2.8, 2.10, 2.11, 2.13 and 2.14 explain in detail the bilateral trade flows among countries for GM and non-GM maize, soya and rapeseed.

Figure 2.6 displays the three largest exporters of maize are the US, Argentina and Brazil. Respective maize exports for the US, Argentina and Brazil total US$10.2 billion, US$2.5 billion and US$2.2 billion with GM maize accounting for US$7.4 billion, US$1.5 billion and US$1.3 billion respectively. The three largest importers of maize are ROW (rest of the World), Japan and Mexico. Maize imports for ROW, Japan and Mexico are US$12 billion, US$3.1 billion and US$1.7 billion from which US$6.8 billion, US$1.9 billion and US$1 billion are GM maize imports respectively.

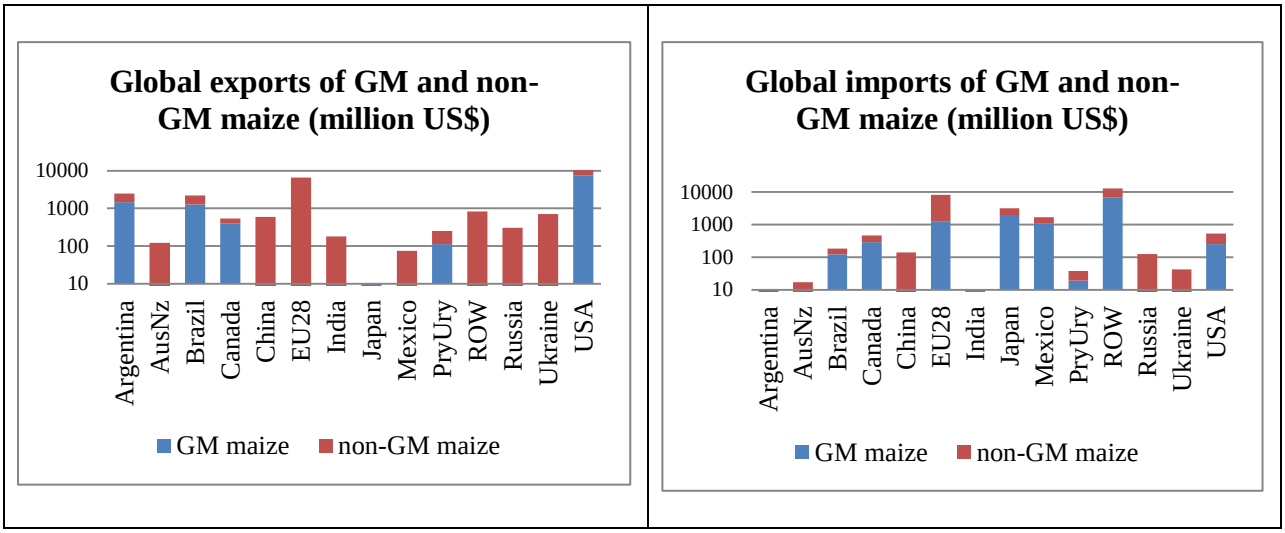

Figure 2. 6: Global trade of GM and non-GM maize
Source: GTAP 8 analysis

Figures 2.7 and 2.8 provide a detailed overview about the trade flows for the largest exporters and importers of GM and non-GM maize. Major destinations for US GM maize are ROW, Japan and Mexico with total exports of US$6.9 billion. Brazil's major partners are the EU28 and ROW with total exports of US$1.2 billion of GM maize. For Argentina the major destination for GM maize is ROW with a total of US$1.4 billion.

For GM maize imports, ROW sources the majority of their imports from the US and Argentina for a total value of US$5.7 billion. The US is the largest supplier for Japan and Mexico with an import value of US$1.8 billion and US$1 billion respectively. The results indicate that the majority of maize traded by the largest exporters and importer is genetically modified. Hence, the US, Argentina and Brazil maize exports are 72%, 59% and 58% genetically modified. For the largest maize importers the results show that GM maize comprises 57%, 61% and 59% of total maize imports for ROW, Japan and Mexico respectively.

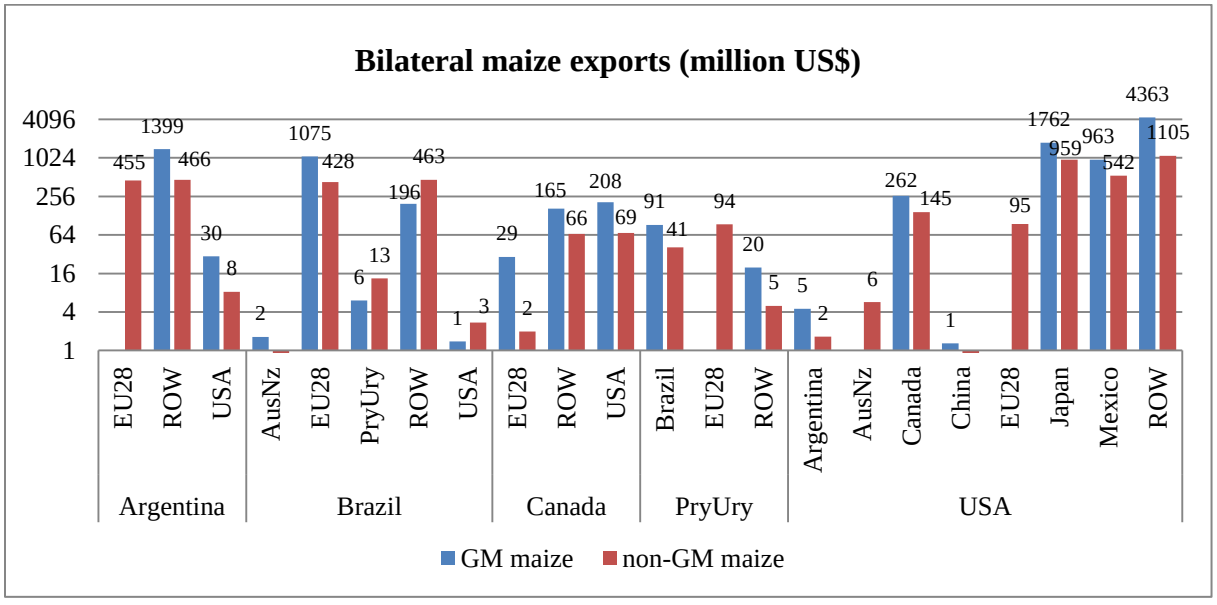

Figure 2. 7: Bilateral exports of GM and non-GM maize
Source: GTAP analysis

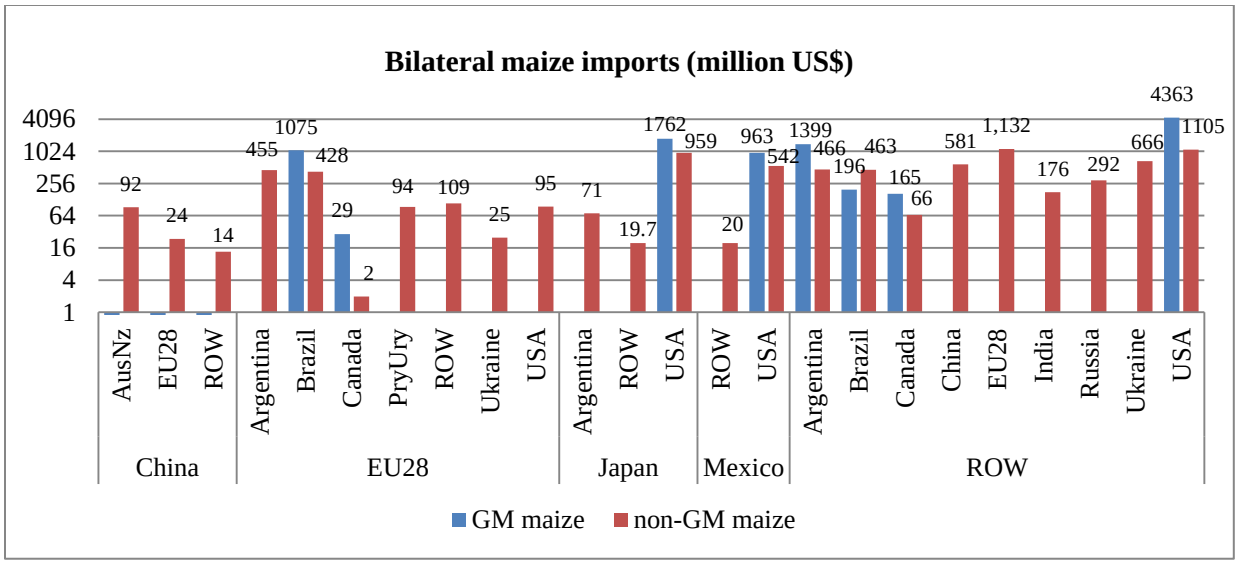

Figure 2. 8: Bilateral imports of GM and non-GM maize
Source: GTAP analysis

For soya the largest exporters are the US, Brazil and Argentina with total exports of US$ 7.7 billion, US$6.7 billion and US$3.5 billion respectively. GM soya exports account for US$6.5 billion for the US, US$4.4 billion for Brazil and US$3.4 billion for Argentina. The largest importers of soya include China, EU28 and ROW with US$12 billion, US$4.7 billion and US$4.4 billion of which GM soya accounts for US$9.4 billion, US$3.3 billion and US$3.4 billion respectively.

Figures 2.10 and 2.11 overview the major trade flows between the largest exporters and importers of soya. In the global soya market there are six countries that account for the majority of bilateral trade flows. The three major soya exporters are the US, Brazil and Argentina who supply China, EU28 and ROW, the three major soya importers. GM soya accounts for 97%, 84% and 66% of total soya exports from Argentina, the US and Brazil respectively. Imports of GM soya into China, ROW and the EU28 accounts for 78%, 77% and 70% of total soya imports respectively.

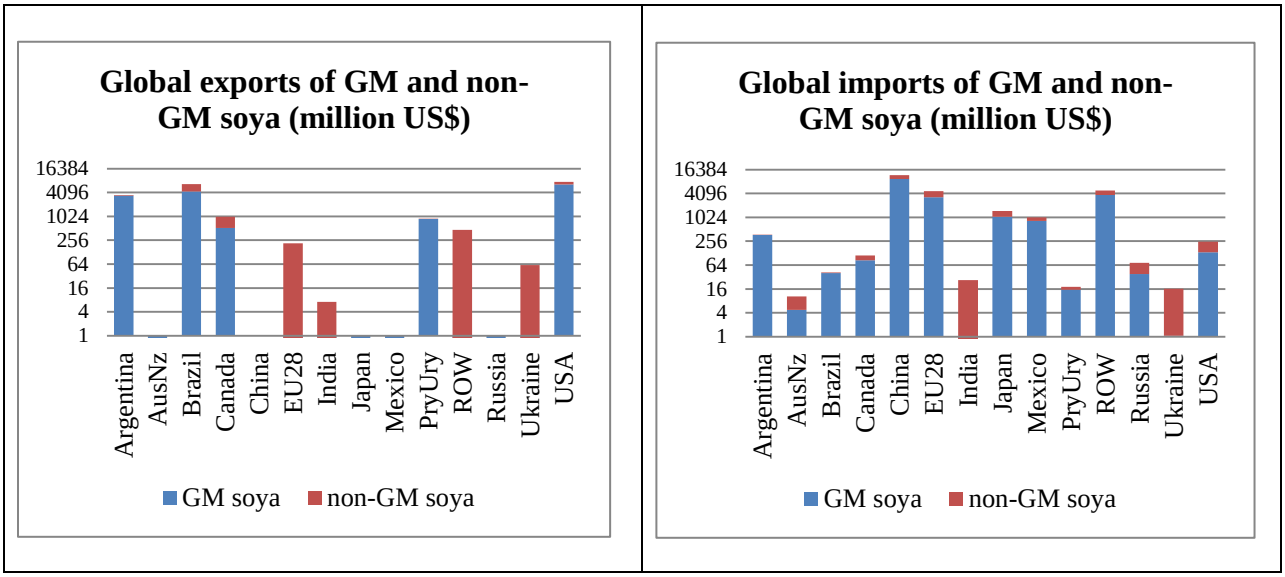

Figure 2. 9: Global trade of GM and non-GM soya
Source: GTAP analysis

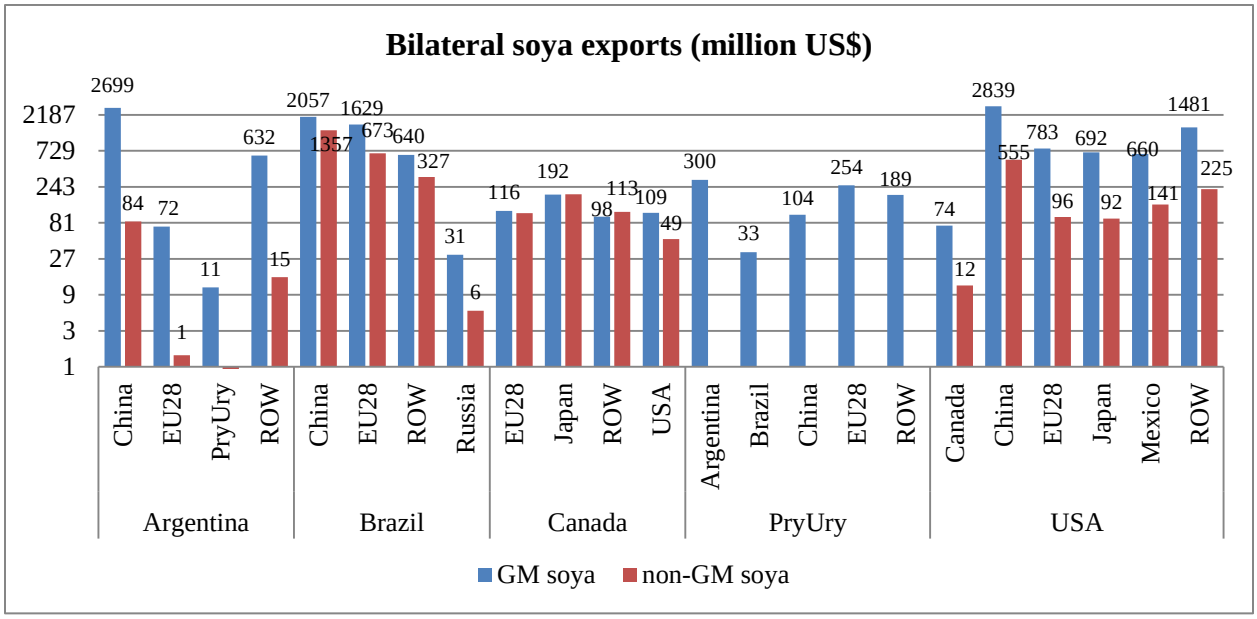

Figure 2. 10: Bilateral exports of GM and non-GM soya
Source: GTAP analysis

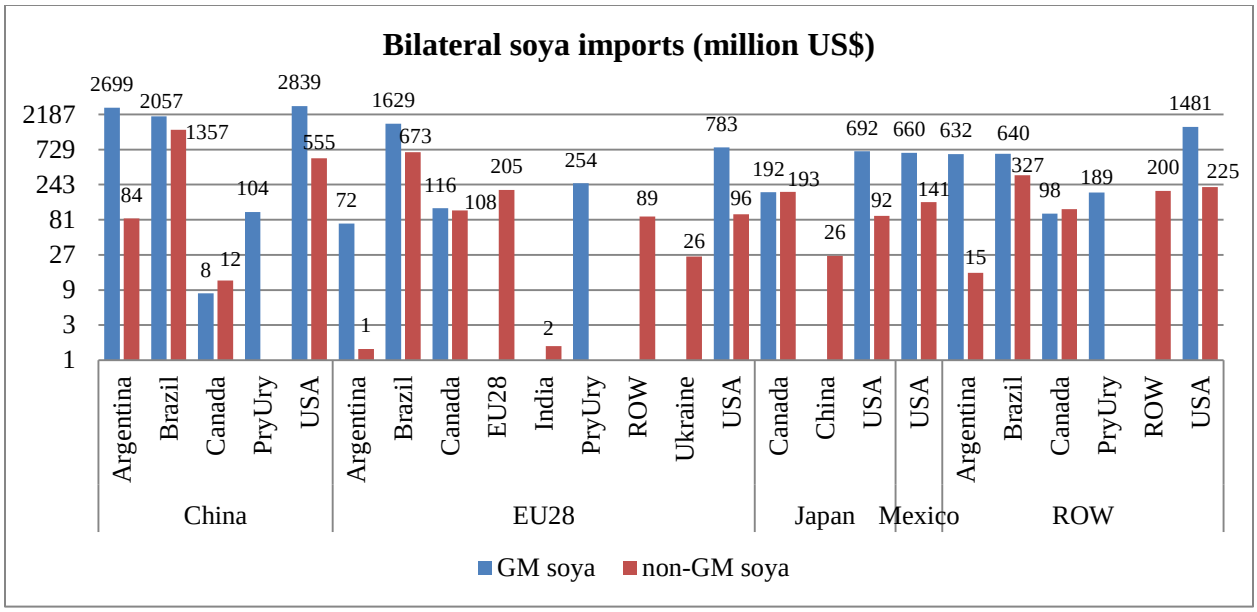

Figure 2. 11: Bilateral imports of GM and non-GM soya
Source: GTAP analysis

The base data results for the largest rapeseed exporters are Canada, ROW and Ukraine with total exports of US$1.4 billion, US$595 million and US$511 million respectively. Canada is the only country exporting GM rapeseed which is valued at US$829 million. The largest rapeseed importers are Japan, Mexico and EU28 with US$506 million, US$486 million and US$416 million of which US$262 million, US$265 million and US$3.9 million are GM rapeseed respectively.

Figures 2.13 and 2.14 overview of the bilateral rapeseed trade flows amongst the largest exporters and importers. Canada exports GM rapeseed to Japan, Mexico, China and ROW with trade values of US$238 million, US$231 million, US$174 million and US$134 million respectively. Genetically modified rapeseed accounts for 59% of Canada's rapeseed exports.

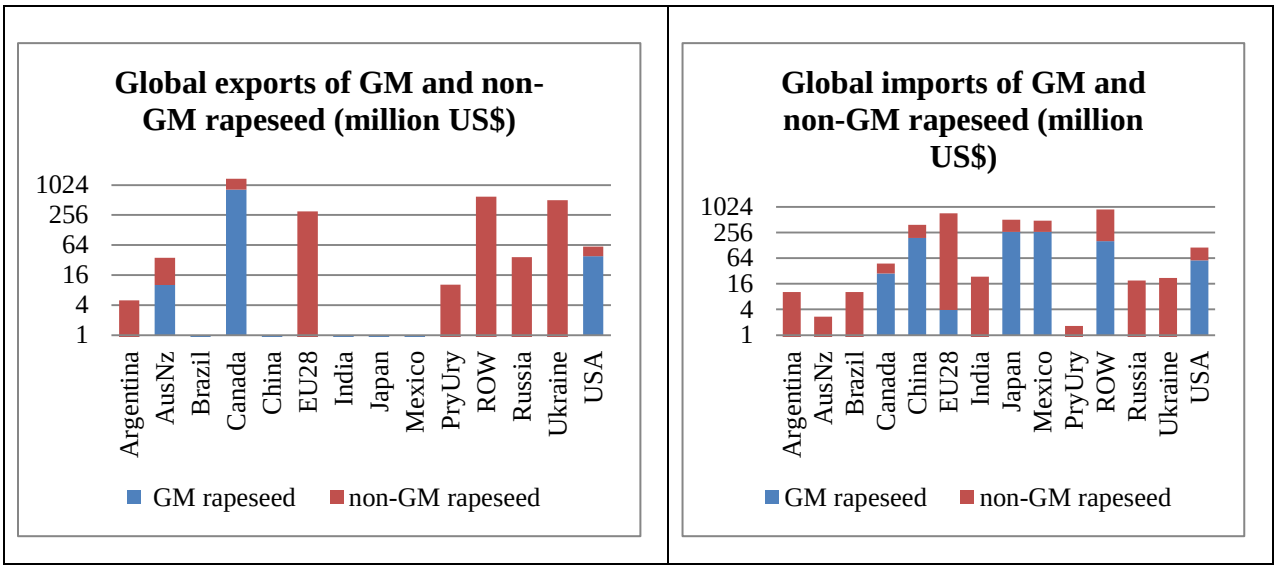

Figure 2. 12: Global trade of GM and non-GM rapeseed
Source: GTAP analysis

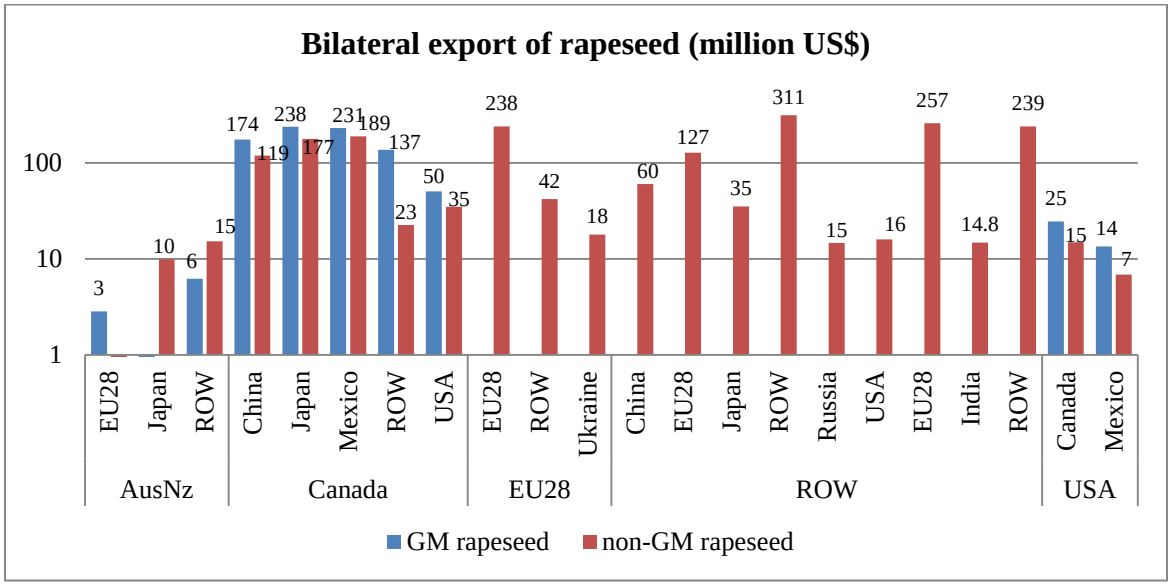

Figure 2. 13: Bilateral export of GM and non-GM rapeseed
Source: GTAP analysis

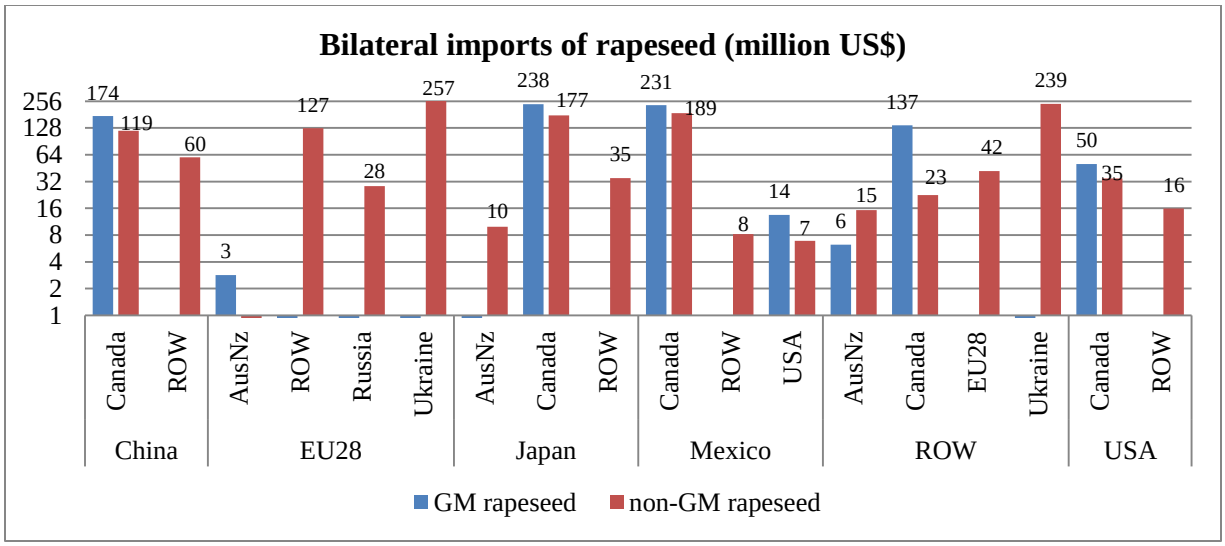

Figure 2. 14: Bilateral imports of GM and non-GM rapeseed
Source: GTAP analysis

2.3.5.2 Results for Scenarios 1 and 2

The first scenario describes the global trade of maize, soya and rapeseed by considering the efficiency gain that GM technology can bring in the absence of technological trade barriers. Current commercial GM events are considered based on country level adoption rates described in Appendix D Table 2.D.1. The CGE model assumes perfect competition with producers earning zero profit and the producers (sectors) that adopt the technology reduce their input cost which reduces output prices.

GTAP utilizes the Armington assumption for international trade which indicates that the source of imports for a specific country will be determined by the lowest price. Countries adopting the technology in the three sectors, maize, soya and rapeseed, become more competitive on the export market if there is no trade barrier as a result of a reduction in prices. The export flow of the countries that have adopted the technology should increase, but this is dependent on the volume traded of the three crops. Additionally, the technology gain may transfer to other sectors;

however, the application of the GTAP model will create those linkages between sectors and countries via the bilateral trade flows.

Tables 2.15, 2.17 and 2.19 display the changes in export values from the base data for the largest exporters of GM maize, soya and rapeseed as a result of implementing the technological change. Tables 2.16, 2.18 and 2.20 display the changes in import values from the base data for the largest importers of GM maize, soya and rapeseed. For simplicity the trade data is shown in aggregate and only for the GM crops where a large change in the result was found.

In scenario 1 the influence of technology adoption by certain countries results in a total change in trade flows of US$287 million for maize, US$591 million for soya and US$44 million for rapeseed. With the US being a technology adopter and having the largest trade share in the maize and soya markets it benefits to the greatest degree and receives the major share of the increased exports which are valued at US$222 million or a 3% increase for the maize sector and US$623 million or a 9.5% increase for the soya sector (see Table 2.15 and 2.17). Argentina and Paraguay-Uruguay GM maize exports increase 3.7% and 6% respectively from the base values. The increased exports of maize and soya crops are mainly absorbed by imports to ROW, Mexico and EU28. ROW and Mexico imports of GM Maize increased by 3.4% and 3.3% respectively. Imports of GM soya increased 7.1% for the EU28 for a total value of US$235 million and 6.1% for ROW or a total value of US$227 million. The rapeseed export market is dominated by Canada and thus the adoption of technology boosts the export of GM rapeseed by 4.5% or US$37.7 million. On the import side the largest increase of imports is by ROW with 17.8% growth or US$28.4 million.

Table 2. 15: Changes in the export value of GM maize due to shocks in scenario 1 (million US$)

Description	Argentina	Canada	Paraguay and Uruguay	US	Total
GM maize base value	1,461.7	402.9	112	7,358	10,616
Changed in values due to scenario 1	53.4	5.291	6.8	221.7	286.8
Percent change in value	3.7 %	1.3%	6%	3%	2.7%

Source: GTAP analysis

Table 2. 16: Changes in the import value of GM maize due to shocks in scenario 1 (million US$)

Description	EU28	Mexico	ROW	Total
GM maize base value	1,218	1,061.7	6,780.5	11,697.6
Changed in value due to scenario 1	14.5	34.7	229	286.7
Percent change in value	1%	3.3%	3.4%	2.5%

Source: GTAP analysis

Table 2. 17: Changes in the export value of GM soya due to shocks in scenario 1 (million US$)

Description	Argentina	US	Total
GM soya base value	3,428.2	6,529.6	15,723
Changed in value due to scenario 1	37.3	622.9	591
Percent change in value	1.1%	9.5%	3.8%

Source: GTAP analysis

Table 2. 18: Changes in the import values of GM soya due to shocks in scenario 1 (million US$)

Description	China	EU28	Japan	ROW	Total
GM soya base value	9,442.8	3,313.6	1,069.3	3,715.9	19,054.4
Changed in value due to scenario 1	118.7	235	14.8	226.8	591
Percent change in value	1.3%	7.1%	1.4%	6.1%	3.1%

Source: GTAP analysis

Table 2. 19: Changes in the export value of GM rapeseed due to shocks in scenario 1 (million US$)

Description	Australia and New Zeeland	Canada	Total
GM rapeseed base value	10	829.7	878.2
Changed in value due to scenario 1	6.9	37.7	44
Percent change in value	68.6%	4.5%	5%

Source: GTAP analysis

Table 2. 20: Changes in the import value of GM rapeseed due to shocks in scenario 1 (million US$)

Description	China	EU28	ROW	Total
GM rapeseed base value	189	3.9	160	965
Changed in value due to scenario 1	7.5	1.2	28.4	44
Percent change in value	4%	31.3%	17.8%	4.6%

Source: GTAP analysis

Scenario 2 examines the impact on trade flows as a result of the asynchronous approval of the commercial GM maize, soya and rapeseed events. These impacts are shown in Tables 2.21 to 2.26. The GM maize sector is the most affected by the asynchronous approval with a total reduction of trade flows pegged at US$239.6 million or 2.3% from the base value and US$527 million or 5% compared to scenario 1 if the sector was synchronized. Brazil's GM maize exports suffer a significant reduction of 28% (see Table 2.21). This is as a result of the existing asynchronicity on events GA21 and MON 863 with the EU28 as its largest importing market. Hence, the import of GM maize in the EU28 decreases by a total of 30.3% (see Table 2.22). The major markets for exports of US GM maize are Japan and ROW and the presence of synchronicity leads to a smaller impact with exports only decreasing by 1.7% compared to scenario 1, but exports increase 1.3% compared to the base values.

Table 2. 21: Changes in the export value of GM Maize due to shocks in scenario 2 (million US$)

Description	Argentina	Brazil	Canada	Paraguay and Uruguay	US	Total
GM Maize base value	1,461.7	1,281.5	402.9	111.96	7,358	10,616
Changed in value due to scenario 2	56.6	-358	-18.4	-13.5	93.7	-239.6
Percent change in value	3.9%	-27.9%	-4.6%	-12%	1.3%	-2.3%

Source: GTAP analysis

Table 2. 22: Changes in the import value of GM maize due to shocks in scenario 2 (million US$)

Description	EU28	Japan	Mexico	ROW	Total
GM Maize base value	1,218	1,944.8	1,061.7	6,780.5	11,697.5
Changed in value due to scenario 2	-368	4.3	-61	231	-239.6
Percent change in value	-30.3%	0.2%	-5.7%	3.4%	-2%

Source: GTAP analysis

The GM soya and rapeseed sectors are less affected by the asynchronous approval since approvals happen more evenly and there are less commercialised GM events present in these sectors. There is only one GM soya event commercialized and four GM rapeseed events compared to nine commercialized GM maize events. Application of the general equilibrium model shows the linkages between the various sectors and regions did affect these two markets. Even though the total trade flows increased US$295 million for GM soya and US$34 million for GM rapeseed, the result is less when compared to scenario 1 because of the linkage effect caused by the asynchronous shock. Since maize, soya and rapeseed are used as inputs in other industries such as meat products, food products, vegetable oils, etc. changes in the three crop sectors can cause changes in these other industries due to the linkages effect. In the first scenario there is a total increase of US$1.3 billion in trade flows for all industries including the maize, soya and

rapeseed sectors. In the second scenario where trade barriers are included there is a decrease of US$22 million in trade flow for all sectors compared to the base data values.

Table 2. 23: Changes in the export value of GM soya due to shocks in scenario 2 (million US$)

Description	Argentina	Brazil	Canada	US	Total
GM Soya base value	3,428.2	4,360	524.5	6,529.6	15,723
Changed in value due to scenario 2	253.7	-150.7	38	148	294.6
Percent change in value	7.4%	-3.5%	7.3%	2.3%	1.9%

Source: GTAP analysis

Table 2. 24: Changes in the import value of GM soya due to shocks in scenario 2 (million US$)

Description	China	EU28	Japan	ROW	Total
GM Soya base value	9,442.8	3,313.6	1,069.3	3,715.9	19,054.4
Changed in value due to scenario 2	63.3	99.7	10.6	131.8	294.6
Percent change in value	0.7%	3%	1%	3.5%	1.6%

Source: GTAP analysis

Table 2. 25: Changes in the export value of GM rapeseed due to shocks in scenario 2 (million US$)

Description	AusNz[13]	Canada	Total
GM rapeseed base value	10	829.7	878.2
Changed in value due to scenario 2	-1.6	37.1	34
Percent change in value	-16.2%	4.5%	3.9%

Source: GTAP analysis

Table 2. 26: Changes in the import value of GM rapeseed due to shocks in scenario 2 (million US$)

Description	China	EU28	ROW	Total
GM rapeseed base value	189	3.9	160	965
Changed in value due to scenario 2	3.9	-0.5	12.6	34
Percent change in value	2%	-12.8%	7.9%	3.5%

Source: GTAP analysis

[13] Australia and New Zealand

2.3.5.3 Scenarios 3 and 4

Scenario three examines the impact on trade flows when GM events in the commercial, regulatory and advanced R&D pipelines are adopted at a 5% level by countries that have previously adopted GM maize, soya and rapeseed. These effects are shown in Tables 2.27 to 2.32. Scenario three includes a total of 38 GM events in the pipeline for the crops maize, soya and rapeseed. There are no trade barriers for the events in the pipeline, however, the trade barriers for the commercial GM events from scenario two are present.

Considering the existence of free trade for the events in the pipeline the results indicate a boost in global trade flows. Hence, the total trade boost is US$1.24 billion for GM maize, US$1.5 billion for GM soya and US$114 million for GM rapeseed. The existence of new varieties of GM maize reduced Brazil's export loss that arose in scenario 2. In scenario 3 Brazil's export loss is 12% lower than the base value (see Table 2.27), comparatively in scenario 2 the export loss was 37.9% lower than the base value. The situation on the import side is similar for the EU28's imports of GM maize that come mainly from Brazil. The reduced EU28 imports are reduced 16.6% from the base values (see Table 2.28), comparatively in scenario 2 import losses were 30.3% lower than the base values.

Exports of GM maize from the US actually increase US$1.3 billion or 17.9% from the base value. Japan and ROW, two major importers of GM maize from the US, increased imports 14% and 14.6% respectively from the base values.

Table 2. 27: Changes in the export value of GM maize due to shocks in scenario 3 (million US$)

Description	Argentina	Brazil	Canada	China	US	Total
GM Maize base value	1,461.6	1,281.5	402.9	0	7,358	10,616
Changed in value due to scenario 3	89.4	-154.9	92.9	51.4	1,315.3	1,240.7
Percent change in value	6.1%	-12%	23%	N/A	17.9%	11.7%

Source: GTAP analysis

Table 2. 28: Changes in the import value of GM maize due to shocks in scenario 3 (million US$)

Description	EU28	Japan	Mexico	ROW	Total
GM Maize base value	1,218	1,944.8	1,061.7	6,780.5	11,697.5
Changed in value due to scenario 3	-202.8	274.9	79.9	989.6	1,240.7
Percent change in value	-16.6%	14.1%	7.5%	14.6%	10.6%

Source: GTAP Analysis

In the soya sector the US and Argentina received the largest export boost with values of US$708 million and US$638.7 million respectively compared to the base values (see Table 2.29). Brazilian soya exports only increased US$82 million from the base value, but when compared to scenario 2 soya exports increased US$232.7 million. The increased exports from US, Argentina and Brazil are absorbed by the largest importers: China, ROW and EU28 whose imports increased US$619 million, US$363 million and US$318million respectively (see Table 2.30).

Table 2. 29: Changes in the export value of GM soya due to shocks in scenario 3 (million US$)

Description	Argentina	Brazil	China	US	Total
GM Soya base value	3,428.2	4,360	0	6,529.6	15,723
Changed in value due to scenario 3	638.7	82	67.4	708.4	1,515.1
Percent change in value	18.6%	1.9%	N/A	10.9%	9.6%

Source: GTAP analysis

Table 2. 30: Changes in the import value of GM soya due to shocks in scenario 3 (million US$)

Description	China	EU28	Japan	ROW	Total
GM Soya base value	9,442.8	3,313.6	1,069.3	3,715.9	19,054
Changed in value due to scenario 3	619.2	318.1	79.7	363.4	1,515
Percent change in value	6.6%	9.6%	7.5%	9.8%	8%

Source: GTAP Analysis

Canada and the US as adopters of the new GM rapeseed events in the pipeline generate large export growth US$66.5 million and US$43.8 million respectively (see Table 2.31). The EU28 experiences the largest percentage increase for GM rapeseed imports at 124% or US$4.8 million (see Table 2.32). In dollar value terms the largest import increase of GM rapeseed happens in Mexico and ROW with US$28 million and US$32 million. China has two domestic GM events in the pipeline, a GM soya and a GM rapeseed event, and while the purpose of their development is for domestic use the results did list China as a small exporter for both crops.

Table 2. 31: Changes in the export value of GM rapeseed due to shocks in scenario 3 (million US$)

Description	Canada	China	US	Total
GM rapeseed base value	829.7	0	38.19	878.2
Changed in value due to scenario 3	66.5	12.648	43.753	114
Percent change in value	8%	N/A	115%	13%

Source: GTAP Analysis

Table 2. 32: Changes in the import value of GM rapeseed due to shocks in scenario 3 (million US$)

Description	China	EU28	Japan	Mexico	ROW	Total
GM rapeseed base value	189	3.9	262	265.3	160	965
Changed in value due to scenario 3	14.2	4.8	14	28	32.4	114.3
Percent change in value	7.5%	124%	5.3%	10.6%	20.23%	11.8%

Source: GTAP Analysis

Scenario three only considered 38 single GM events in the pipeline. The literature predicts significantly more events forthcoming by way of stake events, and if stake events are to be considered then the trade growth would be considerably higher.

Scenario four considers the existence of GM events in the pipeline where selected importers impose a trade ban for certain GM events. The asynchronicity is again considered as in scenario 2, but with the presence of additional events and their effects on trade flows. Tables 2.33 to 2.38 outline the changes in trade flows given the imposition of trade barriers for certain GM events in the pipeline.

The common conclusion for scenario four is that the global trade for GM maize, soya and rapeseed is drastically reduced compared to scenario three even though there is an improvement from the base values. Comparison with the second scenario indicates that global trade is growing more when there are fewer asynhronized GM events on the market. With the presence of more GM events that are asynhronized there are more trade barriers placed for those events which have a negative impact on global trade flows.

The total value of global trade increased by US$97 million for GM maize (see Table 2.33), US$1.1 billion for GM soya (see Table 2.35) and US$106 million for GM rapeseed (see Table 2.37). However, export growth is actually reduced when scenario 4 is compared to scenario 3 from 11.7% to 0.92% for GM maize, from 9.6% to 7.3% for GM soya and from 13% to 12% for GM rapeseed. Equivalently to the export growth there is reduction in import growth when scenario 4 is compared scenario 3 (see Table 2.34, 2.36 and 2.38).

Table 2. 33: Changes in the export value of GM maize due to shocks in scenario 4 (million US$)

Description	Argentina	Brazil	PryUry	US	Total
GM Maize base value	1,461.6	1,281.5	112	7,358	10,616
Changed in value due to scenario 4	71.6	357.3	-98.3	409.6	97
Percent change in value	4.9%	27.9%	-87.8%	5.6%	0.92%

Source: GTAP Analysis

Table 2. 34: Changes in the import value of GM maize due to shocks in scenario 4 (million US$)

Description	EU28	Japan	Mexico	ROW	Total
GM Maize base value	1,218	1,944.8	1,061.7	6,780.5	11,697.6
Changed in value due to scenario 4	-48.2	483.1	-650.7	240	97.2
Percent change in value	-4%	24.8%	-61.3%	3.5%	0.8%

Source: GTAP Analysis

Table 2. 35: Changes in the export value of GM soya due to shocks in scenario 4 (million US$)

Description	Argentina	Brazil	US	Total
GM Soya base value	3,428.2	4,360	6,529.6	15,723
Changed in value due to scenario 4	331.4	275	600	1,147.7
Percent change in value	9.7%	6.3%	9.2%	7.3%

Source: GTAP Analysis

Table 2. 36: Changes in the import value of GM soya due to shocks in scenario 4 (million US$)

Description	China	EU28	Japan	ROW	Total
GM Soya base value	9,442.8	3,313.6	1,069.3	3,715.9	19,054.4
Changed in value due to scenario 4	723.3	104.2	95.5	77.2	1,147.7
Percent change in value	7.7%	3.2%	9%	2%	6%

Source: GTAP Analysis

Table 2. 37: Changes in the export value of GM rapeseed due to shocks in scenario 4 (million US$)

Description	Australia and New Zeeland	Canada	China	US	Total
GM rapeseed base value	10	829.7	0	38	878.2
Changed in value due to scenario 4	-0.9	65.5	12.7	43	105.9
Percent change in value	-9%	7.9%	N/A	112%	12%

Source: GTAP Analysis

Table 2. 38: Changes in the import value of GM rapeseed due to shocks in scenario 4 (million US$)

Description	China	Japan	Mexico	ROW	Total
GM rapeseed base value	189	262	265.3	160	965
Changed in value due to scenario 4	14.2	14.4	26.6	32.4	105.9
Percent change in value	7.5%	5.5%	10%	20.3%	11%

Source: GTAP Analysis

2.3.5.4 Scenario 5 and Systematic Sensitivity Analysis

As a result of the asynchronous GM event approvals, exporters take expensive measures to segregate GM and non-GM crops in their shipments. However, those measures are not successful at all times and can create shipment incidents that can be very costly for the exporter and can have a negative effect on the sector level. Past examples of such incidents are discussed in section 2.2.1.

This scenario discusses the change in trade flows with an initial 5% co-mingling and cross co-mingling rate for non-GM maize, non-GM soya, non-GM rapeseed, rice and wheat in the EU28 region. Table 2.39 displays the results from scenario 5. A 5% co-mingling in the rice sector creates a reduction in trade for US$54 million, for the wheat sector the value is US$543 million, for the non-GM maize the value is US$543 million, for the non-GM soya the value is US$45 million and for the non-GM rapeseed the value is US$5.8 million. The linkages effect captured

in the general equilibrium model indicates a decrease in the trade flows of meat products of US$390 million and vegetable oil of US$652 million.

Table 2. 39: Changes of trade flow values with 5% of co-mingling and cross-co-mingling

Description	Total
Rice base values (millions US$)	1,562
Changed in values due to scenario 5 (millions US$)	-53.7
Percent change in value	-3.4%
Wheat base value (million US$)	29,820
Changed in value due to scenario 5	-543.4
Percent change in value	-1.8%
Non-GM maize base value (million US$)	14,436.4
Changed in value due to scenario 5	-345.9
Percent change in value	-2.4%
Non-GM soya (million US$)	4,928.5
Changed in value due to scenario 5	-44.8
Percent change in value	-0.9%
Non-GM rapeseed (million US$)	2,050.5
Changed in value due to scenario 5	-5.8
Percent change in value	-0.3%

Source: GTAP analysis

The 5% assumption regarding co-mingling and cross co-mingling between GM and non-GM crops varies for each individual incident. For example Viju et al. (2011) indicates the case that seven percent of Canadian flax export shipments being comingled with CDC Triffid Flax. The known case of conventional US rice shipments destined for the EU market that were contaminated with GM event LL601 resulted in a 95% reduction in US rice exports to the EU market.

Capturing the variation or sensitivity of co-mingling and cross co-mingling between GM and non-GM crops is implemented through a systematic sensitivity analysis. Figure 2.15 shows the systematic sensitivity analysis for scenario 5 with 100% variation in the external shock for co-

mingling. In GTAP the 5% co-mingling is shown as a 5% reduction in the imports for the specific non-GM crops. In the rice sector the calculated mean for the shock is -5.7% and the deviation of the result is US$40.8 million, thus the final result can be in the range between negative US$86.4 million to US$ 29 million. The wheat sector has a 5% calculated mean and a standard deviation of negative US$40.8 million, therefore the final result can range between negative US$421.9 million to US$312 million. The mean for the non-GM maize is -6.9% with a standard deviation of US$40.8 and the final result ranges between -US$381.7 million to -US$ 266.3 million. The calculated mean for non-GM rapeseed is -2.2% with a standard deviation of 40.8 million and the final results ranges between negative US$74 million to US$7.5million. The mean for non-GM soya is 0% with a standard deviation of US$40.8 million and range between negative US$115.8 million and negative US$-6 million.

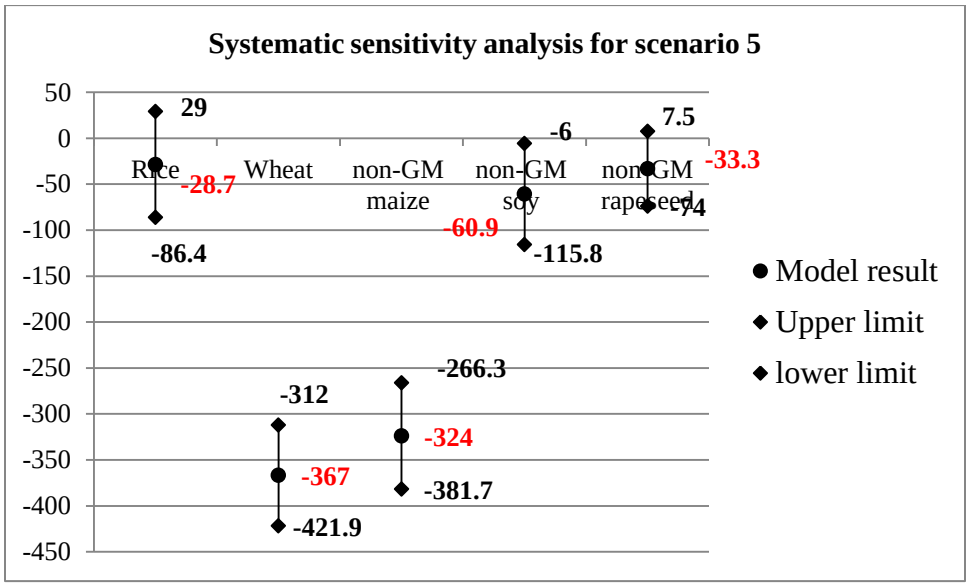

Figure 2. 15: Systematic sensitivity analysis for co-mingling and cross co-mingling between GM and non-GM crop shipments
Source: GTAP analysis

2.3.5.5 Summary of the Scenarios

In summary, each scenario supplements the previous scenario through additional levels of protection or consideration of a new GM event and the gain that this technology can produce. Thus, reviewing the aggregate results provides a good view of the total effect that asynchronicity can cause in the presence of more and new GM events on the market.

Table 2.40 summarizes aggregate trade flows for scenarios 1 through 4. The first scenario describes the global trade of maize, soya and rapeseed by considering the efficiency gain that GM technology can bring in the absence of technological trade barriers. The results reveal an increase in global trade of maize, soya and rapeseed valued at US$ 927 million. When the linkages to the other industries are considered, the increased trade flows is valued at US$ 1.28 billion in total global trade. Scenario 2 assesses trade flows when the technological trade barriers are considered as a result of the asynchronous approval of commercial GM maize, soya and rapeseed events. As a result of barriers for certain commercial GM events there is a reduction in the trade value of maize, soya and rapeseed of US$ 843 million from scenario 1, and when linkages to other industries are considered the total reduction of global trade is US$ 1.3 billion, erasing the trade gains in scenario 1. Scenario 3 examines changes in trade flows when new GM events currently in the pipeline for maize, soya and rapeseed are considered, resulting in an aggregate trade increase to US$ 3.7 billion for the three crops from scenario 2. When the linkages to other industries are considered, global trade increased to US$ 4.2 billion in scenario 3. Scenario 4 builds on scenario 3 by only considering certain trade barriers for particular GM events in the pipeline for the three crops. The results show a decrease in global trade flows for

the three crops to US$2.4 billion compared to scenario 3 and when linkages to other industries are considered trade flows decrease to US$ 2.8 billion.

Table 2. 40: Aggregate changes in trade flows due to shocks in scenario 1 through 4

Crop type	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Maize	0.5	-7.4	-1.68	4.62
GM maize	287	-527	1,767.7	-1,670.7
Soya	1.6	0.8	4.42	-1.02
GM soya	591	-296	1,811	-664
Rapeseed	2.9	-3.2	11.07	-4.83
GM rapeseed	44	-10	124.33	-19.33
Total	927	-842	3,716.48	-2,355.26

Source: GTAP Analysis

The asynchronized approval does reduce the benefit that biotechnologies can generate. This can be seen in scenarios 2 and 4 where asynchronicity is present for certain GM events as indicated by lower trade flows compared to scenarios 1 and 3 where trade flows are without barriers. As the availability of GM events increases in the pipeline there will be a larger impact on trade and thus a larger reduction in the absolute trade value flow when asynchronicity is present. This is shown in scenarios 2 and 4, where in scenario 2 there are fewer GM events commercialized and thus less of a reduction in trade compared to scenario 4 where more GM events are available. The reduction in trade flow in scenario 2 is US$ 843 million compared to scenario 4 where trade flows were reduced by US$ 2.4 billion. However, society is better off having more GM events on the market even with the presence of asynchronicity, as the increase in trade flows is larger as a result of new GM events over the reduction in the trade flows caused by asynchronicity. Thus, scenario 4 with more GM events available on the market resulted in an increase of overall trade flows for the three crops of US$ 1.4 billion from the base value, compared to scenario 2 with

fewer GM events that only resulted in an increase of trade flows of US$ 84 million from the base value.

Asynchronicity also impacts co-mingling and cross-comingling of an unapproved GM event in non-GM crops. Scenario 5 considers trade flow changes for non-GM maize, non-GM soya, non-GM rapeseed, rice and wheat in the EU28 region when there is a 5% co-mingling and cross-co-mingling rate. Aggregating the losses of scenario 5 and scenario 4 results in a reduced trade flow value of US$ 3.4 billion from the presence of asynchronicity and co-mingling and cross-co-mingling. Additionally, these crops are crucial inputs in the feed, food, and drink industries as shown in Appendix A, Figure 2.A.1. Thus, as mentioned in scenario 5 it does cause a certain level of reduction in the trade of meat products and vegetable oils, bringing the total aggregated loss of trade flows to US$ 4.4 billion.

2.4 Conclusion

In this essay a global measurement was completed on the effect that the expanding GM pipeline has on international trade given the constraint of asynchronous regulations for a new GM event among countries. More specifically it concentrated on the opportunities foregone including the gains and losses that evolved in the trade flows between countries caused by the asynchronous approval of GM events. Further to this, the increasing exports of non-GM crops being comingled with GM traits were evaluated. Therefore, the main measurements completed in this essay were the trade flow changes as new GM maize, soya and rapeseed events became available and were adopted by the following countries: US, Argentina, Paraguay, Uruguay, Brazil, Canada and China (discussed in scenarios 1 and 3). Next, scenarios 2 and 4 calculated the trade flow changes

that arose from the asynchronous approval of these GM events, through the implementation of import bans for specific events. Lastly in scenario 5 the trade flow changes arising from co-mingling and cross-co-mingling between GM and non-GM crops for EU28 region was calculated.

The empirical measurements were conducted through the utilization of the GTAP model. GTAP uses global datasets and through summation of the microeconomic activities within the economies in question, can describe the macroeconomic behavior of those specific economies including the bilateral trade flows among the included countries. The advantage of utilizing a global computable general equilibrium model is when specific shocks are imposed the change in trade flows for the sector of interest can be measured while also capturing the trade flow changes resulting from the sector linkage effect. Moreover, the three crops of interest in this essay, maize, soya and rapeseed, are used as important inputs in the meat and food product sectors and capturing the linkage effect is an important component.

The simulation results indicate that asynchronicity does affect trade flows on a global level. When commercial GM events were considered in scenario 2, the total trade flow reduction for GM soya, maize and rapeseed is US$833 million. When the linkages to other industries are considered as a result of this asynchronicity the value of trade lost is much larger at US$1.3 billion compared to free trade. Moreover, the higher the number of GM events available with less synchronicity between them the greater the impact on trade flows. Scenario 2 shows that for the soya and rapeseed sectors that have fewer GM events commercialized the trade flow impact

is less severe compared to the maize sector that has significantly more commercialized GM events.

In scenario 3 the adoption of additional new GM varieties by countries which have previously adopted GM maize, soya and rapeseed see a significant boost of US$2.8 billion in global trade for these crops when free trade for these new varieties is present. However, when asynchronicity is introduced in scenario 4 the trade gain is reduced to US$1.35 billion. While scenario 4 has an increased number of GM events available and trade barriers reduce the trade flow gain, the outcome is still an improvement over scenario 2 where the total trade gain across the three sectors was only US$89 million.

The trade consequences resulting from the unintended presence of GM events in the shipment of non-GM crops has been of great concern since the asynchronicty of GM events evolved. This essay also considered the effect this trend has had on rice, wheat and the non-GM maize, soya and rapeseed sectors. The results for scenario 5 indicate a reduction in trade flows of US$993.6 million for all of the sectors. Systematic sensitivity analysis indicates a larger variation in the value of rice, wheat and non-GM maize as a result of co-mingling and cross-co-mingling.

Simulations that are conducted with general equilibrium models have the disadvantage of sizeable sector and region aggregation. However, this essay did extend alteration of sector disaggregation and included a wide range of region. In this way the results from the modified model reveal the need for better synchronization of GM events so that trading partners can absorb the technological benefits.

2.4.1 Contribution, Limitations and Suggestions for Future Research

The major contribution of this research is quantifying the effect that asynchronized regulations for GM maize, soya and rapeseed have on international trade when GM events in the pipeline for the same crops are considered. Secondly, this research assesses the trade flow effect that asynchronized regulation through non-approval in the EU28 region have on co-mingling and cross-co-mingling for non-GM maize, non-GM soya, non-GM rapeseed, rice and wheat. Lastly, it contributes to GTAP modeling through the extended alteration for the maize, soya and rapeseed sectors by disaggregating them to GM and non-GM crops and finally the GM crops to GM events.

The main limitation of this research relates to the GTAP analysis using a general equilibrium model. Thus, the model applies the assumption of full employment, perfect competition and consumer decision on purchasing a product based on the lowest price. However, preference and taste may be the factors that likely influence the purchase decision by EU consumers when deciding between GM or non-GM products. A second limitation of this study is that GTAP data is gathered from many sources and has to be adjusted for the assumptions of a general equilibrium model, thus some data values become an approximation to the real values.

Based on the limitations, future work on this research question may include the application of different models where the factors of taste and preference are considered. Another area of future research would be to analyse the impact of asynchronous regulation on trade flows in the feed, food and drink industries given that maize, soya and rapeseed are crucial inputs in those industries On the production side, future research on the acreage changes between GM and non-

GM crops given the commercialization of new GM events and the presence of asynchronicity constraints. Lastly, the application of biotechnology on other plants and crops and the impact on international trade given the constraint of asynchronicity is another potential extension of this research topic.

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APPENDIX A - SOYBEAN, MAIZE AND CANOLA IN THE FOOD PRODUCTION

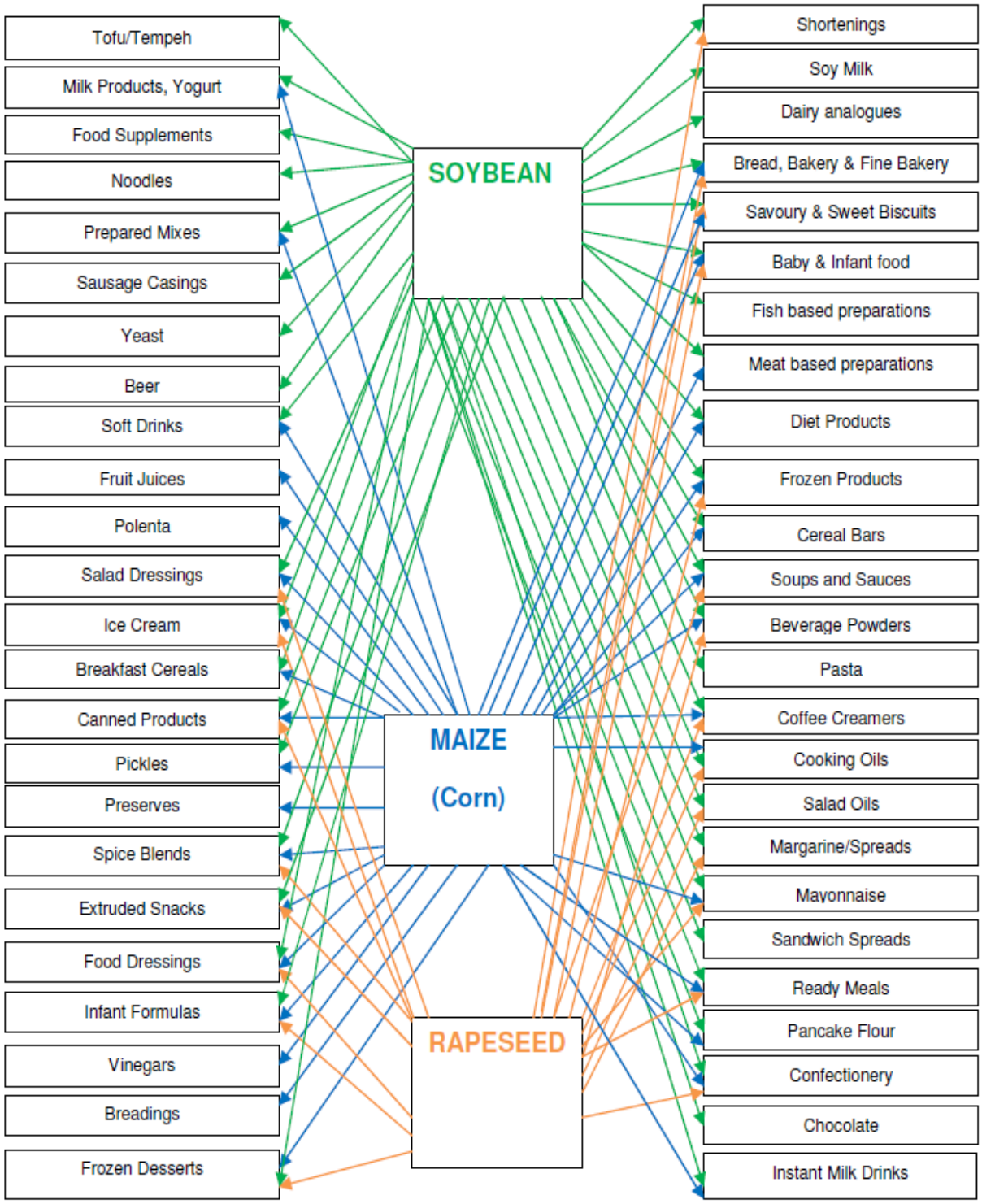


Figure 2.A. 1: Use of soybean, maize and rapeseed in the food production

Source: Landmark Europe, (2009)

APPENDIX B – REGIONS, SECTORS, AND SAM IN THE GTAP

Table 2.B. 1: Region in the GTAP 8

Code	Region Description	Code	Region Description	Code	Region Description
aus	Australia	nic	Nicaragua	kgz	Kyrgyztan
nzl	New Zealand	pan	Panama	xsu	Rest of Former Soviet Union
xoc	Rest of Oceania	slv	El Salvador	arm	Armenia
chn	China	xca	Rest of Central America	aze	Azerbaijan
hkg	Hong Kong	xcb	Caribbean	geo	Georgia
jpn	Japan	aut	Austria	bhr	Bahrain
kor	Korea	bel	Belgium	irn	Iran Islamic Republic of
mng	Mongolia	cyp	Cyprus	isr	Israel
twn	Taiwan	cze	Czech Republic	kwt	Kuwait
xea	Rest of East Asia	dnk	Denmark	omn	Oman
khm	Cambodia	est	Estonia	qat	Qatar
idn	Indonesia	fin	Finland	sau	Saudi Arabia
lao	Lao People's Democratic Republ	fra	France	tur	Turkey
mys	Malaysia	deu	Germany	are	United Arab Emirates
phl	Philippines	grc	Greece	xws	Rest of Western Asia
sgp	Singapore	hun	Hungary	egy	Egypt
tha	Thailand	irl	Ireland	mar	Morocco
vnm	Viet Nam	ita	Italy	tun	Tunisia
xse	Rest of Southeast Asia	lva	Latvia	xnf	Rest of North Africa
bgd	Bangladesh	ltu	Lithuania	cmr	Cameroon
ind	India	lux	Luxembourg	civ	Cote d'Ivoire
npl	Nepal	mlt	Malta	gha	Ghana
pak	Pakistan	nld	Netherlands	nga	Nigeria
lka	Sri Lanka	pol	Poland	sen	Senegal
xsa	Rest of South Asia	prt	Portugal	xwf	Rest of Western Africa
can	Canada	svk	Slovakia	xcf	Central Africa
usa	United States of America	svn	Slovenia	xac	South Central Africa
mex	Mexico	esp	Spain	eth	Ethiopia
xna	Rest of North America	swe	Sweden	ken	Kenya
arg	Argentina	gbr	United Kingdom	mdg	Madagascar
bol	Bolivia	che	Switzerland	mwi	Malawi
bra	Brazil	nor	Norway	mus	Mauritius
chl	Chile	xef	Rest of EFTA	moz	Mozambique
col	Colombia	alb	Albania	tza	Tanzania

ecu	Ecuador	bgr	Bulgaria	uga	Uganda
pry	Paraguay	blr	Belarus	zmb	Zambia
per	Peru	hrv	Croatia	zwe	Zimbabwe
ury	Uruguay	rou	Romania	xec	Rest of Eastern Africa
ven	Venezuela	rus	Russian Federation	bwa	Botswana
xsm	Rest of South America	ukr	Ukraine	nam	Namibia
cri	Costa Rica	xee	Rest of Eastern Europe	zaf	South Africa
gtm	Guatemala	xer	Rest of Europe	xsc	Rest of South African Customs
hnd	Honduras	kaz	Kazakhstan	xtw	Rest of the World

Source: GTAP 8 database

Table 2.B. 2: Sectors in the GTAP 8

Code	Sector Description	Code	Sector Description
pdr	Paddy rice	lum	Wood products
wht	Wheat	ppp	Paper products, publishing
gro	Cereal grains nec	p_c	Petroleum, coal products
v_f	Vegetables, fruit, nuts	crp	Chemical,rubber,plastic prods
osd	Oil seeds	nmm	Mineral products nec
c_b	Sugar cane, sugar beet	i_s	Ferrous metals
pfb	Plant-based fibers	nfm	Metals nec
ocr	Crops nec	fmp	Metal products
ctl	Cattle,sheep,goats,horses	mvh	Motor vehicles and parts
oap	Animal products nec	otn	Transport equipment nec
rmk	Raw milk	ele	Electronic equipment
wol	Wool, silk-worm cocoons	ome	Machinery and equipment nec
frs	Forestry	omf	Manufactures nec
fsh	Fishing	ely	Electricity
coa	Coal	gdt	Gas manufacture, distribution
oil	Oil	wtr	Water
gas	Gas	cns	Construction
omn	Minerals nec	trd	Trade
cmt	Meat: cattle,sheep,goats,horse	otp	Transport nec
omt	Meat products nec	wtp	Sea transport
vol	Vegetable oils and fats	atp	Air transport
mil	Dairy products	cmn	Communication
pcr	Processed rice	ofi	Financial services nec
sgr	Sugar	isr	Insurance
ofd	Food products nec	obs	Business services nec
b_t	Beverages and tobacco	ros	Recreation and other services

	products		
tex	Textiles	osg	PubAdmin/Defence/Health/Educat
wap	Wearing apparel	dwe	Dwellings
lea	Leather products		

Source: GTAP 8 database

Table 2.B. 3: Accounting identities in SAM

Aggregate demand= Aggregate supply
Aggregate demand= Intermediate consumption(C_{IN})+ Household consumption(C_H)+ Government spending (G)+ Gross capital formation(I)+Export(E)
Aggregate supply= Domestic production (Y)+Imports(M)
C+G+I+E=Y+M
Y=C+T(tax payments)+S_h (private savings)
I=S_h+S_g(government savings)+S_f(foreign savings)
E+S_f=M

Source: Kerkela, (2009)

	Producer	**Commodities**	**Factor of production**	**Household**	**Government**	**Savings-Investment**	**Rest of the World**	**Total**
Producer		Domestic production						Domestic sales
Commodities	Demand for domestic and imported intermediates			Household demand	Government demand	Domestic and import demand	Exports	Aggregate demand
Factor of production	Factor payment							Factor income
Household			Net factor income	Household income				Aggregate income
Government	Taxes on firm	Import/Export taxes	Income taxes	Household /sales taxes		Taxes on capital goods	Transfer from the rest of the world	Government income
Savings-Investment			depreciation	Domestic savings/investment	Government savings		Foreign savings	Savings
Rest of the World		Imports						Foreign value outflow
Total	Gross value of production	Aggregate supply	Factor expenditures	Household expenditures	Government expenditure	Investment expenditure	Foreign value inflow	

Figure 2.B. 1: Social Accounting Matrix in GTAP
Source: Burfisher, (2011)

APPENDIX C – LISTS OF APPROVED AND UNAPPROVED GM EVENTS IN THE PIPELINE

Table 2.C. 1: Commercial GM events approval in certain regions

		Argentina	AusNz	Brazil	Canada	China	EU28	India	Japan	Mexico	PryUry	ROW	Russia	Ukraine	USA
Maize	MON810	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes
	NK603	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes
	MON863	no	yes	no	yes	yes	yes	no	yes	yes	no	yes	yes	no	yes
	MON88017	no	no	no	yes	no	no	no	yes	yes	yes	yes	yes	no	yes
	1507	yes	yes	yes	yes	no	yes	no	yes	yes	yes	yes	no	no	yes
	59122	no	yes	no	yes	yes	yes	no	yes	yes	no	yes	no	no	yes
	Bt11	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes
	GA21	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes
	MIR604	no	yes	no	yes	no	no	no	yes	yes	yes	yes	yes	no	yes
Soybean	MON 40-3-2	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes
Rapeseed	T45 (HCN28)	no	yes	no	yes	yes	yes	no	yes	yes	no	yes	no	no	yes
	GT73 (RT73)	no	yes	no	yes	yes	yes	no	yes	yes	no	yes	no	no	yes
	MS8	no	yes	no	yes	yes	yes	no	yes	yes	no	yes	no	no	yes
	RF3	no	yes	no	yes	yes	yes	no	yes	yes	no	yes	no	no	yes

Source: Stein, A.J. and E. Rodríguez-Cerezo (2009a)

Table 2.C. 2: GM Events in the Pipeline Approved in Certain Regions

		Argentina	AusNz	Brazil	Canada	China	EU28	India	Japan	Mexico	PryUry	ROW	Russia	Ukraine	USA
Maize	MON89034	yes	yes	yes	yes	yes	yes	no	yes	no	n/a	n/a	no	No	yes
	LY038	n/a	yes	n/a	yes	n/a	no	no	yes	yes	n/a	n/a	no	no	yes
	3272	no	n/a	n/a	yes	yes	no	n/a	n/a	yes	n/a	n/a	n/a	n/a	yes
	MIR162	yes	yes	yes	yes	n/a	n/a	n/a	no	no	n/a	n/a	n/a	n/a	yes
	n/a(China)	no	no	no	no	yes	no	no	no	no	no	no	no	no	no
	98140	n/a	n/a	n/a	yes	n/a	no	n/a	no	n/a	n/a	n/a	n/a	n/a	yes
	n/a(China)	no	no	no	no	yes	no	no	no	no	no	no	no	no	no
	n/a(China)	no	no	no	no	yes	no	no	no	no	no	no	no	no	no
	MON87460	n/a	yes	n/a	yes	yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes
	MON87754	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes
	n/a(Monsanto)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	n/a(Monsanto)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes
	DHT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	n/a(India)	n/a	n/a	n/a	n/a	n/a	n/a	yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	n/a(BASF)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soya	A2704-12	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes
	MON 89788	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes
	356043	no	yes	no	yes	no	no	no	yes	yes	no	yes	no	no	yes
	A5547-127	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	no	yes
	305423	n/a	n/a	n/a	yes	n/a	no	n/a	yes	n/a	n/a	n/a	n/a	no	no
	n/a(China)	no	no	no	no	yes	no	no	no	no	no	no	no	no	no
	CV127	n/a	n/a	n/a	yes	n/a	no	n/a	yes	n/a	n/a	n/a	n/a	no	no
	n/a(Syngenta)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	n/a
	MON87769	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	n/a	n/a	n/a	n/a	no	yes

	n/a(Syngenta)	n/a	n/a	yes	yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	yes
	n/a(Monsanto)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	yes
	n/a(Monsanto)	n/a	n/a	yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	yes
	MON87754	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	n/a	n/a	n/a	n/a	no	yes
	n/a(Bayer)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	n/a
	n/a(Bayer)	yes	n/a	yes	yes	n/a	yes	n/a	n/a	n/a	n/a	n/a	n/a	no	yes
	n/a(DHT)	yes	n/a	yes	yes	n/a	yes	n/a	n/a	n/a	n/a	n/a	n/a	no	yes
Rapeseed	CPGMRap	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	n/a(China)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	n/a(Bayer)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	n/a(Bayer)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	n/a(Bayer)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	n/a(BASF)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	n/a(BASF)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Source: Stein, A.J. and E. Rodríguez-Cerezo (2009a)

APPENDIX D- ADOPTION RATE OF GM CROPS ACROSS REGIONS

Table 2.D. 1: Cultivation of GM crops in regions in percent value

GM	Soybeans	Rapeseed	Maize
1 Argentina	100	0	86
2 Australia and New Zeeland	0	8	0
3 Brazil	75	0	56
4 Canada	73.3	94	90
5 China	0	0	0
6 EU28	0	0	1.35
7 India	0	0	0
8 Japan	0	0	0
9 Mexico	83	0	0
10 Paraguay and Uruguay	97	0	83
11 Rest of World	0	0	0
12 Russia	0	0	0
13 Ukraine	0	0	0
14 US	93	88	86

Source: James, 2011

CHAPTER 3

EU Regulation of Genetically Modified Products: Implications for Exporter's Risk

3.1 Introduction

The EU's cautious approach towards biotechnology has resulted in import restrictions on GMOs including a de facto import moratorium from 1999 until 2003. This moratorium was perceived as a nontariff trade barrier by many countries whose export opportunities were reduced as a result of the EU's domestic policy regulations. As a result, the US, Canada, and a number of other countries filed complaints with the WTO regarding the restrictive effect of the moratorium. The decision of the WTO Panel charged with resolving the dispute ruled in September 2006 that the EU restrictions on GM products were in violation of international trade rules and that the EU had acted in ways which contradicted its obligations under the Sanitary and Phytosanitary (SPS) Agreement.[14,15] Specifically, the Panel indicated that the EU had ignored its obligations to provide a justification for product-specific measures, allowed the use of non-science-based criteria, and failed to undertake a risk assessment. Shortly after the WTO Panel handed down

[14] The purpose of the SPS Agreement is to regulate the movement of products across international borders and to ensure that sanitary and phytosanitary regulations are not being used as disguised barriers to trade.
[15] The panel found that EU Communities applied a general de facto moratorium on the approval of biotechnology products between June 1999 and August 2003, and thus violated Article 8 and Annex C(1) of the SPS Agreement. Further, it found that the EU acted inconsistently in respect to the approval of 24 out of 27 biotech products. Finally, with regards to European Communities' member state safeguard measures, the panel found that that EU acted inconsistently with its obligation under Article 5.1 and 2.2 of the SPS Agreement regarding all of the safeguard measures at issue. These findings indicate that the EU moratorium and product-specific measures undertaken were not based on scientific evidence or on risk assessment requirements as specified under the SPS Agreement.

their ruling, the EU announced its intention to comply with the Panel's recommendations and to work to resolve GMO legislative and trade issues within a reasonable period of time (RPT)[16].

Meanwhile, in 2003 a new stringent regulatory system was put in place regarding the approval, labeling, and traceability of GM products. This was accomplished through EU Commission directive 2001/18, and regulations 1829/2003 and 1830/2003. These regulations accommodated the preferences of various anti-GM groups and interests in the EU[17].

The first product that successfully passed the new EU regulation regime of 2003 was BASF's Amylopectin (Amflora) potato, which received approval on March 15, 2010, five years after the original application in February 2005 (Viju et al., 2011). The case of a GM product being licensed even after five year long period in the approval process was very contentious in some quarters. It precipitated further changes in the EU GM regulations. These changes resulted from domestic political difficulties in some of the individual Member States (MS) that continued to oppose the presence of any type of GM product in their territory, and these states continued using an internal EU safeguard measure as a tool to limit market access. This behavior resulted in new recommendations proposed by the EU Commission in July 2010. The suggested modifications were based on granting more freedom to the member states regarding the decision as to whether or not they will allow cultivation of GMOs that have been approved by the EU in their individual national territories. Under this recommendation member states (MS) can

[16] Due to the complexity of the issue, the EU asked for a reasonable period of time for implementation.
[17] According to Viju, et al. (2011) there are four anti-GM groups with strong preferences: 1) consumers worried about the safety and quality of their food; 2) environmentalists; 3) those with ethical concerns; and 4) groups concerned about the influence of multinational corporations on the food supply.

prohibit, partially prohibit, or allow GMO cultivation when drafting and setting legislation for cultivation of GMOs. However, the authorization for allowing GMOs market access remains at the EU level.

According to the EU, the changes made at EU level for the approval process of a GM product (with the passing of directive 2001/18 and regulations 1829/2003 and 1830/2003) along with the changes at the MS level (with the passing of recommendations 2010/C200/01) are in conformity with the SPS Agreement.

The SPS Agreement justifies the adoption of new stricter standards that are above the international level, but only if there is a scientific justification for doing so. Additionally, these stricter measures must be based on a risk assessment. However, the EU considers speculative risk[18] in the adoption of stricter standards, stating that the existence of no long term health effects and benign environmental impacts for GMO products has not been proven. As a result, the EU argues it is justified in using the precautionary[19] principle to introduce a more stringent regulatory system, temporary or not. Thus, the EU, by moving away from science-based decision making, allowed the influence of political factors to impose more stringent GMO import regulations on the grounds of potential harm to human, animal and plant health. By choosing this approach, the EU increased the risk for firms that want to invest in biotechnology and bring GM products into the EU market (Kerr, 2004). Further, the EU argued that exporting firms should

[18] Speculative risk is explained by Isaac (2007) "as risk which lacks experience, data, a casual-consequence mechanism and accepted analytical method for assessment, they are logical possibilities, irrefutable and untestable".

[19] The precautionary principle allows protective action to be taken before there is complete scientific information to justify that a risk is present, implying that protective action precedes scientific proof.

carry the burden of proof to demonstrate the safety of a product that an importing country had found to be "unsafe" and supported the "use of criteria other than science to justify SPS measures" (Freeman, 2004). Hence, when an exporting firm wants to sell a GM product on the EU market, it has to go through a lengthy approval process at the EU level, and, if needed, the cultivation process at the MS level. Both processes can be influenced by socio-economic factors beyond the control of the firm, and in spite of a product having received a science-based approval in the EU (as well as in the exporting country) (Viju et al., 2011).

The structure of the regulations regarding GMO approval in the EU and it's inconsistency with the multilateral trade commitments[20] indicates potential presence of risk for firms in agricultural biotechnology that want to enter the EU market. Bridging the regulator risk of the country with the investment consequences for the exporting firm in an economic theory model is the subject of this essay. Hence, the specific objectives of this essay is: evaluating the regulations in the decision approval process of a GMO in the EU and their consistency with the multilateral trade agreements; examining the literature for political risk where it reveals that regulatory burdens can be considered as a risk that can affect the investment of a firm; linking the political risk and the regulation for approval of GMOs in the EU into a specific definition; and designing a theory which will incorporate the complexity of the decision process in the EU for GMO as political risk and the effect of that risk on the investment decisions of the firm wishing to invest in new GM crops. Based on the stated objective, the two research questions that are addressed are defining and modeling the specific political environment created by the regulation decision

[20] Section 2 discusses further the apparent inconsistency of EU GMO approval regulations with multilateral commitments.

approval process of GMOs in the EU, and incorporating this political risk into the investment decision of firm wanting to invest in new GM crops.

3.2 EU Approach to the SPS Agreement and Risk Analysis Framework

In order to understand the functioning of the SPS agreement, the broader scope of multilateral trade liberalization and agreements should be considered (Isaac, 2007). The EU accepted the SPS as part of its signing on to the Uruguay round outcomes. The relevant provisions for agriculture biotechnology in the General Agreement on Tariffs and Trade (GATT) arising from the Uruguay round are national treatment (Article I) and most-favored nation (Article III). It should also be noted that the concept of like products should be included as a third provision even though it was not formally acknowledged in the GATT (Isaac, 2007). These provisions state that the treatment of foreign products must be the same as domestic products; that there should not be discrimination between like products from different countries; and that all like products should be treated the same way regardless of the processes and production methods (PPM) used.[21]

Incorporating biotechnology into these provisions means there should be no difference in the treatment of GM products and non-GM products because they are only un-like in their PPM. Thus, the international trading system should consider the outcome of the technology rather than the process of the technology (Isaac et al., 2002). As it is often not possible to physically distinguish the final GM product from the non-GM product, there should not be a trade barrier put in place on GM products on the basis of the PPM used (Dayananda, 2011). Hence, the end

[21] As described by Isaac et al. (2002) these three provisions are the baseline principles of the WTO principle of non-discrimination (PND) and can be used to identify legitimate violations of this principle given sufficient evidence.

use of the GM and non-GM product is the same regardless of the PPM that has been used in their creation (Isaac et al., 2002). However, under the SPS Agreement the violation of these three baseline principles can be allowed and will not be considered as discrimination of "like" products in cases where human, animal, and plant health and safety are at risk.

On the 1st January 1995 the SPS Agreement came in force; it includes human, animal and plant safety, and health regulations that a particularly country may put into place to restrict imports (Isaac, 2007). The purpose of the SPS Agreement is to regulate the movement of products across international borders without rules justified on Sanitary and Phytosanitary grounds being used as a disguised barrier to trade. Further, the SPS Agreement encourages countries to use agreed international standards[22] pertaining to health and the environment that are consistent with the WTO regulations. Countries can create domestic standards that are stricter than those agreed in the CODEX, OIE or IPPC, but only if there is scientific justification for doing so. If no international standards exist, countries can develop their own standards. According to the agreement, the most objective way to decide the legitimacy of a measure is through a scientific risk assessment procedure (Isaac et al., 2002). In order to assess risk, members are committed to consider the risk assessment techniques used in the international standards setting institutions, even if the relevant international standard is not being used. This raises the issue of the quality and appropriateness of the science used. If the quality and type of science is equivalent, then how can one know when enough science has been completed to constitute an acceptable degree of

[22] Organizations that establish international standards and that are recognized and considered consistent with the WTO are; the Codex Alimentarius Commission (CODEX) which handles food safety; the World Organization for Animal Health (OIE) which handles animal safety; and the International Plant Protection Convention (IPPC) which handles plant safety.

risk? Hence, the major challenge is in finding the compromise between SPS measures that legitimately restrict trade in order to protect human, animal, and plant safety or health and those measures justified on SPS grounds that unnecessarily restrict trade (Isaac et al., 2002).

Underlying the SPS Agreement is the Risk Analysis Framework (RAF), which provided boundaries on the type of unilateral trade restriction measures permissible to WTO Members if they wish to discriminate to restrict import of unsafe and risky agriculture products for the purpose of protecting human, animal, and plant health and safety (Issac, 2007). According to Issac (2007) there are three important provisions outlining circumstances when members are not required to grant either national treatment or most-favoured nation status. These are: to agricultural exporters whose products with unacceptable levels of risk associated with them are contaminating the domestic food supply or threatening the environment; they may establish domestics SPS measures higher than the international standard if there is legitimate justification to do so; and they may establish trade barriers based on the precautionary principle in event that there is insufficient scientific evidence to conduct an appropriate risk assessment (Isaac, 2007). These are described in Article 2:3, 3:3 and 5:7 of the SPS Agreement respectively. However, even though the SPS agreement is written in the language of the RAF, the interpretation and the application of the RAF is defined by domestic regulators when determining what is legitimately justifiable and what constitutes sufficient scientific evidence (Isaac, 2007).

The two alternative interpretations to the Risk Analysis Frameworks are described by Isaac et al. (2002) as the scientifically rationality approach and the socially rationality approach. Accordingly, the EU practices the socially rationality approach where science is just one facet of

the society, and that society also consists of other stakeholders that should be a part of the decision process. Thus, science has an informative role in the decision process for what can be considered legitimately justifiable, along with the non-science information which is also considered as legitimate factors to be included in the decision to arrive at a legitimate justification. Accordingly, the socially rationality approach uses speculative risk in defining the safety level of new technology resulting in an adoption of zero risk and a perfectly safe market access rule for GM technology. Hence, the use of precautionary principle as trade barrier in the case of insufficient scientific evidence to conduct an appropriate risk assessment is becoming political precaution[23], allowing the influence of political factors when deciding market access for GM products.

3.3 Process management of the approval of a GM product at the EU level

When an exporting firm from outside the EU wishes to market a GM product in one of the EU member states, then a certain processes are followed that must be considered both within the EU governmental structure and in the context of the interaction between those governmental institutions. Hence, each individual GM product to be sold on the EU market as either seed or used in the human food and animal feed industries must be approved through Directive 2001/18 or Regulation 1829/2003[24,25]. The length of the application process ranges from 1.5 to 8 years, regardless of the type of authorisation required (Viju et al., 2011).

[23] The 'precautionary principle' is nothing more than a retreat from decision making on the basis of scientific principles so that 'political precaution' can dominate decision making (Isaac et al., 2002).
[24] Regulation 1823/2003/EC regulates the placement of food and feed on the market; and Directive 2001/18/EC regulates the deliberate release of GMOs into the environment.

3.3.1 Approval Process through Regulation EC 1829/2003

Regulation 1829/2003/EC regulates the placement of food and feed on the EU market. The process for approval through this regulation starts by the firm submitting an application to the national competent authority (NCA) of one of the EU member states (Wesseler and Kalaitzandonakes, 2011). Potential factors determining the MS through which the firm will start the application process are explained by Viju et al. (2011) as: interest of the MS in the specific GMO; whether the applicant company is a crucial component of a strategic sector for the MS; the political and economic influence of the applicant company in the MS; whether the GMO in question is a significant component in the feed and food of a specific livestock sector or manufacturing industry in the MS respectively; MS history of successful applications for authorisation and its lobbing abilities at the community level; applicant prior experience working with the MS in GMO authorization; relationship between the firm applicant and the MS; and the location of the field trials. The NCA does the assessment of the application within 14 days and submits it to the European Food Safety Authority (EFSA) (Viju et al., 2011; Wesseler and Kalaitzandonakes, 2011). Further, the NCA informs all other MS about the application being made and informs the public by making summary of the application available (Wesseler and Kalaitzandonakes, 2011).

The EFSA preforms the scientific risk assessment of GMO products regarding food and feed safety and environmental safety. The EFSA provides a scientific opinion and advice through supporting decisions in the design of policy and legislation for the European Commission (EC)

[25] The difference between the regulation and directive is that the regulation is more binding in its definitions and each MS has to accept the same definitions, whereas the directive gives more freedom to the MS to interpret the ruling in various ways.

(EFSA, 2013a). After receiving the application the EFSA has a six month period to provide scientific opinion to the EC, this period can be extended if further data is required. Approval times vary with each individual evaluation (Viju et al., 2011). Lastly, the EFSAs opinion on the validity of the detection method[26] provided by the applicant to the EFSA is included, even though validation of the detection method is conducted by the EC Joint Research Center (JRC) (Wesseler and Kalaitzandonakes, 2011). The EFSA does not approve or authorise GMOs, it provides a science-based assessment (opinion) to the European Commission and the MS who take this into account together with other factors when deciding on the approval of the GMO (EFSA, 2013b).

After receiving the EFSAs opinion, the EC has to produce a draft decision within three months. In this period the EC releases the EFSAs opinion to the public and the MS. The EFSAs opinion is published on the Commission's website, where public has the opportunity to comment within 30 days of its publication (Viju et al., 2011). The EC analyzes all public comments and by consultation with the EFSA determines if the comments have an impact on the EFSA's opinion and if it should be considered in the draft decision by the EC.

The EC's formal draft decision leads into the Examination procedure[27,28] (Viju et al., 2011). The Examination procedure begins with submission of the EC draft decision to the Examination

[26] Detection method is test using biochemical (molecular) techniques to detect the type of GMO and amount present in the specified food or feed.
[27] The legislative approval in this essay is described under the Treaty of Lisbon, post March 1, 2011. For further description of the differences pre and post March 1, 2011 see Viju et al. (2011), and Hardacre and Kaeding (2011a).
[28] Article 5 of the Implementing Regulation 182/2011 EU.

Committee, known as the Standing Committee on Food Chain and Animal Health (SCoFCAH)[29]. The Examination Committee evaluates the draft decision of the EC and uses a voting procedure to ascertain its position based on Qualified Majority Voting (QMV)[30]. If the Examination Committee accepts the draft decision with a positive opinion, the EC will implement the draft decision. In a case where the Examination Committee rejects the draft decision, the EC cannot implement the draft decision and will either propose a new version to the Examination Committee or refer the original version to the Appeals Committee (AC) (Viju et al., 2011). In a case where the Examination Committee expresses no opinion, the EC may adopt the draft decision, however, it cannot adopt the measure in a case when the implementing act is related to issues of health and safety or if the majority of the Examination Committee votes are opposed to the adoption of the draft decision (Viju et al., 2011). GMOs are often considered as raising the question related to consumer health and safety, despite the EFSA declaring them as safe, which led to the EC not being able to adopt the draft decision. In this case the EC has the option to either propose a new version to the Examination Committee within a period of two months or submit the same draft decision to the AC within a period of one month. The examination procedure[31] is described in Figure 3.1.

[29] The SCoFCAH consists of representatives of all member states.
[30] Post-Lisbon calculations of QMV represent 55% or more of the Member States and 65% or more of EU citizens (EC, 2015a).

[31] The GM event will receive a "positive opinion" if the Committee vote is with a QMV for approving the specific GM event. If the Committee vote is with a QMV to not approve the GM event then the result is a "negative opinion" situation. If the Committee is unable to get a QMV for approving or not approving the GM event then the committee issues a "no opinion" result.

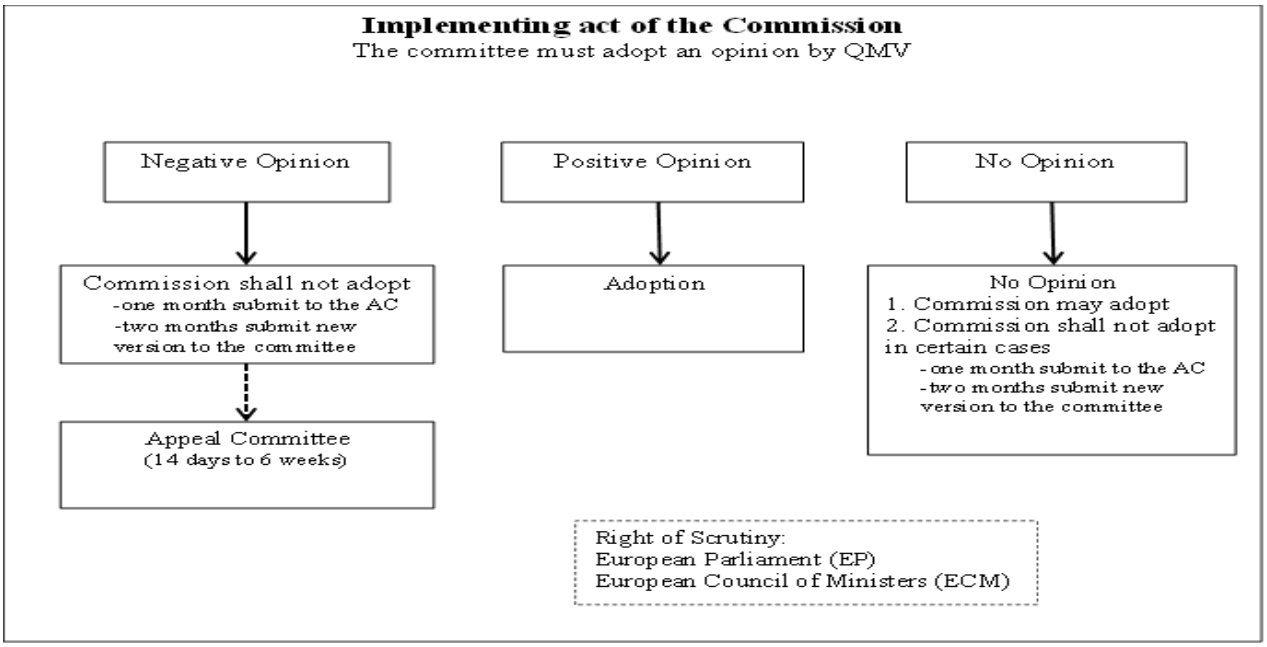


Figure 3. 1: Examination Procedure
Source: Hardacre and Kaeding (2011b).

The AC is composed of one representative from each MS, mainly a Director-General of a Ministry or a representative from a higher political level and is chaired by the Commission (Hardacre and Kaeding, 2011b). As described by Hardacre and Kaeding (2011a, p.18):

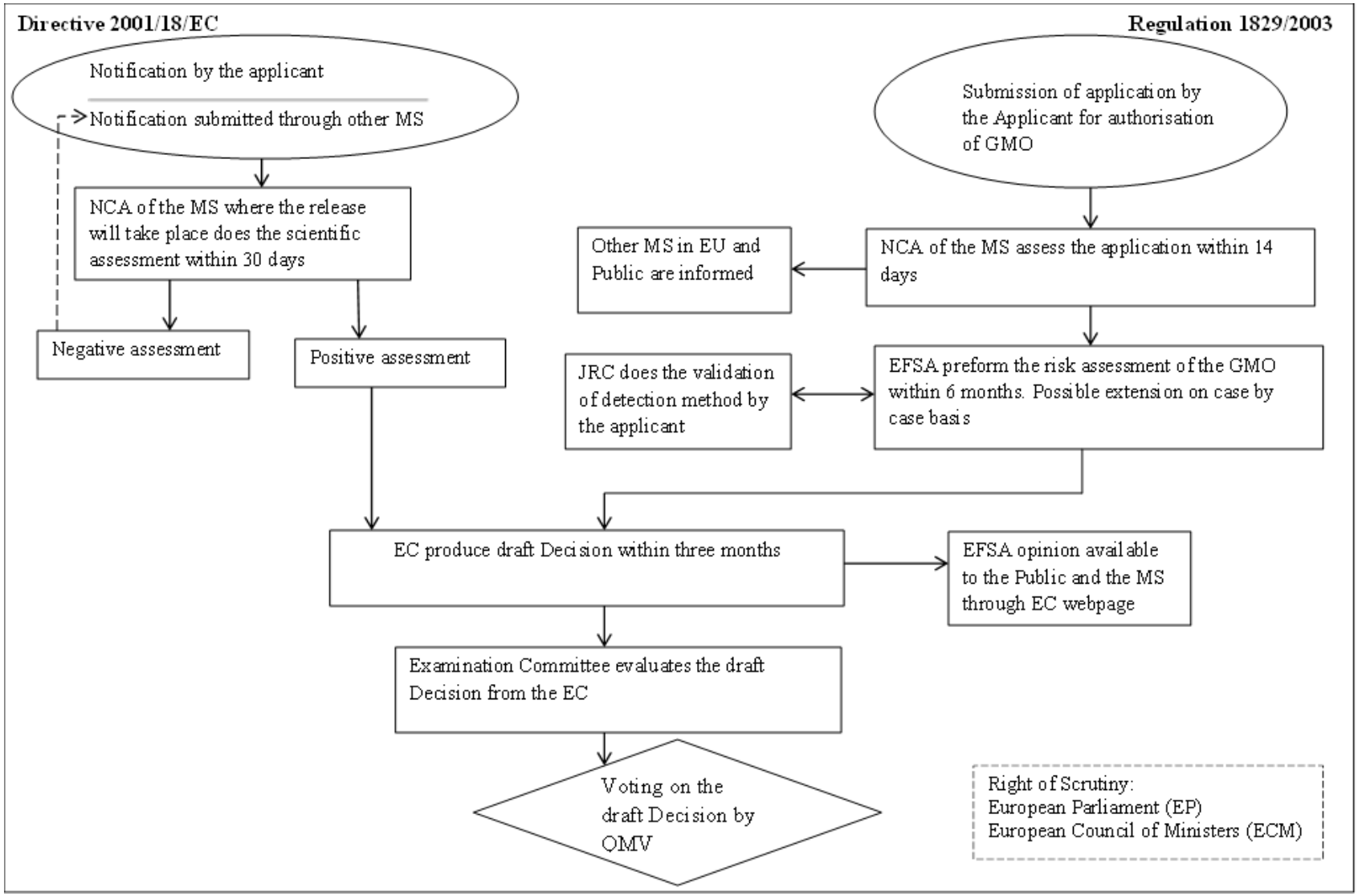
> AC will have the power to vote changes to the text, to adopt the text or to reject it. The Appeal Committee was created because the Council wanted to have a political body to look at controversial acts, i.e. ones that have been voted against, or received no opinion, in committees – which whilst not significant in number can be very sensitive for the Council.

The AC evaluates the draft decision and decides based on QMV within two months (Wesseler and Kalaitzandonakes, 2011). If AC give a positive opinion the GMO is approved, if the opinion is negative the GMO is not approved. In case of no opinion by the AC, the EC may adopt the decision but it can also refer it back to the Examination Committee (Viju et al., 2011). Hence, for

highly controversial GMOs the decision process can result in the expressing no opinion by the Examination Committee and then no opinion under the AC, leading to a circle of no opinion and an issue of who is making the final decision regarding approval of the GMO, whether it will be the EC or the MS (Hardacre and Kaeding, 2011b). Lastly, the Parliament and Council, by Article 11, have the right of scrutiny which allows them to pass a non-binding resolution at any time during the draft act process if they believe that the Implementing Act exceeds the implementing powers of the Commission (Hardacre and Kaeding, 2011a). Figure 3.2 describes the decision approval process for a GM product in the EU.

If a draft decision is successfully implemented by the EC, then the particular GMO in question is granted authorisation to the EU market for the following 10 years (Viju et al., 2011). After ten years authorisation must again be granted through the same decision process if the firm desires continued market access. Once authorised, the GM product must be labeled as "genetically modified" and is subjected to specific labeling requirements[32].

[32] As of April 22, 2015 the EC proposed that MS have the option to implement opt-out measures regarding regulation 1829/2003. Thereby giving MS the right to decide on GMO use for food and feed in their territory (EC, 2015b)


Directive 2001/18/EC
Regulation 1829/2003
Notification by the applicant
Notification submitted through other MS
NCA of the MS where the release will take place does the scientific assessment within 30 days
Negative assessment
Positive assessment
Submission of application by the Applicant for authorisation of GMO
Other MS in EU and Public are informed
NCA of the MS assess the application within 14 days
JRC does the validation of detection method by the applicant
EFSA preform the risk assessment of the GMO within 6 months. Possible extension on case by case basis
EC produce draft Decision within three months
EFSA opinion available to the Public and the MS through EC webpage
Examination Committee evaluates the draft Decision from the EC
Voting on the draft Decision by QMV
Right of Scrutiny:
European Parliament (EP)
European Council of Ministers (ECM)

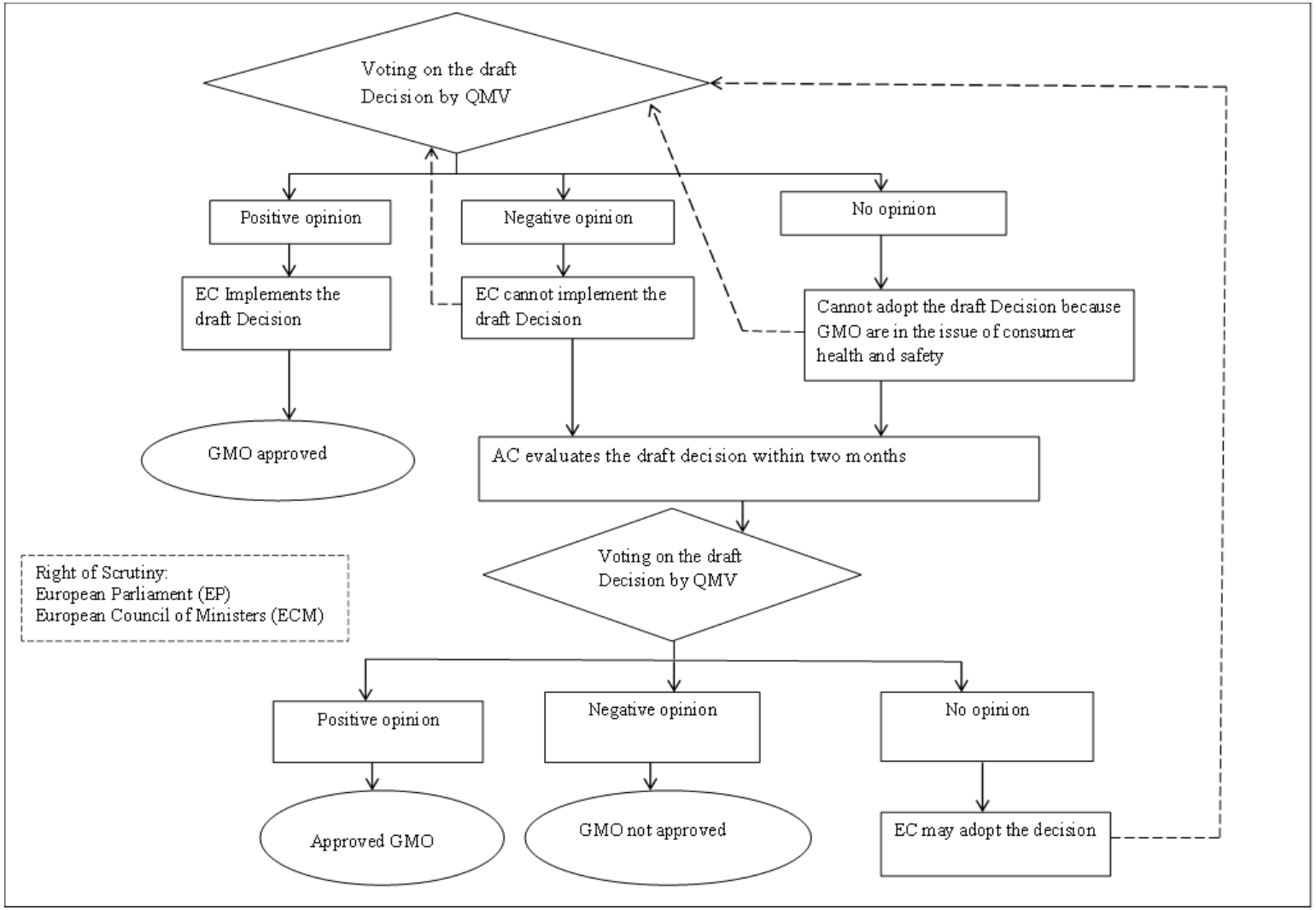


Figure 3. 2: The Decision Process for Approval of GM Product in EU
Source: Authors application

3.3.2 Approval Process through Directive 2001/18/EC

The purpose of Directive 2001/18/EC is to control the risk associated with deliberate release of GMOs into the environment from both research and development and when placed on the market. Examples of deliberate release into the environment includes planting GMO seed for crop or seed production, import of GM commodities for direct use in food and feed, or processing into food products (Viju et al., 2011).

The process for approval through Directive 2001/18/EC starts with submission of notification by the applicant to the national competent authority (NCA) of the MS whose territory the release of the GMO will take place. The MS will complete a scientific assessment report and respond to the notification within 30 days (Viju et al., 2011). If the assessment is negative the applicant can submit a new application through the NCA of another MS. If the assessment is positive and the release of the GMO would be allowed on the MS market, then the assessment report is submitted to the EC. The EC submits the report to the other MS countries within 30 days, after which MS countries have the option, within 30 days, to comment on the report, either through the EC or through the NCA of the MS country where the application took place. If there are no objections to the assessment report by the EC or other MS countries, then the NCA can authorise the GMO product where the original application took place. If there is an objection to the assessment a conciliation period between the MS, the EC, and the applicant takes place to address those concerns. If objections are still present after the conciliation period the decision moves to the EU level for approval. At the EU level, the approval process mirrors the approval process as previously described under regulation EC 1829/2003 in section 3.3.1 and Figure 3.2.

Within this Directive, countries may invoke the safeguard measure under Article 23. The safeguard clause allows MS to place a ban, provisionally restrict, or prohibit the use or sale of a GMO in whole form or in products within their territories. The safeguard clause applies only when new scientific information is available that will affect the risk assessment of the approved GMO, thereby indicating that the GMO constitutes a risk to human health and the environment. Hence, in order to invoke the ban, the MS should have scientific reasoning. A number of MS (Austria, France, Greece, Hungary, Germany, Luxembourg, and Poland) have invoked the safeguard measure on the argument of insufficient and inconclusive risk assessment and insufficient monitoring plans (Greiter and Heissenberger, 2012). However, the majority of bans were found by the EFSA and the EC not to be based on scientific evidence and the information was insufficient to affect the original GMO authorisation (Viju et al., 2011). The EC, using committee processes, has requested the MS to repeal the bans, but the EC has not once received a QMV from the Regulatory Committee in favour of their proposal, therefore the final decision made by the European Council has resulted in rejection of the EC's proposal that the MS should lift the national safeguard measure. Throughout this extremely lengthy process the GMO bans in the MS remain in place, resulting in market withdrawal of selected products subjected to the safeguard measure (EC, 2013).

In attempt to satisfy the demand of the MS and still comply with the SPS regulation, the EC proposed two recommendations in July 2010 regarding greater flexibility for MS to create coexistence measures (Recommendation 2010/C20/01) and the possibility for MS to legally prohibit the cultivation of GMOs in their territories (Recommendation 2010/375; Dobbs, 2010).

These propositions were added under Article 26(b) in Directive 2001/18/EC and Directive 2015/412 in April 2015. The idea behind these recommendations was to provide MS with the possibility to apply veto power on GM products and at the same time reduce the use of safeguard measures (Dobbs, 2010). Thus, MS can now restrict or prohibit the cultivation of GMOs in their territory on criteria other than those assessed by EFSA in its risk assessment (EC, 2015c).

3.4 Defining the Decision Process for GMO approval in EU as Regulation-based Political Risk

As described in section 3.3 the decision approval process is lengthy and complicated, leading to approval delays which can directly affect the investment decisions of agricultural biotechnology firms interested in the EU and global marketplaces. The regulatory burden created by the institutions involved in the decision process creates uncertainty for firms seeking EU market entry, and thus creates an external risk that cannot be controlled by the firm. However, in light of this external risk, the firm can manage the investment decision internally[33]. Under this assumption, the external regulation risk can be broadly included in the theory of political risk.

Political risk has been commonly used in business models, when the firm is developing entrance strategies with the purpose to evaluate the macroeconomic condition of the country, especially political instability in case of war, riots, and terrorism, for example. However, the definition of political risk covers a broader range of events. Root (1973) segregates risk into three areas: transfer risk covering potential restrictions on the transfer of funds, products, technology, and people; operational risk concerning uncertainty as it applies to regulations, hindrance of

[33] Explained later in the model description

governmental administrative procedures on results, policies and management of operations in the foreign country; and lastly, risks on control of capital that discriminate against foreign firms, expropriation and forced local shareholding. Hence, within this definition the policies and regulations for GM approval in EU can be characterised as operational risk. Further, Kennedy (1988) define political risk as strategic, financial, or personnel loss for a firm because of such non-market factors[34] as macroeconomic and social policies (fiscal, monetary, trade, investment, industrial, income, labour, and developmental), or events related to political instability (terrorism, riots, coups, civil war, and insurrection). Therefore, within this definition, social policy factors that firms are exposed to can increase the investment risks for agriculture biotechnology firms. More recent definitions have widened the concept of political risk by including all factors that influence the investment environment (Clark and Tunaru, 2003). Thus, political risk can be simply approached as the risk that arises from the activities of the government or its agents whose policies harmfully impact the interest of the stakeholders by reducing expected return on investment (Chen and Funke, 2008; Jarvis, 2008).

Jarvis (2008) typologies political risk based on its practical application, level of analysis, the dominant risk drivers, actors, and the end users. Based on these factors he segregates political risk into International Business Risk Analysis, Public Sector Risk Analysis, Policy Risk Analysis, and International Risk Analysis. International Business Risk Analysis is one possibility for analysing the effect of country risk on the investments of foreign firms as a result of the decisions by a regulatory body. Hence, this subgroup of political risk is applicable for defining

[34]Kennedy (1988) defined legal-governmental and extra-legal political risks as non-market factors. Legal-governmental risks are produced by events within the legitimate authority structures of the state; extra-legal risks are caused by events that are considered illegitimate by the existing political system.

the risk associated with the decision process for GMO approval in the EU. The political risk typology defined by Jarvis (2008) and its application to the GMO approval process in the EU is described in Figure 3.3.

The Area	The Application	Level of Analysis	Dominant Risk Drivers/Actors/Agents/Processes	Major End Users
International Business Risk Analysis	Country risk analysis	International	Governmental body and agencies/ Regulatory and statutory bodies	Foreign direct investors
GMO approval process in EU				
International Economic Risk Analysis	Specific risk analysis of the decision process in approving GMOs in the EU	International trade	EFSA, MS, EC, Examination Committees, AC, Consumers organizations, and NGOs	GMO Investing firms

Figure 3. 3: Political Risk Typology Defined by Jarvis (2008) and its Application to the GMO Approval Process in the EU
Source: Adopted from Jarvis (2008) with modifications by the author regarding the GMO approval process in the EU

Being consistent with the definitions for political risk described above, the approval process for GMOs in the EU as described in section 3.3 can be defined as political risk driven by the regulatory bodies and lobbying groups involved in the decision process of approving GMOs in the EU. More specifically the time delays in the approval process of GM products in the EU and the presence of non-scientific political factors in the decision process by EC, the Examination Committees, and the AC can cause uncertainty and increase risk in the EU for agriculture biotechnology firms that want to invest in developing new GMOs by reducing the rate of return expected by investors.

3.5 Model Framework

Modeling political regulatory risk will focus on a specific environment, considering the risk generating events that are characteristic for the regulatory decision process in approving GMOs in the EU and, thus, causing uncertainty for the firm investing in biotechnology. Two risk generating events will be examined, the scientific risk assessment process and the legislative approval process. The jurisdiction of the scientific risk assessment is handled by the EFSA (Viju et al., 2011) as outlined in Figure 3.2. Each GMO event is handled on a case by case basis by a 21 independent member GMO Panel. The members have extensive knowledge and experience in the GMO area (EFSA, 2013a).

Tests related to the GMO approval process have fixed protocols that are agreed upon by international risk assessment bodies. GMO studies included in the application regarding the risk assessment must comply with the OECD principles of Good Laboratory Practice (GLP) where applicable and be accompanied by a formal statement of Quality Assurance (EFSA, 2013b). The data supplied is often prepared by an independent private (contracted) laboratory on behalf of the applicant who operates according to international laboratory standards such as GLP, Good Manufacturing Practice (GMP), and International Organisation for Standardisation (ISO) (EFSA, 2013b). To date, the application for approval of a GMO event have, in general, complied with high scientific standards, however in 95 % of the cases the GMO Panel has asked the applicant to supply more information in order to be able to carry out a full risk assessment (EFSA, 2013b). The fact that the majority of applications fulfill the scientific standards of the EFSA creates a lower probability that an investment would be affected by the EFSA assessment, and thus alter the investment decision of the firm. However, the high probability of extra information being

required by the EFSA increases the time element of the risk assessment process. The time element for a GMO event risk assessment can range from 4 to 24 months. This time range can create uncertainty that may negatively impact an investor's investment costs.

The legislative approval process, as discussed in Section 3.3 and Figure 3.2, covers the GMO authorisation process, but excludes the EFSA risk assessment. The EFSA must conclude that science-based risks are sufficiently low for the application to progress. The legislative approval process includes the uncertainty created by the existence of political precaution in the decision process of the EC, the Examination Committees, the AC, and the MS. More specifically, the firm undergoing the rigorous approval process is influenced by political factors beyond the control of the firm and contrary to the scientific evidence. Overall, the average length of time for GM import authorisation is 45 months, however based on past evidence this average can vary from 25 months to 75 months (Europa Bio, 2011). Measured over years the average approval process period has increased, and this extreme variation in process time reveals the lack of predictability of the approval process (Europa Bio, 2011).

The traditional neoclassical method of incorporating political risk into the investment decisions of an exporting firm was to estimate a risk premium, cash flow, or discount rate adjustment factor that is then incorporated into the traditional Net Present Value (NPV)[35] equation (Clark and Tunaru, 2003). With this approach the variables are fixed constant values and future cash flows are discounted to the level that represents the riskiness of the project being modeled (Choi,

[35] The NPV rule is to invest when the discounted present value of the investment return is at least as large as the investment cost.

2011). However, this approach does not consider the three important characteristics of investment decisions: 1) irreversibility, the initial investment costs are partially or fully sunk; 2) the uncertainty about future payoffs from the investment; and 3) the timing of the investment, when you postpone your investment to get more information about the future (Dixit and Pindyck, 1994). Also, the NPV method does not consider the multivariate stochastic nature of political risk, thus resulting in determination of the adjustment factors on ad hoc basis (Clark and Tunaru, 2003). The alternative approach which can capture the characteristics mentioned above is the Real Options model. The Real Options model can capture the uncertainty[36] from the regulatory framework, the future development of the market, and the irreversibility of the investment decision by the biotechnology firms. Adner and Levinthal (2004) depict graphically the boundaries between the application of the Real Options and NPV models in Figure 3.4. Hence, if the investment project has a high level of sunk cost and is highly connected to the uncertainty factor, then the Real Option model should be applied. In contrast, if the investment has a low level of sunk cost and uncertainty, then the NPV model is the more applicable approach.

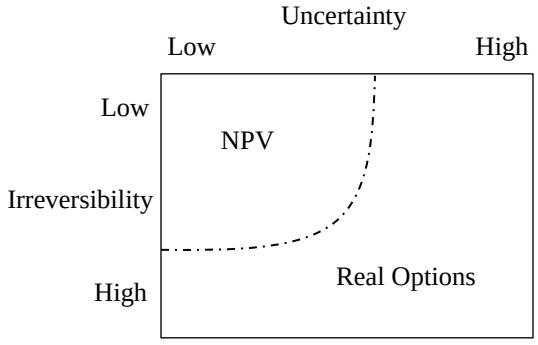


Figure 3. 4: Boundaries of Applicability for Net Present Value and Real Option Model
Source: Adner and Levinthal (2004)

[36] In this essay the terms risk and uncertainty are used interchangeably as in Levy and Sarnat (1984).

To combine multiple sources of uncertainty by the risk assessment and legislative approval process, the investment decision is modeled as the investor holding an option to make an irreversible investment in the project.

3.5.1 Real Options

The development of real options theory is founded in the financial theory of rational option pricing developed by Black and Scholes (1972 and 1973). Thus, the most widely and acceptable definition for financial option is that it gives the holder the right, not the obligation, to buy (call option) or sell (put option) an asset at a given price (also called a strike price or an exercise price) within a specific time period. The last day that the option can be exercised is called the "expiration date" or "maturity date" (Black and Scholes, 1973). For example, the call option gives right to the holder to buy an asset at a strike price at any time prior to the expiration date and for that right the buyer pays a fee. At the expiration date if the market price of the assets is greater than the strike price the buyer will exercise the option. Hence, the option is valuable because the holder buys the asset for lower price than the market price, and the difference between the two prices is the gross profit of the investment (Cox and Rubinstein, 1985). Other options include an "American option" and "European option". The holder of an "American option" can exercise the option at any time up till the "maturity date", and the holder of a "European option" has to exercise the option at the "maturity date".

Option pricing theory found rapid and wide application in finance theory. Starting with Cox et al. (1979) the use of option pricing theory penetrated in other fields of investment economics using

real assets as investment rather than using financial assets (stocks and bonds). Subsequent to this, Dixit and Pindyck (1994) developed real options into a more sophisticated real model that included uncertainty. Therefore, a firm that wants to invest holds an option and has the right, but not the obligation to buy or sell an asset at some future time (Dixit and Pindyck, 1994). Thus when a firm makes an irreversible investment it gives up the possibility of waiting for new information that might affect the timing of the expenditure (Dixit and Pindyck, 1994). The lost option value is an opportunity cost that must be included as part of the cost of the investment (Dixit and Pindyck, 1994). The analogy behind the connection between a call option and a real option is the irreversible investment opportunity, which is like a financial call option where the manager can spend (though not obliged) the investment costs to obtain a production asset and the investment opportunity is only available for time interval (Dixit and Pindyck, 1994).

Luehrman (1998) indicated six comparable variables between financial and real options (see Figure 3.5). The financial asset is represented by stock, currencies, debt insurance, futures contract and other financial assets, and their price (values) is defined through capital market trade. The real asset value is defined as the present value of the expected cash flow without considering management flexibility, and this value is determined as a proxy to another asset that can be observed on the market.

Exercise price or strike price of the financial option represents the cost that the buyer has to pay for having the right to buy a security prior to the expiration date. In real options it represents the cost for implementing the investment or the revenue received for abandoning the option. The expiration time in the financial option is the date at which the stock or the security expires, and

with the real option it is the maximum time that the investment can be postponed without losing the option.

The risk free interest rate in financial and real options is the government interest rate that represents no default risk. The standard deviation represents the volatility in the values of the financial asset and in real options it is the uncertainties of the investment asset that can come from external or internal sources. The dividend represents the payment made by the firm to its shareholders as a result of owning the financial asset, whereas in a real option it is the lost project value throughout the life of the option.

Financial Option Value		**Real Option Value**
Financial asset price (ex. stock price)	S	Real asset value (ex. present value of a project)
Exercise price	X	Investment costs
Time to expiration	t	The time frame the investment might be postponed
Risk free interest rate	r	Risk free interest rate
Volatility of the financial asset value	σ^2	Uncertainty of the investment asset
Dividend	δ	Value lost to preserve the option

Figure 3. 5: Comparable Variables between Financial Options and Real Options
Source: Luehrman (1998)

An increase of the present value of the project, the risk free interest rate and the uncertainty of the investment asset increase the value of the real option. However, an increase in the investment cost and the lost value to preserve the option decrease the value of the real option. The extension of time for postponing the investment also has a positive impact on the value of the real option since it gives the investor more time to acquire additional information on the uncertainty of the investment.

The uncertainty that arises from the market and the application of real options theory gives a manager the flexibility to adapt to the new condition and react accordingly. Thus, according to Trigeorgis (1993) the investment opportunity gives the manager flexibility with the option to defer, abandon, contract, expand, or switch. The option to defer the investment indicates that management has the choice to wait (keeping the same status opened or closed) for x number of years to see if the output prices will justify the building of a production asset (V) such as a plant for example. The option to abandon gives the manager the choice to abandon the project permanently in exchange for the salvage value, in a case where the market condition declines severely and the performance of the project is worse than expected. The option to contract allows the manager the option to reduce operations and mitigate losses as a result of less favourable conditions than expected. On the contrary, the manager has the option to expand if the market conditions are more favourable than expected and thus increase operations. Lastly, the option to switch allows managers to alter the mix of outputs or inputs, which affects product and process flexibility respectively, in response to changes in market prices.

3.5.2 Modeling Political Regulatory Risk

Modeling of the regulatory environment for GMO approval in the EU will be based on the work of Clark (1997) and Clark and Tunaru (2003), whose models allow for exposure to investment loss in political environments. Thus, the exposure to investment loss in the regulatory environment when seeking GMO event approval will be equal to RI(t), where R is an index of ongoing regulatory climate that evolves over time as the application goes through the decision

process, and I(t) is the dollar value of the investment that also evolves through time according to geometric Brownian motion[37].

Figure 3.6 describes the regulatory environment (R) in the EU GMO approval process. There are two decisions that can influence the uncertainty of R, the scientific risk assessment process probability (D_S) and the legislative approval process probability (D_L), thus, $R = \lambda D_S + \mu D_L$, where λ is the percentage of loss caused by the scientific risk assessment decision and μ is the percentage of loss caused by the legislative approval process. The scientific risk assessment decision can cause loss for the firm in two ways, the negative risk assessment by EFSA (λ_1) and the time delays as a result of additional information required from the firm by the EFSA (λ_2), thus, $\lambda = \lambda_1 + \lambda_2$. The legislative approval process can also cause losses for the firm in two ways, a negative decision by the EC, AC Examination Committees, and the MS institutions (μ_1), and the time extension due to a no-opinion result by the same institutions (μ_2), thus, $\mu = \mu_1 + \mu_2$. For example, if the EFSA brings a positive opinion, but the loss of the time extension is 20%, then $\lambda = 0.2$, and if the legislative institutions have a positive opinion for the GMO event, but the loss of extension is 30%, then $\mu=0.3$. Therefore, if the probability of the scientific risk assessment process, (D_S), to influence the regulatory environment is 30% and the probability of legislative approval process, (D_L), to influence the regulatory environment is 70%, then the value of R will be: $R = 0.2*0.3 + 0.3*0.7 = 27\%$, which signifies the potential investment loss. Hence the percentage and probability values μ, λ, D_S, and D_L can change from 20-30 in the above example

[37] Brownian motion, also known as Wiener process, is a continuous-time stochastic process that has three properties: 1) it is a Markov process, indicating that the probability distribution for all future values of the process depends only on its current value; 2) it has independent increments, indicating that the change in the probability distribution in any time interval is independent of any other time interval; and 3) the changes are normally distributed over any finite time interval (Dixit and Pindyck, 1994, p63).

to 40-50, which will also influence the value of R. Therefore, the stochastic values of R and I will be modeled as Geometric Brownian motion with drift, as shown in equations (3.1) and (3.2) below.

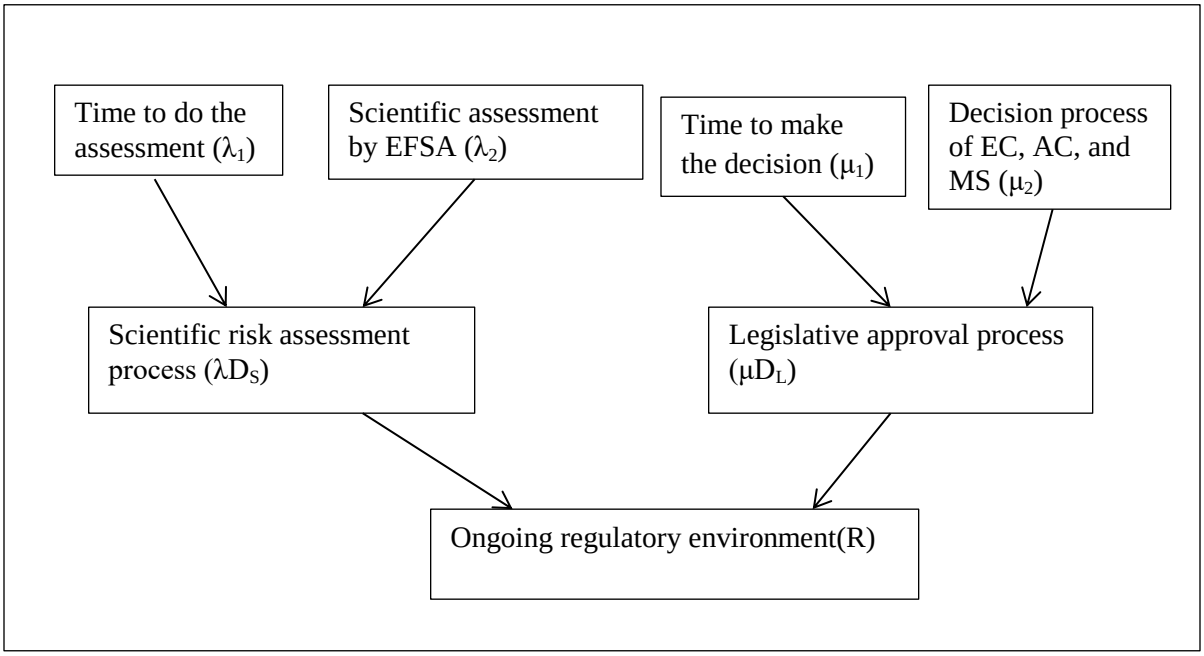


Figure 3. 6: Factors Influencing the Ongoing Regulatory Environment
Source: Authors application

$$dR(t) = \alpha_R R(t)dt + \sigma_R R(t)dZ_R(t) \quad (3.1)$$

$$dI(t) = \alpha_I I(t)dt + \sigma_I I(t)dZ_I(t) \quad (3.2)$$

The drift parameters α_R and α_I represent the rate of growth for *R* and *I* respectively, σ_R and σ_I represent the variance in the drift parameters, and dZ_R and dZ_I are standard Wiener processes with a mean of zero and a standard deviation of *dt*. The existence of correlation between *R* and *I* is reflected in $dZ_R(t)dZ_I(t) = \rho_{RI}dt$, where ρ_{RI} is the instantaneous correlation between *R* and *I*,

where a negative correlation implies that as the index of the regulatory environment increases the dollar value of the investment decreases, $-1 \leq \rho_{RI} \leq 0$.

Let $x(t) = R(t)I(t)$ be a stochastic variable and be the investment dollar value that is exposed to the regulatory environment, knowing that:

$$\frac{\partial^2 x}{\partial R^2} = \frac{\partial^2 R}{\partial I^2} = 0 \; and \; \frac{\partial^2 x}{\partial R \partial I} = 1 \tag{3.3}$$

Using Ito's Lemma[38] and the stochastic processes of *R* and *I* in equation (3.1) and (3.2), we have:

$$dx(t) = R(t)dI(t) + I(t)dR(t) + dR(t)dI(t) \tag{3.4}$$

Substituting equation (3.1) and (3.2) for *dR(t)* and *dI(t)* respectively and reorganizing equation (3.4), we develop:

$$dx(t) = (\alpha_R + \alpha_I + \rho\sigma_R\sigma_I)x(t)dt + \sqrt{\sigma_R^2 + \sigma_I^2 + 2\sigma_R\sigma_I\rho_{RI}}\; x(t)dz(t) \tag{3.5}$$

Where, $dz(t) = \frac{\sigma_R dz_R + \sigma_I dz_I}{\sqrt{\sigma_R^2 + \sigma_I^2 + 2\rho_{RI}\sigma_R\sigma_I}}$ (3.6)

[38] See Dixit and Pindyck (1994) pp. 79.

Let, $A = (\alpha_R + \alpha_I + \rho\sigma_R\sigma_I)$, $and\, \sigma_x = \sqrt{\sigma_R^2 + \sigma_I^2 + 2\sigma_R\sigma_I\rho}$ (3.7)

Substituting equation (3.6) and (3.7) into (3.5), we receive:

$$dx(t) = Ax(t)dt + \sigma_x x(t)dz_x(t) \quad (3.8)$$

In equation (3.8) A is the drift parameter of the dollar amount exposed to regulatory risk, and it is dependent on α_R, α_I, and the volatility of *R (t)* and *I (t)* and the correlation between them, where the Wiener process $dz_x(t)$ has a mean of zero and variance of *dt*. The intuition behind equation (3.8) is that the dollar amount exposed to regulatory risk of the EU GMO decision approval process is expected to change with size of *A*, and the volatility of σ_x multiply with the ongoing stochastic change of the Wiener process.

To solve the investment problem we need to make the growth rate (drift parameter *A*) into a risk neutral rate β. As suggested by Clark and Tunaru (2003) this can be performed through the Girsanov[39] theorem. In an environment where risk is present, the application of the contingent claims approach allows the growth rate to be equal to the differences between total expected rate of return π (compensation the investor obtains for taking risk) and the convenience yield δ (as described by Pindyck (2001), which is the opportunity cost of delaying construction of the

[39] Girsanov theorem is used in financial mathematics to convert probabilities that the underlying derivatives (indexes, cash-flows, etc.) will take into a risk neutral measure. The intuition behind Girsanov theorem is that if we have a random process x generated by Brownian motion with α drift then we can find an equal random process y that will have a drift value of 0, therefore indicating that the expectation of the future value of the process is the same as the current.

project and instead keeping the option to invest alive), thus $\alpha = \pi - \delta$. Therefore, the risk neutral growth rate can be represented as the difference between riskless rate r, that can be observed, and the convenience yield δ, where $\beta = r - \delta$. Applying the risk neutral rate to equation (3.8) becomes:

$$dx(t) = \beta x(t)dt + \sigma_x x(t)dz^*(t) \quad (3.9)$$

3.5.3 Incorporating Regulatory Risk into the Real Option Model

3.5.3.1 Solving the Investment Problem

The solution to the investment problem will be determined by the critical value of x^*, the investment dollar value that is exposed to the regulatory environment when the option to invest will be exercised. To solve the investment problem a calculation of the value of the investment project and the option to invest is required.

The volatility of the investment project is estimated as a function of the investment dollar exposed to the regulatory environment $V = V(x,t)$. Thus, the project value depends on the benefit from x discounted at π, the risk adjusted rate of return, and the annual growth of x at rate β. Thus the present value of the project release at time T is given by:

$$V(x,t) = E\left[\int_0^T x(t)e^{-\pi T}dt\right], \quad (3.10)$$

Considering that x follows geometric Brownian motion, the project V also evolves through time stochastically according to the following geometric Brownian motion:

$$dV(x) = \beta(V(x), t)dt + \sigma_x(V(x), t)dz_V(t) \quad (3.11)$$

As the value of the project is a constant multiplier of the dollar exposed to the regulatory environment *x*, β is the constant drift rate and σ_x is the constant variance parameter for both variables *x* and *V*.

Integrated over the interval *(t,T), V(x,t)* at the point of release is given by:

$$V(x,t) = \frac{x_T}{\pi - \beta} = \frac{x_T}{\delta_x} \quad (3.12)$$

The difference between π and β represents the convenience yield δ or the opportunity cost of delaying the investment and keeping the option to invest alive. In this case where *V* is a constant multiplier of *x*, the risk-adjusted discounted rate of return π is also the market risk-adjusted expected rate of return on *x*. By using the Capital Asset Pricing Model (CAPM) formula $\pi = r + \phi\sigma\rho_{xm}$, where r is the riskless rate, ϕ is the market price of risk and ρ_{xm} is the correlation coefficient between the asset that tracks *x* and the whole market portfolio.

Before the project is set up the firm possess a portfolio (asset) for which it holds an option to invest and the investment opportunity value is $F(V_x)$. However, V_x is a constant multiplier of *x* and it has the same drift and diffusion parameter as x, and thus the value of the option for the holder of the asset is dependent on *x*, and can be written as $F(x(t))$ instead of $F(V_x)$. Solving the option value can be defined as an optimization investment problem where the decision rule

considers the option to defer the investment, and the owner of the option decides whether to invest or wait if regulation risks changes. The analytical derivation of the option employs the contingent claims approach to real option valuation[40].

To find *F(x(t))* the return on the portfolio should be considered, where the opportunity to invest is worth *F(x(t))* and n units of the asset are sold short with price *x*. Thus, the value of the portfolio is:

$$Q=F(x)- nx \tag{3.13}$$

The composition of the portfolio is continuously changing because as *x* changes, *n* will change from one short time interval to the next. However, for each short interval *dt*, n is kept fixed.

A rational investor will not enter into long run investment in this project without a dividend payment, thus the short position of this portfolio requires a payment of δnx dollars per time period to the holder of the long position. δ is the opportunity cost (dividend payment) of delaying the investment and keeping the option to invest alive. Considering the opportunity cost of delaying the investment the total return on the portfolio value is:

$$Q = F(x) - nx - \delta_x nx \tag{3.14}$$

[40] According to Dixit and Pindyck (1994) real options theory valuates investment opportunities in two ways, as either contingent claims or a dynamic programming approach. This research focuses on the contingent claims approach where the discounted rate is determined endogenously as a consequence of the capital markets equilibrium.

The instantaneous change in the value of the portfolio will be:

$$dQ = dF(x) - ndx - n\delta_x x dt \tag{3.15}$$

By Applying Ito's Lemma in equation (3.15) to obtain the expression for *dF*:

$$dF(x) = F_x dx + \frac{1}{2} F_{xx}(dx)^2 \tag{3.16}$$

Where:

$$dx = xdt + \sigma_x x dz_x \text{, and } dx^2 = \sigma_x^2 x^2 dt \tag{3.17}$$

To have a riskless portfolio substitution $n=F_x$ in equation (3.15), and for $dx^2 = \sigma_x^2 x^2 dt$ in equation (3.16) the return on the portfolio value is:

$$dQ = F_x dx + \frac{1}{2} F_{xx}\sigma_x^2 x^2 dt - F_x dx - F_x \delta_x x dt \tag{3.18}$$

Rearranging:

$$dQ = \frac{1}{2} F_{xx}\sigma_x^2 x^2 dt - F_x \delta_x x dt \tag{3.19}$$

In the time interval (t, $t+dt$) the capital gain for the portfolio holding is: $\frac{1}{2} F_{xx}\sigma_x^2 x^2 dt$ and the capital cost is: $F_x\delta_x x dt$. The return of the portfolio in equation (3.19) should be equated with the risk free return where:

$$rQdt = r(F(x) - F_x x)dt \tag{3.20}$$

Applying equation (3.19), (3.20) becomes:

$$\frac{1}{2} F_{xx}\sigma_x^2 x^2 dt - F_x\delta_x x dt = r(F(x) - F_x x)dt \tag{3.21}$$

Dividing by dt and rearranging the equation (3.21) gives the differential equation:

$$\frac{1}{2} F_{xx}\sigma_x^2 x^2 + F_x x(r-\delta_x) - rF = 0, \tag{3.22}$$

Equation (3.22) is a homogeneous and second order differential equation linear in the dependent variable F and its derivatives. By substituting Ax^{θ} in equation (3.22) with θ representing the root of the quadratic equation we get equation (3.23):

$$\frac{1}{2}\sigma^2\theta(\theta - 1) + (r - \delta_x)\theta - r = 0 \tag{3.23}$$

With the two roots being:

$$\theta_1 = \frac{1}{2} - \frac{(r-\delta_x)}{\sigma_x^2} + \sqrt{\left[\frac{(r-\delta_x)}{\sigma_x^2} - \frac{1}{2}\right]^2 + \frac{2r}{\sigma_x^2}} \quad > 1, \tag{3.23.1}$$

$$\theta_2 = \frac{1}{2} - \frac{(r-\delta_x)}{\sigma_x^2} - \sqrt{\left[\frac{(r-\delta_x)}{\sigma_x^2} - \frac{1}{2}\right]^2 + \frac{2r}{\sigma_x^2}} \quad < 0 \tag{3.23.2}$$

Thus, the general solution of the differential equation (3.22) is a combination of any two linear independent solutions presented in equation (3.24):

$$F(x) = A_1 x^{\theta_1} + A_2 x^{\theta_2} \tag{3.24}$$

The solution of equation (3.24) is valid for a range of values in *x*, from zero to an investment threshold x^*, for which it is optimal to hold the option. The unknown x^* and the constants A_1 and A_2 need three conditions in order to be determined as part of the solution. Thus *F(x)* must satisfy the following three boundary conditions for a solution of equation (3.22):

$$F(0,t) = 0 \tag{3.25}$$

$$F(x^*) = V(x^*) - K \tag{3.26}$$

$$F_x(x^*) = V_x(x^*) \tag{3.27}$$

The condition in (3.25) explains when the value of *x* is very small the option should be worthless at this extreme and thus the investment project will have a simple NPV solution. For *F(x)* to go

to zero as x goes to zero the coefficient A_2 of the negative power of x should be set to zero (A_2=0).

For conditions (3.26) and (3.27) we consider the option *F(x)* at the threshold x^*. Thus, condition (3.26) explains that at the threshold x^* it is optimal to exercise the option *F(x)* and thus acquire an asset of the project *V(x)* minus the initial investment cost *K* (sunk cost). This condition is known as the value-matching condition, where the value of the option must equal the net value obtained by exercising the option. Condition (3.27), known as the "smooth pasting" condition, sets the option value $F(x^*)$ at the optimal investment value of the dollar exposed to regulatory risk *x**. Using the functional form for *F(x)* and *V(x)* conditions (3.26) and (3.27) can be written as:

$$A_1(x^*)^{\theta_1} = \frac{x^*}{\delta_x} - K \quad \text{and,} \tag{3.26}$$

$$\theta_1 A_1(x^*)^{\theta-1} = \frac{1}{\delta_x} \tag{3.27}$$

Solving equation (3.23) with the boundary conditions yields the following solutions:

$$x^* = \frac{\theta_1}{\theta_1 - 1}\delta_x K \tag{3.28}$$

$$A_1 = \frac{x^* - K}{(x^*)^{\theta_1}} = \frac{(\theta_1 - 1)^{\theta_1 - 1}}{(K)^{\theta_1 - 1}(\delta_x \theta_1)^{\theta_1}} \tag{3.29}$$

Using equation (3.12) the x^* threshold can be expressed in a value term threshold:

$$V^* = \frac{\theta_1}{\theta_1 - 1} K \tag{3.30}$$

3.5.3.2 Description of the Solution

The solution from equations (3.24) to (3.30) gives the value of the project and the option in terms of the dollar exposed to the regulatory environment of the GMO approval process in the EU. The results provide the threshold critical values (x^*, V^*) at which it is optimal to invest, also known as the optimal investment rule. The value-matching condition in equation (3.26) indicates that when the firm decides to invest the calculation of the full value of the project $V(x^*)$ must include the irreversible sunk cost K and the opportunity cost $F(x^*)$. When $V(x)<V(x^*)$ we have $F(x)>V(x)-K$ and thus the value of the project is less than its full costs $(V(x)<F(x)+K)$. In this situation we say that the stochastic process of $V(x)$ is less than the optimal value of the project $V(x^*)$ and the investor should wait and keep the option alive. The moment $V(x)$ reaches the threshold value $V(x^*)$, the investor should exercise the option.

The optimal conditions are presented in Figure 3.7. The strait line shows the present value of starting the investment immediately, $V(x)-K$, and the nonlinear line shows the option value $F(x)$, both lines should meet tangentially at x^* and continue linearly into one line. In the area to the left of the optimal threshold x^* the option value is above the present value of starting the investment immediately ($F(x)>V(x)-K$), thus keeping the option alive and delaying the investment till more information arrives is more economical than immediate investment. To the right side of the threshold x^* the option value is equal to the value of immediate investment. Thus the optimal rule

for investment will be if the value of the project exposed to the regulatory environment is as high as the critical value $V(x^*)$, then the option value should be exercised.

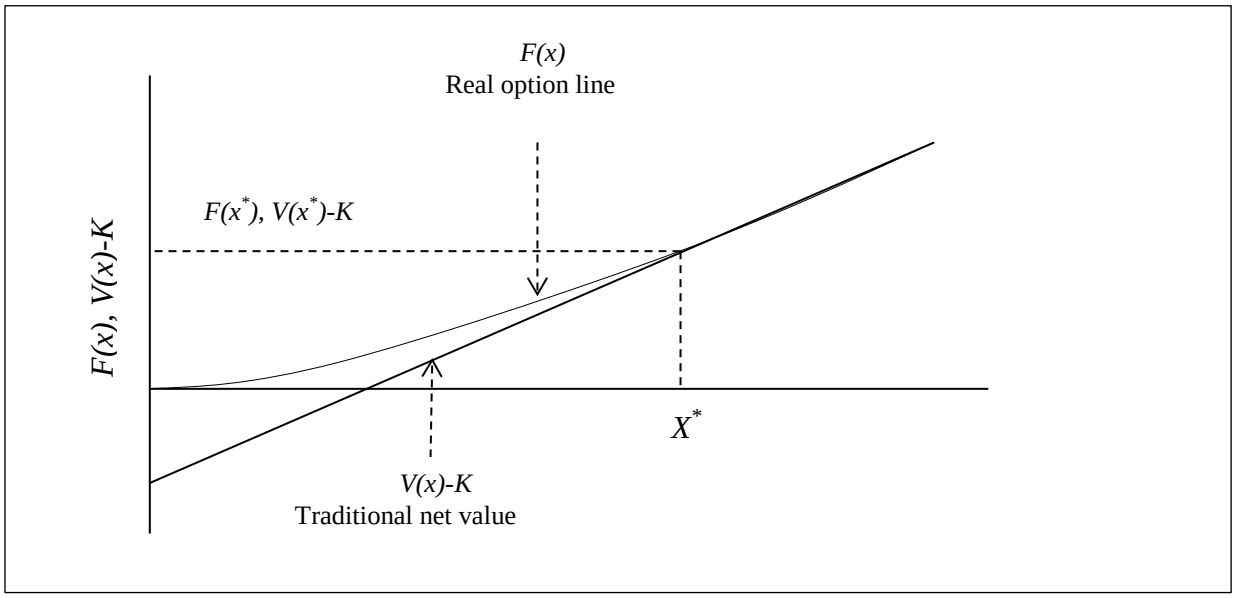


Figure 3. 7: The Real Option Value to Invest as a Function of Dollar Exposed to Regulatory Environment X^*
Source: Authors application

From equations (3.28) and (3.30) we can see that uncertainty creates a wedge between the critical values (x^*, V^*) and the irreversible sunk costs K. This wedge is with a factor magnitude of $[\theta_1/\theta_1-1]\delta_x$ and θ_1/θ_1-1 accordingly, also known as the hurdle rate (Dixit, 1994). From equation (3.23.1) we can determine the magnitude of the hurdle rate depending on the changes of parameters δ_x, σ_x and r. Thus, the optimal investment rule and the regulations implemented on GM approval can be observed based on the changes of parameters δ_x, σ_x and r.

The model till this point has been derived assuming that irreversible cost are certain, however the regulatory environment also creates uncertainty on the sunk cost. The uncertainty arises from the

perspective that it takes a significant amount of time for the GMO event to be approved and the cost for the approval process is carried by the investing firm. According to Wesseler (2003) we can transform equation (3.28) to calculate the threshold for the acceptable level of sunk cost, and thus be able consider the uncertainty of the irreversible sunk cost:

$$K^{*} = x\frac{\theta_1 - 1}{\delta_x \theta_1} \tag{3.31}$$

With the introduction of equation (3.31) we can analyse the maximum acceptable irreversible cost for the firm wanting to invest in the EU market considering the regulatory environment for GMO approval *x*. Figure 3.8 graphically presents the optimal solution for the investor, considering the irreversible cost being stochastic. Hence the optimal investment decision rule is to invest if the stochastic irreversible costs K are less than the critical threshold K^{*}, and if K is greater than K^{*} postpone the decision.

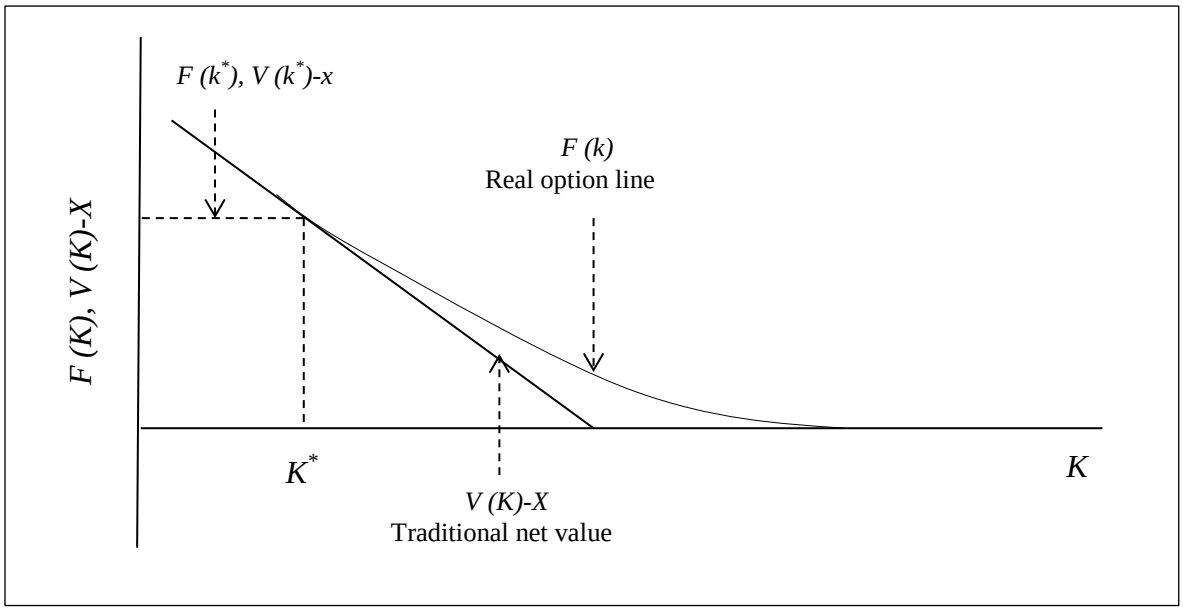


Figure 3. 8: The Real Option Value to Invest with Stochastic Irreversible Cost *K**
Source: Authors application

3.5.3.3 Properties of the Uncertainty in the Investment Solution

The optimal values of the variables X^* and K^* depend on parameter values that include growth rate β, interest rate r, convenience yield δ_x and uncertainties σ_x, σ_I and σ_R. This optimization structure creates opportunities to analyze the effect regulations on GMO approval in the EU has on the firm's investment decision. The impact of uncertainty on the investment can be analysed through comparative statics by looking at the impact of the variance parameters σ_x and σ_R on the critical investment thresholds x^* and K^*. By calculating the partial derivatives of the investment threshold with respect to the uncertainty parameters σ_x and σ_R, we can assess the behaviour of a biotechnology investor in the EU.

The effect on the investment when increasing the uncertainty of the regulatory environment of the GMO approval process can be derived through the partial derivatives of $\frac{\partial X^*}{\partial \sigma_x}$ and $\frac{\partial K^*}{\partial \sigma_x}$.

$$\frac{\partial X^*}{\partial \sigma_x} = \delta K \frac{\partial(\frac{\theta_1}{\theta_1 - 1})}{\partial \sigma_x} = \delta_x K \left(\frac{1}{\theta_1 - 1} - \frac{\theta_1}{(\theta_1 - 1)^2}\right) \frac{\partial \theta_1}{\partial \sigma_x} > 0 \tag{3.32}$$

$$\frac{\partial \mathrm{K}^*}{\partial \sigma_\mathrm{x}} = \frac{X}{\delta} \frac{\partial\left(\frac{\theta_1 - 1}{\theta_1}\right)}{\partial \sigma_x} = \frac{X}{\delta_x} \frac{1}{\theta_1^2} \frac{\partial \theta_1}{\partial \sigma_x} < 0 \tag{3.33}$$

Equations (3.32) and (3.33) are explaining the changes in the threshold values of x^* and K^* with regard to the changes in uncertainty. Thus, when a GMO event goes through the steps of the approval process and the approval is delayed or rejected as described in sections 3.3 and 3.4, the uncertainty of the investment increases. The increase in uncertainty, σ_x, places a higher future value, increasing the option value and moves the line upward in Figure 3.9. However, the

movement of the project value line in Figure 3.9 will depend on the relationship between the convenience yield δ_x and the variance σ_x. No matter the relationship between δ_x and σ_x, with increased uncertainty in the regulation environment the threshold x^* will increase and will move to the right in Figure 3.9. This indicates that future investment is more attractive and results in postponing the investment. Further on, if we look at the changes of the optimal critical sunk cost K^* while uncertainty σ_x is increasing, it can be concluded that the acceptable level of sunk cost that the investor is willing to put in place decreases as shown in Figure 3.10.

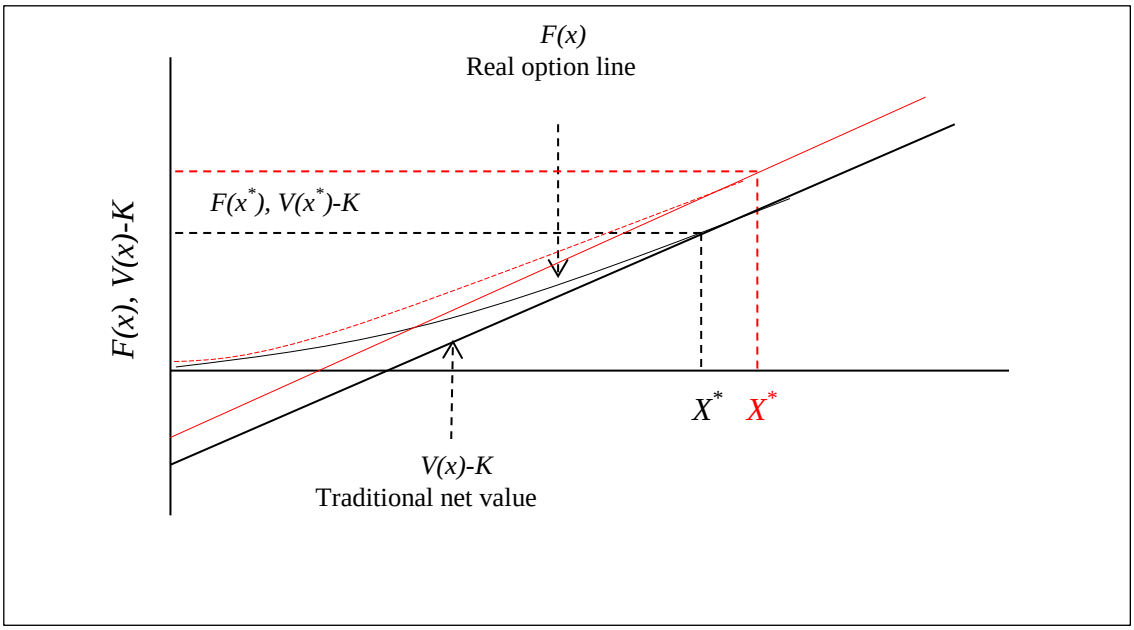


Figure 3. 9: The Real Option Value to Invest with Increased Uncertainty σx
Source: Authors application

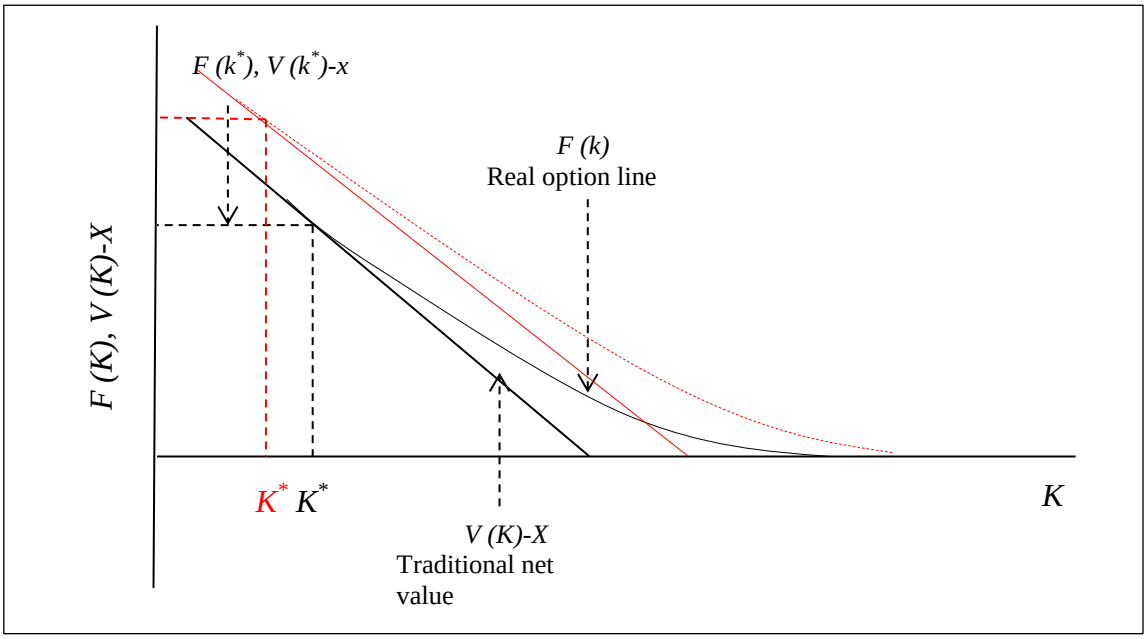


Figure 3. 10: The Real Option Value to Invest with Stochastic Irreversible Cost *K** and Increase in Uncertainty *σx*
Source: Authors application

Evaluating the results with regard to the specific uncertainty of the regulatory step process can be done through the partial derivatives of the threshold values x^* and K^* with respect to the regulatory variance σ_R:

$$\frac{\partial x^*}{\partial \sigma_R} = \frac{\partial x^*}{\partial \sigma_x}\frac{\partial \sigma_x}{\partial \sigma_R} = \delta_x K\left(\frac{1}{\theta_1 - 1} - \frac{\theta_1}{(\theta_1 - 1)^2}\right)\frac{\partial \theta_1}{\partial \sigma_x}\frac{\sigma_R + \sigma_I \rho}{\sigma_x}\,;\left(\frac{\partial x^*}{\partial \sigma_R}\middle|\underset{\rho=-1}{\longleftarrow}\right) > 0 \qquad (3.34)$$

Equation (3.34) implies that the changes of the threshold x^* will depend on the correlation of the variance for the regulatory index σ_R and the dollar value of the investment σ_I. Thus, as the volatility of the regulatory index increases and the dollar value of the investment decreases, this will lead to a correlation value closer to $\rho = -1$. This will increase the threshold value x^* which will move to the right in Figure 3.9. This situation again indicates postponing the investment

until more certain information is known. The acceptable critical sunk cost K^* that the investor is willing to put in place will decrease as the negative correlation between σ_R and σ_I increases. As the uncertainty in each of the approval steps increases, the acceptable level of sunk cost the investor is willing to invest is reducing.

3.5.3.4 Consequences of the Regulatory Uncertainty

We are living in a world where technologies like planes, mobile phones, computers, web applications etc. are important factors of economic growth. Similarly, biotechnology is important factor in both economic growth and agriculture as it can increase global food production in an environmentally sustainable manner. Biotechnology can contribute to the food security in two ways; the first is through increasing agriculture productivity which in turn increases global food availability at affordable prices (Qaim and Virchow, 2000). The second is that the appropriate genetically modified crop can raise agricultural revenues which are the dominant source of income in many poor and rural parts of the world (Qaim and Virchow, 2000). However, this particular contribution of biotechnology should not be considered as solving world hunger and poverty. Many problems in developing countries are not solvable with only the introduction of biotechnology.

Regulating technology is important in order for governments to provide human, animal and plant safety and health. However, inefficiencies in regulations where decision making is based on political factors and not scientific evidence complicate the accessibility of some countries to specific technology, and thus slows technology development. Such an example is EU regulation on biotechnology, where the social rational approach is used when granting GM event approval.

With the EU approval process the EFSA completes the scientific opinion regarding the technology and the decision making for approval is performed by political institutions like EC, Examination Committee and the Appeals Committee. These institutions consist of representatives from the MS higher political level or Ministry, thus political factors are driving the decisions in the regulatory approval of GM events. In this research these political factors are part of the legislative approval process and the political decisions within the approval process slow the growth of the biotechnology industry and constrain the accessibility of this technology for developing and poor countries.

The influence of the political factors on the regulatory decision approval process is explained in the model in sections 2.5.2 and 2.5.3 of this essay. We will explore two conditions that result from political factors. The first being when the uncertainty is large as a result of the variation in the legislative approval process resulting from the presence of political factors in the decision process. Thus, the first condition describes the current situation the decision process for GM approval in the EU. The second condition is when uncertainty is low in the legislative approval process and thus is without the presence of political factors in the decision process. Table 3.1 summarizes the parameter changes when the above two conditions are considered along with the investment decision of the exporting firm.

Table 3. 1: Summary of the parameters when the decision process involves/does not involve political factors

	D_L	D_S	$R/\ \sigma_R/\alpha_R/\sigma_x$	I	ρ_{RI}	Investment decision
With uncertainty of the legislative approval	Large	Small	Large	Small	-1	Increasing $F(x)$
						Increasing x^*
						Decreasing K^*
Without uncertainty of the legislative approval	Zero	Small	Small	Large	0	Decreasing $F(x)$
						Decreasing x^*
						Increasing K^*

Source: Authors application

In the first situation where political factors are present in the decision process and the drivers of the decision regarding whether the GM event will be approved include the EC, Examination Committee and the Appeals Committee, the result is a high probability value for the legislative approval process (D_L). The higher probability increases the value of the regulatory index (R) and the uncertainty of the regulatory environment and the investment (σ_R, σ_x). This leads to a decreased dollar value of the investment (I) indicating a correlation value close to $\rho_{RI} = -1$. As the uncertainty in the legislative approval process increases so does the value of the option to increase $F(x)$, causing the critical threshold x^* to move to the right in Figure 3.9 and K^* to the left in Figure 3.10. Therefore, it is more profitable to postpone the investment and invest in the future when more information will be available. The decision to postpone the investment, in turn, reduces the acceptable level of sunk costs K^*. Thus, given the EU approval process the threshold values of x^* is too far to the right and the value of K^* too far to the left in Figures 3.9 and 3.10 respectively. This reduces the investors willing to invest at the current time and given the high level of uncertainty their acceptable level of sunk cost is low.

In the field of biotechnology as new varieties are developed they have a finite time before they are replaced with newer varieties (Smyth et al., 2014). The variety type has largest economic impact when the adoption rate reaches its peak (Smyth et al., 2014). Therefore, if this phase of crop development does not happen as a result of the delayed regulatory approval process then the cost of the variety will be higher than the benefit for the exporter. Thus, the high uncertainty and value of x^* will result in investment always being postponed and eventually not occurring since there will be no economic importance for the particular variety. Over time this situation will lead to a slowdown in technology development.

In the second situation the parameters and the investment decision of the exporter are opposite to the first situation. This is a theoretical situation where the uncertainty of the legislative approval process is eliminated, thus D_L =0 and there is only a small level of scientific uncertainty D_S. In this situation the option value for future investment decreases and thus it is more profitable to invest earlier as shown in the model where the critical value of x^* is smaller and K^* is larger. In both situations there is a small level of uncertainty arising from the scientific evaluation of the GM product, however, this is considered a necessary step in the regulation decision to provide human, animal and plant safety and health.

3.6 Summary and Conclusion

In this essay a theoretical real options model was developed that considers the political risk of the stringent post moratorium regulations regarding GMO approval in the EU that is imposed on the investing biotechnological firm. More specifically it analysed the decision approval process of a GMO event in the EU, their inconsistency with the multilateral trade agreement and how

that regulation structure can be defined as political risk that can influence the investment decisions of firms that want to bring GM products to the EU market. The regulation (political) risk is captured as uncertainty that can influence the optimal decision of the investment firm.

The real options model was utilized because of its capabilities to capture the uncertainty created by the regulatory environment while considering the irreversible sunk cost of the investing firm. Thus, the model solution is given by a critical cash flow threshold influenced by regulatory environment x^* and a maximum acceptable level of irreversible sunk cost by the investor K^*. This optimal solution can vary with the changes of regulation uncertainty, and thus influence the decision of an investor whether to invest immediately or wait for future times when additional regulation information is available. Through differentiating the critical values with respect to the regulation uncertainty parameter σ_x and more specifically with the uncertainty of each step of the EU decision process σ_R, we can explain the behaviour of the investor regarding decision process risk of the EU GMO approval process.

Figure 3.11 summarizes changes in the optimal solution as we increase specific regulation uncertainties created by the EU GMO approval process. As we increase the uncertainty in the regulation environment the changes in the threshold value x^* increases while the threshold value of K^* decreases. These uncertainties place a higher value on the opportunity cost and thus increase the opportunity value. The increase in opportunity value makes the investment more attractive in the future, and postpones the decision of the investor to invest until a future time when the regulatory environment will improve.

Regulation uncertainty	Partial derivative	Optimal solution (X^*)	Opportunity value $F(x^*)$	Value of the project $V(x^*)$-K	Maximum allowable irreversible cost (K^*)
σ_x ↑	$\frac{\partial X^*}{\partial \sigma_x}>0$	↑	↑	↑ ↓	↓
σ_R ↑	$\frac{\partial X^*}{\partial \sigma_R}>0$	↑	↑	↑ ↓	↓

Figure 3. 11: Summery of Changes in the Investment Decision as Uncertainty Changes
Source: Authors application

By taking a closer look at the specific steps in the approval process of a GMO event in the EU we can evaluate whether uncertainty comes from the scientific risk assessment process or the legislative approval process by increasing the volatility of the regulatory index σ_R. The increase of a specific uncertainty also increases the threshold value of x^* and the option value. With each step of the approval process gradually increasing the uncertainty, the threshold value x^* is also gradually increasing which postpones the investment decision into the future. However, the postponement of the investment and the increasing uncertainty (σ_x and σ_R) causes the investor's acceptable level of irreversible costs, K^*, to decrease. This leads to a situation where over time the actual investment may not happen.

The contribution of this research defines the regulatory GMO approval process in the EU as political risk and as such incorporates it into a theoretical real options model. The incorporation of the regulation decision process steps into the real options model is an addition to the literature. However, an empirical and policy analysis on the theoretical model would be beneficial and should be considered in future research.

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CHAPTER 4

An Appropriate Policy to Inhibit Smuggling to Preserve "Disease Free" Status under SPS Regulation

4.1 Introduction

The management of diseases is an important topic in the trade of agricultural goods, especially when one considers the significant impact that international agricultural trade may play in the spread of diseases from one region of the world to another. Until the Uruguay Round, when a country experienced a localized disease outbreak the entire country was considered infected for the purposes of international trade. Thus, an importing country could embargo meat and/or live animals originating from an entire country where a disease had been found – even if the disease outbreak was localized and contained in a geographic sub-region. The Uruguay Round, however, included the possibility of regionalization or zoning. Regionalization, or zoning, allows, in principle, for countries to differentiate disease-free areas from infected areas within a specific country or group of countries (Australia Department of Agriculture Fisheries and Forestry, 2001). The concept of the regionalization means that if an outbreak occurs, but can be controlled and localized to a specific area within the country, then constraints on international trade need only apply to products originating from the infected area, thereby allowing the uninfected area of the country or countries in question to continue exporting (Loppacher et al., 2006). Guaranteeing that the country can control and localize a disease outbreak may lead to significant economic and trade benefits. Thus, the concept of regionalization under the WTO is likely to be of growing importance in international agriculture markets.

Article 6 of the Sanitary and Phytosanitary Agreement (SPS)[41], describes regionalization and its application as defined within WTO regulations.

> "SPS Agreement recognizes the concepts of pest- or disease-free areas. Such an "area" may be only part of a country, or all or parts of several countries, in which a specific pest or disease is not prevalent. The efficiency of control measures and epidemiological surveillance are important factors in defining such areas. The practical implication is that an importing Member should not deny access to goods from such areas even if the disease prevails elsewhere in the exporting country(ies). Similar to the provisions for equivalence, it is the exporting Member's burden to prove the disease-free status that it claims for the region, and the exporting Member is obligated to grant access to the importing Member for investigation of the claim." (WTO, 2006, pp.1)

When the WTO designed the compliance system for regionalization under the SPS Agreement, specific measures where established regarding recognition of a member country's regionalization efforts. Under the SPS Agreement the World Animal Health Organization (OIE) and the International Plant Protection Convention (IPPC) are the organizations housing the technical expertise that member countries must work with to gain regionalization recognition. Once a member country has accessed assistance and subsequently gained approval[42], then the decision to allow imports from a disease-free area belongs to the importing country.

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[41] On the 1st January 1995 the SPS Agreement was came into force as part of the new WTO. It includes human, animal and plant safety, and health regulations that a particularly country may put into place (Isaac, 2007). The purpose of the SPS Agreement is to regulate the movement of products across international borders without the regulations being used as a disguised barrier to trade. To accomplish its objectives, the SPS Agreement encourages countries to use international standards for human, animal and plant health, as well as the environment, that are consistent with the WTO regulations. Countries can create stricter domestic standards but only if there is scientific justification for doing so.

[42] The process for gaining regionalization recognition is described in Terrestrial Animal Health Code of OIE (Chapters 4.3 and 4.4) and in the International Standards for Phytosanitary Measures, ISPM No.29 of IPPC. However these are guidelines for technical recognition of the zone without the presence of administrative procedures and time frame for response.

The regionalization regulation under the SPS agreement provided an incentive for a number of countries to make significant investments in control measures designed by each country's veterinary services. However, a number of countries experienced difficulties in obtaining recognition of their disease free regions due to administrative delays in importing countries. One of the main reasons for the failure of trade taking place under the regionalization provisions of the SPS is that the focus of the WTO, OIE, IPPC, and other regulatory agencies is in improving the technical guidelines for obtaining disease free status rather than ensuring that importing countries recognize and accept this status. While there is general agreement that these administrative guidelines should be created, there is significant disagreement between members as to where they should be created and their scope and detail (Loppacher et al., 2006)[43]. A question that should be considered within the regionalization question is why countries are not willing to accept an exporter's claim that the sub-national region is free from disease, and as a result postpones (sometimes in perpetuity) acceptance by imposing administrative delays.

Loppacher et al. (2006) suggest that administrative delays may stem from the belief that smuggling of agricultural goods from the disease outbreak area to other areas of a country cannot be prevented through regulatory constraints on the physical movements of animals in isolation. Therefore, the potential for disease transmission through exports remains a legitimate concern

[43] For example, Loppacher et al. (2006, pp.52) state: "that some countries wish to see extensive guidelines with timeframes stated for each step. Others are opposed to any set timeframes to be included as they feel it would take away much needed discretion. Some countries, the most active of which is Chile, suggest technical guidelines should be left to those that have the necessary expertise – the OIE and IPPC but that administrative guidelines should be created by the SPS Committee. Other countries that support this position include Peru, Argentina, China, Mexico, Brazil, Colombia, Costa Rica, Uruguay, and the European Union. Canada was the first Member to put forth the position that administrative rules should be created at the OIE and IPPC".

for a potential importer. The potential for smugglings between infected and a disease free area is the significant problem. The use of mechanisms that physically control the movement of animals in and of themselves will not eliminate smuggling between regions and, hence, creates doubts that an exporting country can ensure a disease or pest free area remains so (Loppacher et al., 2008). The existence of smuggling and the inefficiency of the control mechanism to deal with it can be supported by the following examples. The Argentinean National Foot-and-Mouth disease (FMD) control program controlled and eradicated the disease and Argentina received status recognition as an FMD-free country from the United States, Canada, and several other countries. This resulted in the ban on Argentina's exports of fresh, chilled, and frozen beef being lifted in 1997. However, the ban was reinstated in 2000 by the US as a result of smuggled animals infected with FMD crossing the Argentine border. Smuggling led to regulatory breakdowns in seven of the eleven outbreaks of FMD in Europe between 1991 and 1996 (Otte et al., 2004). The illegal importation of livestock or livestock products was the underlying cause in these seven cases. Thus, in one FAO report, smuggling was described as one of the main reasons for the spread of disease – food and mouth disease (FMD) – internationally.

> "The risk of FMD entry into free areas is low through legal trade of animal and animal products from zones or countries officially recognized as FMD-free by the OIE. However, there is evidence of high volumes of animal products entering free countries by various routes, some of which are likely to carry infection. In 2005-6 most of the international spread of the disease has been attributed to movements of live animals but the risk of movement of meat products remains, and is highest. Smuggling of animal products is a significant issue and the probable main route of virus introduction into FMD-free areas [e.g. United Kingdom (2001)]." (FAO, 2007, pp. 9, 10)

Extensive regulations regarding the control measures have been developed under the OIE. However, there is a lack of unified measures regarding the private incentives for farmers. Otte et al., 2004 state that all measures may fail with inadequate funding for private incentives for

farmers. Thus, the efficacy of the regionalization concept can be increased by finding an appropriate balance between the control measures and the private incentives faced by producers (or others that could acquire animals for purposes of smuggling) when attempting to control an outbreak. If individual producer incentives are not considered during regulation design, then the detrimental effect of an outbreak could be increased (Hoag et al., 2006).

There has been a little research done on the reasons why the regionalization concept has failed in implementation, the reasons behind the reluctance of importing countries to accept disease free regions, and the reduction of incentives to smuggle between regions. Previously Loppacher et al. (2006) (2008) and Ferrier (2008) have undertaken research in this topic area. The analysis of Ferrier (2008) is focused on the price disparity arising as a result of a trade ban and its effect on the incentive for smuggling agriculture goods and wild animals. His analysis, however, centers on the smuggling among countries rather than on the regionalization issue.

The objective for this essay is to shed light on how to improve the efficacy of the trade regime for sub-national export under the Agreement on Sanitary and Phytosanitary measures. Thus, assessing cases where countries have difficulty obtaining disease free status for the whole or part of its territory by the importing country is the first objective. This will be followed by the construction of a more detailed partial equilibrium analysis of regionalization accounting for the incentive to smuggle. Further, a more detailed policy analysis of the science-based disease control criteria associated with regionalization is explored through design of a policy regime that would remove the appeal of smuggling from the infected area to the non-infected area.

Based on the stated objective, the following two research questions are addressed: 1) Modeling regionalization accounting for the incentive to smuggle (producers' incentive to smuggle and casual smuggling); and 2) designing a policy for eliminating the incentive to smuggle between regions as a result of a disease outbreak.

4.2 Cases Where the Importing Countries have been Reluctant to Accept Disease Free Status

Obtaining status as a disease free zone within the OIE requirement is costly process that depends on the financial ability of the exporting country to achieve as well as maintain that status. For example, just the global costs for administrating FMD vaccine every year are estimated to be US$2.35 billion (Knight-Jonesa and Rushtonb, 2013). Thus, countries with large exports in certain agriculture goods must invest significant resources in constraining the disease in regions where an outbreak has started. Theoretically, countries recognize the economic and trade benefit the regionalization concept has to offer through obtaining disease free zone. However, the cases for some major exporting countries has revealed that gaining the approval from the importing countries takes a long time after the exporting country has gained OIE approval. This section of the essay presents some cases where the importing countries have been reluctant to accept the OIE evaluation of the disease status of the exporting country.

Example 1(Argentina): Exports of beef products represent important revenue for Argentina as they represent 10 to 15 percent of the national beef production (Deblitz and Ostrowski, 2004).

During the early 1990s the countries of the Southern Cone[44] experienced a major Foot and Mouth Disease (FMD) outbreak, but towards the end of the 1990s they were able to eradicate the disease. In 1997 Argentina received the OIE status of FMD-free with vaccine and in 2000 their status switched to FMD-free without a vaccine[45]. However, an FMD outbreak occurred on August 2, 2000 at Clorinda, in the province of Formoso near the Argentinian-Paraguay border. Only four animals were infected and these animals had been illegally imported from a neighbouring country on July 22, 2000, a discovery that was made through routine epidemiological surveillance activities and procedures carried out in the border zones (OIE, 2000). The next outbreak was found in a province over 500 km away from the initial outbreak. The disease continued to spread during 2000 with OIE suspending Argentina's FMD free status till November 2000. However, the Argentinian government did not acknowledge the spread of the disease, resulting in FMD gaining momentum in May 2001 (Rich and Nelson, 2007).

Argentina's policy of controlling the movement of animals and stamping out the disease were unsuccessful. Hence, Argentina switched to a policy of regionalization and segregated its territory into five regions. Patagonia is among the regions and was declared to be FMD free without vaccination while the other four regions were required to vaccine. Even with this change in policy most of the high valued export markets including the EU, US, Canada, Japan and Korea remained closed for Argentinian beef from the Patagonia region during 2001. Starting in 2003, Argentina was allowed to export precooked and individually frozen meals to the US market and

[44] Argentina, (southern) Brazil, Paraguay, and Uruguay

[45] Countries can be recognized by the OIE as FMD-free with vaccination and FMD-free without vaccination. Countries or zones within countries have the risk of FMD entering from a neighboring region or country and a protective vaccination program is applied but it is thought not to have been exposed to the virus. Vaccinated animals create a barrier to the further spread of the disease.

in 2015 it was announced that Argentina would be allowed to resume fresh beef exports to the US market. Rich and Nelson (2007) remarked that the rationale for the US decision for keeping its market closed to Argentine beef was based, in part, on Argentina not being forthcoming when the outbreak first took place. The Argentine Foreign Minister Hector Timerman has stated that the ban was due to "poor handling of the foot-and-mouth disease by the government in 2001," and that they have been disease-free since 2007 (Illinois Farmers Today, 2015).

Even with its regionalization effort the disease re-emerged in Argentina in the summer of 2003 with outbreaks occurring in a pig farm in the province of Salte near the borders of Bolivia and Paraguay. The OIE suspended the designation FMD-free for regions in Argentina north of the 42nd parallel. The regions south of this parallel were free from FMD without vaccination but some of the high value markets[46] remained closed to exports of Argentinian fresh beef (Rich and Nelason, 2007).

The US market closure for Argentinian beef ended in 2015 after Argentina filed a complaint on August 30, 2012. In the complaint, Argentina claimed that the United States had imposed an undue delay in the approval procedures on Argentina's requests regarding import authorization for fresh beef and recognition for the Patagonia region as FMD-free. Argentina also argued that, with respect to products from Patagonia, the United States had not complied with its obligations to adapt its measures to accommodate pest or disease-free areas and to recognize the concept that such areas exist (WTO, 2015). A WTO disputes panel found that the United States measures applied to Patagonia were inconsistent with Article 6.1 of the SPS Agreement.

[46] Canada, Japan, Korea, and the United States.

The Patagonia region had been free from FMD since 1994 and was recognized by the OIE as FMD-free without vaccination in 2002 (USDA, 2014). However, the sequences of FMD outbreaks that happened between 2000 and 2007 in the other regions of Argentina led to the closure of the high valued US market to Argentinian product, including the Patagonia region. Argentina's Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA) requested the US recognize the Patagonia region as free from FMD and submitted information supporting the request to the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS). Table 4.1 summarizes the timeline regarding the US recognising Patagonia as FMD free. From the table we can see that took 13 years for Argentina's request that the Patagonia region be accepted as FMD-free to be approved by the importing country. The Patagonia region was accepted as FMD-free at the same time that all of Argentina was accepted as FMD-free by the US, even though Argentina in its entirety was recognised by the OIE as FMD-free without vaccination in 2007.

Table 4. 1: Timeline for the Patagonia region to obtain FMD-free status by the US

Time	**Action**
2002	SENASA submitted information to APHIS and USDA
December 2003	APHIS evaluates the submitted information and visits Argentina
2005	APHIS completed the Patagonia South risk analysis
January 2007	APHIS published the risk analysis report in the Federal Register
February 2009	APHIS revisited the region in order to update the 2005 risk analysis
November 2013	Conducted another visit to further update the risk analysis
August 2014	APHIS announced its intention to add Patagonia to a list of countries deemed free of FMD
June 2015	USDA announced changes to the rules that would allow imports of fresh beef from Argentina

Sources: USDA, 2014; Bridges Weekly, 2015

Example 2 (Brazil): Brazil, like other countries from Southern Cone, struggled with FMD outbreaks through much of the 20th century. Since 1999, the Brazilian government has adopted the SPS regionalisation concept and the guidelines of the OIE. It divided its territory into five regions. The FMD outbreak in 2000 and 2001 across the Southern Cone countries also included Brazil, initially in the Rio Grande do Sul and Santa Catarina regions. Prior to 2000, both regions were recognised by the OIE as FMD-free with vaccination and FMD-free without vaccination respectively. The 2000 and 2001 outbreaks were mitigated by switching export markets for beef from the high value markets to low value markets in the Middle East and Eastern Europe. The additional increase in domestic production and higher exports to the low value markets helped limit the loss of the high value markets. Hence, the effect on the export markets was minimal as a result of diversity in its destination markets and increased quantities of exports.

The last FMD outbreak in Brazil was first reported in September 2005 in the provinces Mato Grosso do Sul and subsequently one month later in Parana. This outbreak affected both the export quantities and prices of beef and pork. Several countries imposed a ban on imports of meat from Brazil; not just from the two infected regions but also neighboring regions. The exports from these provinces account for over 50% of Brazil's total beef and pork exports (FAO, 2006). The impact of the bans was greater for the Brazilian pork industry compared to the beef industry due to the larger export volume of pork going to Russia. Approximately 65% of pork exports were going to the Russian market (FAO, 2006). Thus when the import ban was implemented by Russia and 50 other countries to regions of Brazil that were free from FMD (i.e. Santa Catarina and Rio Grande do Sul) the previous exports from these provinces was redirected to the domestic market. This resulted in domestic pork market prices dropping by 30% (FAO,

2006). The extension of the import ban to two provinces free from FMD resulted in a 30% drop in exports of beef (Costa et al., 2015). After 28 months, Russia lifted the import ban in December 2007 (Costa et al., 2015).

Example 3 (Canada and US): On May 20, 2003 the Canadian Food Inspection Agency (CFIA) confirmed that a cull cow sent for slaughter in Peace River, Alberta in January 2003 was infected with Bovine Spongiform Encephalopathy (BSE) (Forge and Frechette, 2005). In December of 2003 a case of an infected cow with BSE was found in Washington State in the US. These BSE cases led to the closure of major export markets for Canada and the US. Additionally, the import ban remained in place for specific Asian markets for 30 months for Canadian beef, even though Canada was registered as minimum-risk country for BSE under the OIE code.

Prior to 2003 Canada and the US together represented 25% of world beef exports[47]. Thus the prolonged ban by the importing countries resulted in a reduced supply of beef in world markets and created a nearly 20 % rise in the Pacific market prices for beef (FAO, 2006). The extra supply of beef from Canadian and US had to be redirected to their domestic markets. The US is large beef exporter as well as a large beef importer, therefore the net result was little change in domestic prices as a result of the increased domestic beef supply. However, Canada exports 12 percent of its live animals and nearly 50 percent of its total beef production, thus the import bans resulted in cattle prices dropping by approximately 50 percent as domestic beef supplies increased (FAO, 2006).

[47] 10% comes from Canada (FAO, 2006)

Example 4 (Indonesia): Indonesia is considered an FMD-free country without vaccination under the OIE code. Indonesia is a large importer of beef and its policy states that beef imports have to come from countries free from FMD without vaccination and, hence, these policies result in high domestic beef prices. Domestic beef prices also face pressure from rising incomes and changing consumption preferences for meat (Knight-Jonesa and Rushtonb, 2013). A lower beef price due to the presence of FMD in neighbouring India creates an incentive for larger quantities of meat to be smuggled into Indonesia from India (Knight-Jonesa and Rushtonb, 2013).

Summarising the cases presented above brings to light several important points. Importing countries prefer to place a ban on the entire exporting country when a disease outbreak occurs. Hence, even with the regionalisation concept available and put into practice by beef exporting countries, the ban is still placed on the whole country or in a best case scenario on only the infected regions and the neighboring disease free regions. For example, the import ban placed on Brazilian beef by Russia was imposed on the neighboring provinces of Mato Grosso do Sul and Parana. Thus, the final outcome is a larger share of exports being banned. The reason for this kind of action may be due to the fact that most of the cases where the disease has spread it came from a neighboring country or region through illegal channels. A summary of selected FMD outbreaks from Knight-Jonesa and Rushtonb (2013) is presented in Table 4.2. The summary lists the country of the FMD outbreak along with certain details on the cause of the outbreak. In most cases, the cause of the FMD outbreak is due to illegal importation of diseased animals from a neighboring country.

Table 4. 2: Details surrounding the detection of FMD that occurred between 1992–2003 in countries and zones considered FMD-free by the OIE

Country/Year	**Premises/Species**	**Details of the cause of an outbreak**
Italy 1993	Detected on a farm/ beef cattle	Cattle entered Italy with forged import certificates
Greece 1994	Cattle	Illegal importation of infected live sheep from Turkey to Lesbos
Taiwan 1997	Farrow-to-finish farm/Pigs	Pigs or other animal products illegally imported by fishing boats
S. Korea 2000	Dairy farm/ Dairy cattle	Imported hay, international travelers, and windborne introduction by Asian (yellow) dust suggested
Greece 2000	Free-grazing beef herd/ beef cattle	Animals from Turkey crossing the Evros river
Argentina 2000	Communally owned establishment/cattle	Illegal importation of cattle
Uruguay 2000	Field shared by 3 owners/ beef cattle	Sow that consumed feed of animal origin
France 2001	Cattle farm/ Dairy cattle	Infected sheep imported from UK by neighbor
Ireland 2001	Holding with cattle and sheep/sheep	'Strong circumstantial evidence' of spread by indirect contact with index case in N. Ireland via neighboring farm
Uruguay 2001	Farm with cattle and sheep/cattle	Spread from Argentina
Botswana 2002	Crush area with cattle/cattle	Spread from Zimbabwe, probably by smuggling due to price differentials.
Paraguay 2002	Cattle farm on border with Brazil/ Breeding cattle	Unknown

Source: Knight-Jonesa and Rushtonb, 2013

4.3 Modelling Regionalization Accounting for the Role of Incentives

Loppacher et al. (2006) developed an economic model of why the agreed regionalization provisions are not being implemented along with ways that can improve the effectiveness of regulatory attempts at regionalization. The model looks at the occurrence of an outbreak and the effect it has on two regions within a single country. Thus, when regionalization is applied as a

result of an outbreak, exports will continue to originate from the uninfected region, whereas the infected region would be subject to an export ban.

In the short run, the infected region suffers from not being able to export outside the region either internationally or to disease-free parts of its own country. The previously exported supply must be consumed within the infected region. Further, demand may decrease due to an adverse consumer reaction; the result is lower prices. The uninfected region is still able to export and receive the export price. The export ban on the infected region reduces world supply and, hence, increases the world price of the agriculture product in the non-infected market – both domestic and international. The price differential between an infected region and the uninfected regions may create incentives for smuggling. Ferrier (2008) has shown that as the price differences between the two regions increases, so does the incentive for smuggling agriculture goods.

Research on smuggling agricultural goods has shown that increasing the risk for risk averse smugglers through penalties and higher probabilities of being caught as a result of government enforcement will significantly reduce smuggling (Pitt 1981; Martin and Panagariya 1983; Ferrier 2008; Ferrier 2009). However, a significant reduction of smuggling is not enough to prevent the spread of a disease outbreak. Even a single smuggling incident from the infected region can cause the disease to spread in the uninfected region, thus endangering the exporting status of the entire country. Therefore, even the positioning of a control points to manage and limit livestock movements and deter smuggling will not be effective, as economic studies have shown that if

there exists an incentive to smuggle, then some smuggling will occur even with the presence of control points (Saba et al., 1995)[48].

The existence of an incentive for smuggling from the infected region can lead to an outbreak in the uninfected region. Thus, the end result is increased importer risk. Hence, the result is an export ban on the entire exporting country. Adding the topics of smuggling and incentive removal pertaining smuggling to the discussions between WTO members may be the best way to break the holdup that currently exists in regionalization negotiations which focus on non-economic aspects such as restraints on the movement of animals (Loppacher et al., 2006).

Additionally, Loppacher et al. (2006) discuss the design of incentive prices that should eliminate smuggling. They suggest that the equalization of the prices between the infected and the non-infected area could be accomplished through a deficiency payment policy[49]. The producers in the infected area should be guaranteed the market price received in the non-infected area and be allowed the increase in production that is associated with that price. As such, producers in the infected area should be allowed to increase their output to the point where marginal cost equals price. Currently, the policy typically applied in a case of disease outbreak is compensation only for animal destruction/disposal costs (OECD, 2012). Hence, reducing and banning further production in the infected area is a normal process in managing a disease outbreak.

[48] The literature on the economics of smuggling is reviewed in section 3 below.
[49] Loppacher et al. (2006) considers only commercial smuggling in the analysis and deficiency payment as a policy application only for commercial smuggling.

An important indicator that can reduce the price disparity between the regions is the size of the infected area. As the size of an infected area decreases there is less export disruption which reduces the price disparity in the infected areas. This will also reduce the budgetary cost for compensating producers in the infected area based on the daily market price in the non-infected area.

The current management of diseases determines the size of the infected zone based on the possibility and opportunity to control the physical movement of the agriculture product. The criteria for establishing regions are mainly strategic geographical points, pre-existing administrative units, and sub-national political jurisdictions. Establishing the affected region using these criteria, as described by Loppacher et al. (2006), is not determined by science-based criteria, and can result in the size of infected area being larger than needed with the accompanying larger export disruption, and larger price disparity between the regions, ultimately increasing the incentive for smuggling.

4.4 Literature Review for Smuggling

Among the first inclusion of smuggling within trade theory was in the paper by Bhagwati and Hansen (1973). They applied a Hicks-Samuelson theoretical model, and concluded that when a prohibitive tariff is in place, the non-smuggling situation is autarkic and that smuggling brings the benefits of trade. Thus, smuggling is necessarily superior to non-smuggling, even if smuggling is competitive or monopolistic; and whether it is subject to constant or increasing costs. However, Bhagwati and Hansen (1973) do not incorporate the possibility of coexistence of smuggling with legal trade and price disparity between markets.

Later, Pitt (1981) included the coexistence of smuggling, legal trade, and price disparity and evaluates the coexistence of these three factors in a case where there is an export tariff or export quotas. Pitt (1981) used legal trade to evaluate smuggling activities and concluded that the greater the legal trade is, the easier it is to hide smuggling activities from enforcement agencies, and thus the less costly it will be to smuggle. Therefore viewing legal trade as an input into smuggling activities and maintaining a legal trade quota in a combination with corrupt enforcement leads to a smuggling boom as a result of the price differential between the domestic and world price. Pitt (1981) introduces smuggling as a constant function over time and assumed smuggling is a monotonically increasing function of the incentive to smuggle.

Martin and Pangariya (1983) build a link between the models of Bhagwati and Hanson (1973) and Pitt (1981) by considering illegal trade through illegal entry points and illegal trade through legal entry points. Additionally, Martin and Pangariya (1983) model smuggling as an illegal act for which the consequences are unknown, ex-ante, by the traders. Thus, it incorporates the risk and uncertainty associated with smuggling, and the cost of smuggling to the firm is considered endogenous. In their model the probability of detection is a strictly increasing function that depends upon the ratio of illegal to legal trade. Lastly, Martin and Pangariya (1983) only considered transport at zero cost, which was later criticized by Norton (1987).

Norton (1987) studied the smuggling of agriculture goods between two specific regions, the Republic of Ireland and Northern Ireland. To benchmark his model with previous research, he decides that smuggling cannot influence the market price as a result of the quantity increase. In

his model, he uses “iceberg” transportation costs for the smuggled good with the explanation that live animals do lose weight with transport. Therefore, transportation cost will have a greater effect on the marginal smugglers who earn an insignificant rent compared to those located closer to the frontier who can earn large rents from smuggling.

Norton (1987) also considers the impact that increasing taxes will have on prices between the two countries in his model. As taxes increase it will extend the distance from where the marginal smuggler can earn small rent even with higher transport costs. Based on previous indicators, he concludes that the smuggling of agriculture goods is an increasing cost industry. For example, in order for smuggling to increase, there has to be an increase in price disparity, considering that the transport cost of smuggling will increase with distance.

Thus far the literature examined has only considered the case of professional smuggling across borders. However, in agriculture goods the possibility of casual unintended smuggling is also a possibility. Saba et al. (1995) measure the motivation for casual smuggling of cigarettes across state boundaries in the United States. They conclude that the primary reason for smuggling (referred as border-crossing), is the often significant divergence between locational prices caused by varying tax treatments across US states. Additionally, their research also found in the state of North Carolina that when the border crossing is controlled, there still exists a certain level of organised smuggling. The findings of Saba et al. (1995) indicate that casual smuggling cannot be eliminated to zero even with a border control program, rather the level of smuggling that exists will transform into a more organized form.

Heltberg (2001) looks at the incentive to engage in poaching. Poaching and smuggling share similar traits, mainly the desire to move a banned product to another location for profit. Heltberg (2001) looks at the effect of the ivory trade ban on the poaching incentive. He concludes that the ban increases the incentive to smuggle as well as the poacher's risk premium. He indicates that even though the primary goal of trade bans is to save biodiversity, they are rarely fully enforced and, thus, illegal markets exist.

The previous studies about smuggling mainly focus on goods that, through economic analysis, can increase the welfare of the final consumer due to the decrease in price as a result of smuggling. However, in the case of smuggled agriculture products that carry the high risk of being infected, additional externalities are created that must be considered. A recent study by Ferrier (2008) looks at an agriculture trade ban arising from SPS risk. The risk that an invasive disease may become established domestically creates negative externalities for society.

Ferrier (2008) made four prepositions regarding the smuggling of agriculture goods with respect to price disparity between three trading countries. Proposition one reveals that the smuggling of goods depends on the elasticity of supply and demand. The more inelastic demand or supply is, smuggling will increase since the disparity between prices will increase. Proposition two reveals that smuggling will increase as the number of partners which trade that product decreases. Therefore, the greater the number of partners supplying that product, the less pressure there will be on the price of the product in the importing country. Proposition three explains that when risk averse traders face higher risk, less smuggling occurs. Thus, when penalties for smuggling and the probability of detecting smuggling are high, the supply of smuggling will decrease due to

increased smuggling costs being a deterrent. Proposition four concerns the regionalization of the SPS agreement. Smuggling is more likely to happen when the restricted region is the primary supplier of that product but it does not consume majority of the product. Hence, the region is export dependent leading to the price in the restricted region to fall drastically, creating large price disparity between the region and the world price. This, in turn, provides an incentive to engage in smuggling.

4.5 Model Framework

Loppacher et al. (2006) consider an economy where world trade consists of only two countries, an exporter and an importer which is formally defined as the Rest of the World (ROW). The market in the exporting country is divided into two regions, one region is where the disease outbreak has occurred ("infected area") and the other is where the disease has not yet emerged ("non-infected area"). The model constructs the infected area based on the OIE requirements for geographical regionalization, as designed by veterinary criteria. Under the OIE, zoning is the geographical segregation of the region where a disease outbreak has occurred. Zoning is defined as determining the subpopulation of distinct health status primarily on geographical basis (using either natural, artificial, or legal boundaries) within its territory for the purpose of disease control or international trade (OIE, 2013). Additionally, the model explains the trade flow between the countries in two scenarios. The first scenario evaluates the trade effect and flows when the disease outbreak has not occurred and thus there are no trade bans imposed. The second scenario evaluates the trade effect and flows with the occurrence of a disease outbreak. Thus, there is a trade ban imposed on the infected region in the exporting country. Within this second scenario, the economic reason for the failure of regionalization is evaluated. The major reason is the

unwillingness of the importing country (ROW) to accept the disease free status of the region due to the presence of the incentive to smuggle between the two regions within the exporting country.

The model framework in this essay is elaborated in two sections. The first section is the algebraic evaluation of the partial equilibrium before the disease outbreak, the first scenario in Loppacher et al. (2006). The second section is the algebraic evaluation of the partial equilibrium with the disease outbreak. Within the second section, the existence of smuggling is shown in the presence of price disparity between the regions. Additionally, the model designs the appropriate policy response in the infected area to eliminate the incentive for smuggling resulting from the price disparity between the two regions within the exporting country. When considering the elimination of the incentive for smuggling two cases are studied. The first case is organized smuggling, where the primary motive is earning profit as result of the price disparity between the two regions. The second case is the casual smuggling, when people unintentionally spread the disease by crossing the border from the infected to the non-infected region through transport of an infected product or visiting a farm that contains the virus.

4.5.1 International Trade Market Equilibrium Before the Disease Outbreak

The assumptions used in Loppacher et al. (2006) model include that the infected area and the non-infected area in the exporting country are competitive on the world market and thus can influence the world price[50]; transportation and transaction costs are significantly small so they

[50] The quantities supplied by the exporting county are large enough on the world market that any variation in supply from the exporting country can influence world prices.

are ignored in the analysis; one homogeneous good is traded; the capacity constraint that may arise from the trade ban in the exporting country are not considered[51]; all countries that are aggregated as importing countries in the ROW have the same sanitary or phytosanitary regime for the product in question and, thus, are treated as a single market.

Loppacher et al. (2006) developed a two country model with three trade regions and one commodity traded. For each region *r*, Q_r^D and Q_r^S are quantities demanded and supplied, respectively. The difference between the quantities supplied and demanded at the world price, P_o, in the exporting country represents the excess of supply ES_{if} for the not yet infected region and ES_{nif} the non-infected region. Where the differences between the quantity demanded and supplied in the importing country represent the excess of demand in the ROW, ED_{row}. Thus, the world equilibrium is when the excess supply of the two regions in the export country equals the excess demand in the ROW.

$$ES_{if} + ES_{nif} = ED_{row} \tag{4.1}$$

By applying the demand and supply functions from each of the markets in equation (4.1) we get:

$$Q_{if}^S(P_o) - Q_{if}^D(P_o) + Q_{nif}^S(P_o) - Q_{nif}^D(P_o) - Q_{row}^D(P_o) + Q_{row}^S(P_o) = 0 \tag{4.2}$$

[51] Such as slaughter facilities in the infected area.

4.5.2 International Trade Market Equilibrium After the Disease Outbreak

In the second scenario, when a disease outbreak has occurred in the "infected region" of the exporting country, a trade ban is imposed on that region. However, the non-infected region from the exporting country can still export to the ROW. Thus, the world equilibrium will be formed based on the non-infected region in the exporting country and the ROW. If the trade ban is applied perfectly by the government authorities the world equilibrium will be:

$$ES_{nif} = ED_{row} \tag{4.3}$$

Applying the supply and demand functions in equation (4.3) from each market:

$$Q^S_{nif}(P_1) - Q^D_{nif}(P_1) - Q^D_{row}(P_1) + Q^S_{row}(P_1) = 0 \tag{4.4}$$

In equation (4.4), P_1 represents the new equilibrium world price with the occurrence of disease in the infected region, with the assumption that segregation between the infected and the non-infected region in the exporting country is perfect. Since a trade ban is imposed in the infected area, the region will be in autarky and the equilibrium will simply be that infected region supply equals infected region demand, or:

$$Q^S_{if}(P_2) - Q^D_{if}(P_2) = 0 \tag{4.5}$$

In equation (4.5), P_2 represents the price equilibrium in the infected area with the existence of a trade ban. As a result of the trade ban the price in the infected area will fall, whereas the new

world price will rise. So, $P_2 < P_1$ and $P_1 > P_o$, it is this price difference between P_2 and P_1 in the two regions that will create an incentive to smuggle, which is consistent with the conclusions by Pitt (1981), Norton (1987), Saba et al., (1995), and Ferrier (2008).

Applying Ferrier (2008) model for smuggling and Loppacher et al. (2006) assumption of zero transportation cost between the two regions, firms will smuggle agriculture goods as long as the price differences between the two regions is greater than or equal to the smuggling cost (SC):

$$P_1 - P_2 \geq SC \tag{4.6}$$

thus,

$$\Delta P_w = P_1 - P_0 \geq 0 \text{ and } \Delta P_{ia} = P_2 - P_0 \leq 0 \tag{4.7}$$

Where ΔP_w represents the change in the world price and ΔP_{ia} represents the change in the price in the infected area. Smuggling costs can be modeled as a cost function of the quantity smuggled *SC (q).* Yang (2004) illustrates that it becomes increasingly difficult to hide evidence of smuggling when the total amount of smuggling is large, therefore $\partial SC/\partial q > 0$. Hence, based on the smuggling function and equations (4.6) and (4.7), the condition for smuggling can be reiterated as:

$$\Delta P_w - \Delta P_{ia} \geq SC(q) \tag{4.8}$$

4.5.2.1 Incentive for Producer Smuggling

If we observe the behavioural equation we can say that in order for producers to be in equilibrium they need to maximize their aggregate net profit, however, this is not the case with producers in the infected area who receive price, P_2, for their products. Producers in the infected area are able to achieve an improved outcome through smuggling. These producers have two options: 1) sell all production in the infected region and receive price P_2 with certainty; or 2) smuggle a portion of their production where they will receive price P_1 minus smuggling cost in the non-infected region and price P_2 for the remaining production sold in the infected region. The producer that decides to sell their production in the domestic market will maximise profit as follows:

$$\Pi(P_2) = max_Q(P_2)Q_{if} \tag{4.9}$$

Where P_2Q_{if} represents the total revenue a producer receives with zero smuggling costs[52]. Hence, their profit will be dependent on the market price in the infected region. Producers that decide to smuggle incur two types of costs. The first are costs associated with all activities associated with the violation of the ban in order to transport the goods from infected region to the non-infected region. The magnitude of these costs are represented by the cost function $C(Q_s)$ that is convex in the value of smuggled goods Q_s. The second type of costs a producer incurs is when smuggling is detected and the smuggler punished. The magnitude of these costs is measured through the fine function $F(Q_s)$ that is convex and increasing in the quantity smuggled. If

[52] For simplicity, production costs are not considered in this analysis.

smuggling were riskless the producer that decides to smuggle a fraction of their production will earn a profit of:

$$\Pi(P_1, P_2) = max_q(1-\gamma)(P_2)Q_{if} + \gamma(P_1)Q_{if} - SC(\gamma Q_{if}),\ \gamma\epsilon[0,1] \quad (4.10)$$

Where, γ represents the fraction of smuggled goods $\gamma=Q_s/Q_{if}$ and can range from 0 to 1, $0\leq\gamma\leq1$. We assume that the cost of smuggling is always positive $SC(\gamma Q_{if})>0$, and increasing in the fraction of smuggled goods $(\partial SC/\partial\gamma Q_{if})>0$. Thus, the producer will maximise their profit from the revenue P_1Q_{if} received by smuggling a fraction of γ, the revenue P_2Q_{if} by selling a fraction of (1-γ) on the domestic market minus the smuggling cost. The producer will decide to smuggle as long as his utility improves from smuggling. Since his utility depends only on the profit earned and there are no risk associated with the decision to smuggle the utility will be improved as long as the profit from smuggling is equal to or larger that the profit from selling the product on the domestic market. Algebraically this can be shown as follows:

$$\Pi(P_1, P_2) \geq \Pi(P_2), \text{ or}$$
$$(1-\gamma)(P_2)Q_{if} + \gamma(P_1)Q_{if} - SC(Q_s) \geq (P_2)Q_{if} \quad (4.11)$$

Taking the derivative of (4.11) with respect to the quantity smuggled Q_s[53]:

$$\frac{\partial\pi(P_1P_2)}{\partial Q_{if}} \geq \frac{\partial\pi(P_2)}{\partial Q_{if}} \quad (4.12)$$

[53] The smuggling cost in equating (4.11) can be presented as $SC(Q_s)$, as $Q_s=\gamma Q_{if}$.

The result from equation (4.12) yields equation (4.13):

$$P_1 - P_2 \geq SC, \text{ or } P_1 - SC \geq P_2 \tag{4.13}$$

Thus, the decision to smuggle will exist as long as price minus the smuggling costs in the non-infected area exceeds that of the infected area, therefore the producer is able to achieve higher a profit level from smuggling.

When we consider the risk of being caught, producer profit will have two outcomes. The first one is when the producer successfully smuggles and the producer incurs only the cost of smuggling *SC* (Q_s). The second outcome is when the producer is caught smuggling and, in addition to the smuggling cost, has to pay a fine for the illicit activity. Algebraically, this can be shown as:

$$\Pi_s(P_1, P_2) = (1-\gamma)(P_2)Q_{if} + \gamma(P_1)Q_{if} - SC(\gamma Q_{if}) \tag{4.14}$$

$$\Pi_{ns}(P_1, P_2) = (1-\gamma)(P_2)Q_{if} - SC\left(\gamma Q_{if}\right) - F(\gamma Q_{if}) \tag{4.15}$$

The profit denoted by Π_s and Π_{ns} shows when smuggling is and is not successful, respectively. The producer will receive revenue of $(1-\gamma)(P_2)Q_{if} + \gamma(P_1)Q_{if}$ if not caught by the authority but only $(1-\gamma)(P_2)Q_{if}$ if caught, since the attempted smuggled quantity(γQ_{if}) is confiscated. If caught, in addition to the smuggling cost producers are fined in the amount of F(Q_s). We assume that the fine is positive $F(Q_s)>0$, and increasing in the fraction of smuggled goods $(\partial F/\partial Q_s)>0$.

Producers are assumed to be risk neutral and make the decision to smuggle based on the expected profit state of successful or unsuccessful smuggling. Using equation (4.14) and (4.15) the producer expected profit function can be shown as:

$\text{Max}_{Q_s} E(\Pi) = (1-\alpha)\Pi_s + \alpha\Pi_{ns}$, or

$$\text{Max}_{Q_s} E(\Pi) = \{(1-\alpha)[(1-\gamma)(P_2)Q_{if} + \gamma(P_1)Q_{if} - SC(\gamma Q_{if})] + \alpha[(1-\gamma)(P_2)Q_{if} - SC(\gamma Q_{if}) - F(\gamma Q_{if})]\} \quad (4.16)$$

With the risk factor considered, again the producer will decide to smuggle as long as his utility improves from smuggling. His utility depends on the expected profit state of a successful or non-successful smuggling. Hence his utility will be improved as long as his expected profit is equal to or larger than the certainty profit in the infected region. This condition is shown in equation (4.17):

$$E(\Pi) \geq \Pi(P_2) \quad (4.17)$$

Taking the derivative of (4.17) with respect to the quantity smuggled Q_s:

$$\frac{\partial E(\Pi)}{\partial Q_s} \geq \frac{\partial \Pi(P_2)}{\partial Q_s}, \quad (4.18)$$

The result from equation (4.18) yields equation (4.19):

$$(1-\alpha)P_1 - P_2 \geq SC + \alpha F \quad (4.19)$$

Equation (4.19) shows the condition for producer incentive to smuggle when the risk of being caught is considered. The condition depends on the probability of being caught α, the higher it is the lower the incentive for smuggling will be due to the loss of revenue in the non-infected market and the additional cost of being fined. If the probability of being caught is 0, the condition becomes the same as in equation (4.13) which means as long as the difference between the prices in the two regions is larger than the smuggling costs there will be an incentive to smuggle.

To increase the effectiveness of regionalisation as policy under the SPS agreement the incentive for smuggling between the infected and the non-infected regions needs to be completely eliminated. In equation (4.13) where we did not considered the risk of the decision to smuggle we were able to show that the current regionalisation policy creates an incentive for producers to smuggle from the infected to the non-infected region through the price differences. However, the smuggling and crime literature reveals that there is risk associated with the decision to do crime. When we incorporate the risk of being caught and punished for smuggling into the producer's decision we arrive at equation (4.19). In this situation the incentive to smuggle depends on the price differential between the regions, the probability of being caught α and the severity of the punishment measured through fine F. Thus in order for the regionalisation policy to be effective the incentive for smuggling needs to have zero value and that can be achieved either through equalization of prices between the infected and non-infected regions or through increasing the probability of being caught in conjunction with raising the severity of the punishment. The probability of being caught has to be one so that every smuggling incident is caught by the

authorities and thus smuggling moves to zero. However, in practice this would require high enforcement costs and legislation to enforce in place for severe punishment.

4.5.2.2 Casual smuggling

The regional price difference may cause individuals from the non-infected region to purchase goods in the nearby lower priced infected region. This consumer behaviour, known as "casual smuggling"[54], is unlike commercial smuggling where the goal is to make profit from the illicit action. Rather casual smuggling happens in modest quantities and is mainly for personal consumption within the family. Goods like cigarettes, alcohol and gasoline are the most common goods examined in the literature for casual smuggling. For example, these goods are subject to different taxation across US states, and since border crossing is feasible it is expected that consumers will use the opportunity to purchase these goods from the neighboring region for a lower price (Beard et al.1997).

Saba et al. (1995) is one of the first to analyze casual smuggling, looking at cigarettes where casual smuggling is motivated by the tax difference between various US states. They found that the trend of individuals crossing the border in response to the price difference of cigarettes affected sales in some US states. Beard et al. (1997) found that casual smuggling of alcohol is significant in at least some US states. Lovenheim (2007) examined how the elasticity of demand for cigarettes in combination with casual smuggling between borders can contribute to government tax policy. He suggested that when demand is inelastic, governments in states with

[54] In the literature of smuggling the "casual smuggling" is also referred as "petty smuggling".

large populations near a lower priced border should focus on expanding enforcement to reduce casual smuggling or simply decrease taxes to reduce the incentive to smuggle.

There is sparse literature with regards to casual smuggling motivated from the price differences in regions where disease outbreaks have occurred. However, there are reports that diseases spread to other regions and countries is often result of incidents where individuals have crossed borders with disease contaminated product. The framework for casual smuggling in this essay was motivated from the application of regionalisation regulation as drawn from the literature on casual cigarette and gasoline smuggling (Saba et al., 1995; Kabur and Keen, 1993; Beard et al., 1997; Lovenheim, 2007; Mlachila et al., 2016).

Therefore, we assumed a representative consumer in the non-infected region will allocate their total product consumption between the non-infected market and smuggle from the lower priced infected market. Where Q_T represents the total consumption of the product and β is the share of Q_T allocated to consumption from the infected market can be presented as follows:

$$Q_T = (1 - \beta)Q + \beta Q \tag{4.20}$$

We have price P_1 in the non-infected region and price P_2 in the infected region. Since $P_2 < P_1$ the consumer's disposable personal income benefits from purchasing the product at a lower price as shown in equation (4.21):

$$Y = (P_1 - P_2)\beta Q \tag{4.21}$$

Following this, the consumer in the non-infected region has an option to buy the product locally at price P_1 or travel a specified distance and buy the same product at price P_2 in the infected area. Thus traveling to the infected region denotes transportation cost of Sd for the consumer. Where S is the cost per km traveled and d is the distance. Considering the transportation cost for travel we can modify the price P_2 as follows:

$$P_2 = P - Sd \tag{4.22}$$

Following Mlachila et al., (2016) we can assume a standard convex cost function for the representative consumer equal to:

$$C = \frac{1}{2k}\beta^2 Q, \quad 0 \leq k \leq 1 \tag{4.23}$$

Where k is a parameter revealing the easiness to evade authorities when smuggling. The higher the parameter reveals the easier it is to avoid authorities and thus lower the smuggling cost. Considering the personal cost for a representative consumer, the net benefit from crossing the border and purchasing the product in the infected area is:

$$B = (P_1 - P_2)\beta Q - \frac{1}{2k}\beta^2 Q \tag{4.24}$$

The consumer will choose the level of β that maximise equation (4.24). Thus, by derivation, B with respect to β ($\partial B/\partial \beta = 0$) and solving for β we get:

$$\beta = k(P_1 - P_2) = k(P_1 - P + Sd) \quad (4.25)$$

Equation (4.25) represents the optimal share of consumption by the representative consumer from the infected region based on the price disparity. Hence, for the regionalisation policy to be effective we need the share of goods consumed from the infected region to be zero, $\beta=0$. This can be achieved either through price equalization between the infected and the non-infected regions, $P_2 = P_1$, or have the parameter $k=0$. In practice for k to be zero authorities need to capture each smuggled good, however as explained in the literature on crime enforcement costs are very high and unrealistic to apply.

4.6 Policy Implications to Remove the Incentive to Smuggle

Early disclosure and containment of the disease are big challenges when designing instruments for risk mitigation (Graming et al. 2006). One of the major problems is that the individual behaviour of the producer needs to be considered. Incorporating the individual producer behaviour when designing a policy will increase the likelihood of early disclosure and the success of a control and management program. Currently, control and management programs are a large part of the costs associated with a disease outbreak because these programs are generally not complete and disclosure is happening too late, allowing the outbreak to become larger in size. Comprehensive polices directed at individual producer behaviour would motivate early disclosure, leading to smaller areas of disease outbreak and costs. For complete policy directed at individual producer behaviour, the Incentive for Producer smuggling in section 4.5.2.1 of this essay should be considered.

In order to reduce the incentive for smuggling there are two categories of policies that can be implemented:

1. Equalizing the prices in the two areas by implementing a price support policy.
2. Significantly increase the enforcement and severity of the punishment.

4.6.1 Price Support as Policy to Deter the Incentive to Smuggle

Price equalization between the two regions is considered a very effective policy in eliminating the casual and commercial incentive to smuggle. This is based on the fact that calculating smuggling costs (SC) and the parameter to evade authorities (k) is very difficult in practice and risky to apply since a single smuggling incident can cause a serious trade disruption. Price equalization can be implemented through government intervention in the form of a price support policy. A price support program allows the government to increase the price in the infected region to the level of the price in the non-infected region P_1. This policy response is graphically presented in Figure 4.1. When government price support in the infected region is at P_1, producers are willing to produce quantity Q_{1S} and the consumers willing to purchase Q_{1D}. Hence, with this policy program there would be an excess supply of (Q_{1S} - Q_{1D}) that the government is required to buy in order to maintain the price at level P_1. The resulting purchasing cost for the government is $(Q_{1S} - Q_{1D}) \times P_1$ as shown the shaded area in Figure 4.1. In addition the government has to handle the excess supply of potentially infected animals. In conjunction the existing price support policy can be applied to the governmental payment amount for animals that are required to be destroyed due the outbreak. In addition the payment amount for destroyed animals, the costs of cleaning and disinfecting the facilities used while transporting and destroying the

infected animals must be considered to ensure proper control of the disease. Thus we can formalize government costs in Equation (4.26):

$$G_c = (Q_S - Q_D)P_s + C_d \tag{4.26}$$

Where, G_c represents the government's total costs with the price supporting program, P_s is the price support and represents the daily market price, and Q_S is the quantity supplied by the producers at P_s price and Q_D is quantity purchased by consumers at the same price.

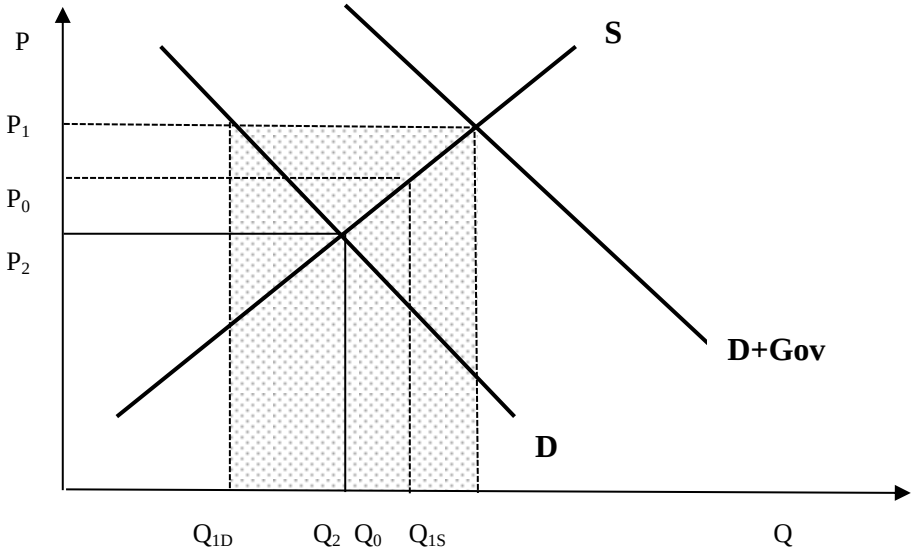

Figure 4. 1: Government Intervention with Price Support Policy
Source: Authors application

Aspects that should be considered when implementing a price support policy in conjunction with government purchase of animals to be destroyed in order to eliminate the incentive for smuggling should include:

- the price differential between the infected and non-infected regions,

- the relative geographical size of the infected area, and
- the elasticity of either supply or demand.

Price Differential between the Infected and Non-Infected Region

The price differential between the two regions creates the incentive for smuggling. Hence, if the regional price differential is comparably smaller than the incentive to smuggle then smuggling will be reduced to the point where smuggling one extra unit of product into the non-infected region will cost more than selling the same unit in the infected region. With a smaller price differential there will be less excess supply, smaller government purchasing cost (gray area in Figure 4.1) and thus less total governmental costs G_c.

Based on Equation (7) we can say that $P_s = \Delta P_w + P_o$, and a smaller change in the world price, ΔP_w, will move P_s closer to P_o, the world price prior to the disease outbreak, thereby decreasing total government cost in equation (26). Hence, if government implements a price support policy with purchase of excess output, and it is known by the producer ex ante, then during a disease outbreak there will be early disclosure by producers affected by the outbreak. For example, if a producer knows that he will be paid a price for diseased animals that is equal to that received in the disease free areas following an outbreak, then the producer will disclose the disease case the moment he is certain.

Casual smuggling happens when the price differential between the regions is large enough to cover the traveling costs and the parameter of avoidance authority is high enough (or the cost to avoid the authorities is low) that when the consumer smuggles the product has higher utility. As

long as there is a price differential between the regions there will be a marginal consumer that will smuggle the product to achieve higher utility. However, with the price support policy the prices between the regions is equalized and thus the motivation for casual smuggling is eliminated.

With this price support policy the cost will be covered by the exporting country. At the same time it will reduce the risk for smuggling between the regions, which is the main concern of an importing country when accepting the exporting country's disease-free status.

Relative geographical size of the infected and the uninfected areas

The existence of a price support policy that is known to producers prior to a disease outbreak provides an incentive for early reporting of the diseased animal. Therefore, the spread of the disease can be contained in a small region. With the infected region being geographically small compared to the non-infected area, the $\Delta P_w = 0$ and the quantity banned for export from the infected region is not large enough to cause a change in the world price, thus the world price will remain at P_o. The price in the infected region will ether stay the same or decrease, but the difference between the infected and the non-infected region will be smaller. In this case, a slight decrease in price implies the condition for smuggling agriculture goods in equation (4.6) is:

$$P_o - P_2 \geq SC \tag{4.27}$$

The purchasing cost of the government will also be smaller (the gray area in Figure 4.1) since the price supported will be the old world price P_o. In the case where the price does not change in the infected area then the government cost will be zero.

Elasticity of supply or demand

When designing the price support policy for a potential disease outbreak the elasticity of demand and supply for the particular agricultural good should be considered. Elasticity can influence the price disparity which is influenced by the smuggling incentive and government purchasing cost.

Both regions belong to the same country and have the same elasticities of supply and demand for specific agricultural goods. When supply and demand are inelastic, consumers and producers are less responsive to a price change. Thus, when there is a trade ban on exports from the infected region a small reduction in quantity can cause larger price disparity between regions and thus a larger incentive for producers to smuggle into the non-infected region. However, with a price support policy, the inelasticity causes a small reduction in the quantity purchased (Q_{1D}) and sold (Q_{1S}), thus creating smaller excess of supply and government purchasing costs. The opposite happens when demand and supply are elastic. In this case the price disparity is lower for a larger reduction in quantity when a trade ban is imposed on the infected region, and in turn excess supply and government costs increase as a result of the larger reduction in the quantity demanded by consumers (Q_{1D}) and increased quantity supplied by producers (Q_{1S}).

When there are differences in elasticities between supply and demand the following can be stated:

1. For small values of E_d/E_s we have a case where demand is more inelastic and therefore the large price difference between the equilibrium price and the supported price means that consumers are less responsive to the price increase than producers.
2. For large values of E_d/E_s we have a case where supply is more inelastic, therefore the large price difference between the equilibrium price and the supported price means that producers are less responsive to the price increase than consumers are.

One important issue that should be considered with a price support policy is that supply and demand in long run tends to be more elastic than in the short run. In the short run price support as a policy will have a small impact on the government cost but a considerable impact in the long run. Hence, price support as a policy is more applicable in the short run where it has small impact on government costs but a large impact in eliminating the casual and commercial incentive to smuggle, thereby bringing it to zero.

4.6.2. Enforcement and Punishment as a Policy to Deter the Incentive to Smuggle

Another policy very commonly used to reduce smuggling is to increase enforcement in conjunction with significant punishment penalties. The economics behind this policy is to raise the risk for the smuggler to a level where it would reduce profit and hence divert them from smuggling. This policy is mainly used as tool in fighting crime like smuggling cigarettes, drugs, ivory, wild life, illegal immigrants, etc.

The literature on crime focusses mainly on the optimal level of enforcement and punishment that will drastically reduce smuggling and minimize government cost. Becker (1974) states that

optimal enforcement depends on the cost of catching and convicting a smuggler, the nature of the punishment and the response of smugglers to changes in enforcement. Van Walbeek et al. (2013) state that when combating cigarette smuggling, a certain optimal level of illicit trade should be considered. Thus the optimal level of illicit trade is where it maximises the net benefit of the tax policy with some acceptable level of tax evasion (Van Walbeek et al., 2013). Ferrier (2008) indicates that smuggling goods decreas as we increase risk aversion among traders, and that can be done through redesigning the penalties for smuggling and increasing the probabilities of detecting smuggling. However, the literature on crime is not consistent regarding the level of penalties and sanctions that deter criminal activities efficiently compared to other measures (Ferrier, 2008). Additionally, the optimal level of enforcement does not reduce smuggling to zero, rather some level of smuggling is assumed to exist.

In the case where a regionalization policy is in place and where smuggling among zones exists, enforcement costs need to be at a level that will bring smuggling to zero. Thus, in terms of crime theory, penalties have to be high and the probability of detecting the crime has to be one. Applying this in practice indicates that every case of smuggling has to be detected and penalties have to be large enough to divert smugglers from participating in illicit trade. Van Walbeek et al. (2013) state that eliminating illicit trade may not be entirely possible and the cost of doing it may be too high. One such example is ivory smuggling in China. China has implemented legislation where the punishment for smuggling ivory includes life imprisonment, in some instances death penalties can be applied in addition to fines similar in value to the smuggled goods (EIA, 2004). The harsh penalties and detection of several cases of large smuggled ivory shipments have been powerful deterrents and led ivory retailers in China to be more cautious

(EIA, 2004). However, China retains a high demand and is an attractive market for illicit ivory trade.

In summary this policy measure allows the government to direct resources at expanding enforcement, which increases the probability of smugglers being detected while also setting penalties at high levels. However, with any disease outbreak it only takes a small inflow of smuggled goods from the infected region for the non-infected region to lose its status as a disease free region and along with its export status (Kerr et al., 2006).

4.7 Conclusion

Disease outbreaks create significant trade disruptions and sizeable international costs. For example, Knight-Jonesa and Rushtonb (2013) estimated the cost of FMD at US$20 billion over the last 15 years or US$4 billion dollars per year including vaccination costs. Hence, regionalisation as a concept under the SPS agreement can bring a significant reduction in monetary losses for an exporting country when a disease outbreak occurs. Although most WTO members have incorporated regionalisation regulation under their sanitary policies, there is still reluctance by importing countries to accept the disease free sub-national zone of an exporting country.

This essay offers examples where the regionalisation concept has failed. In all examples the importing country has imposed a ban on the entire country or has extended the ban to the neighbouring zones of the infected region, even though those zones held disease free status under the OIE. When designing policies for a regionalisation concept we should consider that most

cases related to the spread of animal disease is caused through the illegal entrance of a diseased animal from a neighbouring country or region. Importing countries are aware of this information and request strict control and monitoring measures on the borders with the infected zone by the exporting country. Hence, they postpone the acceptance of a disease free sub-national region through administrative delays, even when required the control measures are in place.

There is valuable literature on smuggling available to analyse the failures of the regionalisation concept and the reluctance of the importing countries to accept the disease free statues of a sub-national region. The economic studies have shown that if there exists an incentive to smuggle, then some smuggling will occur even with the presence of strict control points (Saba et al., 1995). Hence, the importing country is aware that there are risks of the disease spreading even with the physical controls in place to restrict animal movement between regions, thus they postpone the acceptance of the disease free zone through administrative delays.

This essay also examined in detail the incentive to smuggle animal products between regions. Incorporating the presence of the incentive to smuggle is a main factor in solving inefficiencies in the regionalisation concept. Incentives to smuggle arise as a result of the price differential between the infected and the non-infected regions. Loppacher et al. (2006) graphically illustrated that when a disease outbreak occurs, the price differentials arise between the two regions when the regionalisation concept is applied. Therefore, as long as the price differential is higher than the smuggling costs, there will be an incentive to smuggle. By applying a more formal partial equilibrium model we can see that if there is no risk of being caught the incentive to smuggle will exist as long as the price minus the smuggling costs in the non-infected area exceeds that of

the infected area, therefore the producer is able to achieve a higher profit level from smuggling. If we consider the risk of being caught and fined by the governing authorities then the incentive to smuggle will depend on the probability of being caught. The higher the probability of being caught, the lower the incentive for smuggling will be given the losses in revenue in the non-infected market and the additional cost of being fined. If the probability of being caught is zero then the condition on the incentive is the same as when there is no risk of being caught. This condition is important when designing policies to reduce the incentive to smuggle and thus improve the regionalisation concept.

Casual smuggling is also important when looking at disease transfer between regions if price differentials exist between the regions. It is very common for people to consume products by crossing borders in order to get a better deal on price. Casual smuggling depends on the distance the consumer has to travel to the low priced region, the cost of transportation and the easiness of avoiding authorities.

Price support and enforcement and punishment are the two policies discussed and examined in this essay as ways to eliminate the incentive to smuggle between regions. Price supporting producers in the infected region at the daily market price of the non-infected region is an important economic instrument in eliminating the incentive to smuggle. Increased enforcement and punishment as a policy instrument should not be considered as it is hard to estimate the level of enforcement and punishment that will bring smuggling to zero and the risk of a single infected animal being smuggled is always present.

When designing a price support policy the following indicator should be considered to reduce governmental costs. One indicators is the price differential between the infected and non-infected regions. The smaller the price difference between the regions implied smaller governmental costs. Another indicator is the geographical size of the infected region. A large infected region creates large price disparities between the regions and thus leads higher government costs. The last indicators are the elasticities of supply and demand. Inelastic supply and demand create higher price disparity and an incentive to smuggle, however government costs are lower. Elastic supply and demand lead to lower price disparity between the regions but higher government costs. Over the long run supply and demand are more elastic, thus price support is a suitable policy for dealing with a disease outbreak in short run. In the short run a price support policy has a small impact on government costs but a large impact on eliminating the incentive to smuggle through price equalization between the infected and the non-infected regions.

This research contributes to the literature through the design of a formal partial equilibrium framework of the regionalization concept when accounting for the incentive to smuggle. The incentive to smuggle considers both the producers and the act of casual smuggling by consumers. This research also discusses a policy as a mechanism for the elimination of smuggling incentives. Future beneficial research considerations in this area include an empirical analysis on the framework of eliminating smuggling to maintain disease-free status under SPS regulation.

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CHAPTER 5

Conclusion and Implications

5.1 Conclusion

This dissertation covers three topics of importance for international trade. It consists of three independent essays in the area of trade in biotechnology and regionalization of a disease outbreak. The first essay in chapter 2 provides a global measurement on the effect that the expanding GM pipeline has on international trade given the constraint of asynchronous regulations for a new GM event among countries. The second essay in chapter 3 develop a theoretical model that considers the political risk of the stringent post moratorium regulations regarding GMO approval in the EU as imposed on the investing biotechnological firm. Lastly, the third essay in chapter 4 analysing the regionalization concept under the WTO accounting for the incentive to smuggle and determines the appropriate mode to implement the regionalization concept.

The first essay utilizing GTAP measures the effect of the increasing GM global pipeline on international trade flows between countries, and the effect on trade flows between countries given the unintended presence of GM events in the export of non-GM crops. These measurements are achieved through the development of five simulations for the following agriculture goods: maize, soybeans, rapeseed, wheat and rice. Scenario 1 describes the global trade of maize, soya and rapeseed by considering the efficiency gain that GM technology can bring in the absence of technological trade barriers. Scenario 2 looks at the trade flows when the technological trade barriers are considered as a result of the asynchronous approval of the commercialized GM maize, soya and rapeseed events. Scenario 3 presents the changes in trade

flows considering the new GM events in the pipeline for maize, soya and rapeseed. Scenario 4 builds on scenario 3 but only considers certain trade barriers for the GM events in the pipeline for the three crops. Finally scenario 5 examines the trade flow changes for non-GM maize, non-GM soya, non-GM rapeseed, rice and wheat in the EU28 region when there is co-mingling and cross-co-mingling.

Results from the analysis indicate that asynhronized approval does reduce the benefit that biotechnology can bring. This is seen in the scenarios 2 and 4 where we imposed barriers for certain GM events to depict the asynhronicity. In scenario 2 the reduction in trade flow for the three crops, maize, soya and rapeseed, is $US 842 million and for scenario 4 the trade flow reduction is $US 2.4 billion. We can also conclude from scenarios 2 and 4 that the larger the number of GM events available in the pipeline the larger impact on trade flows. In scenario 2 there are l3 GM events commercialized and a lower reduction in the absolute value of trade compared to scenario 4 where there are 38 GM events available. Conversely, in scenarios 1 and 3 where the trade barriers are eliminated to depict a synchronised world there is a boost in the global trade flow of $US 927 million in scenario 1 with 13 GM events and $US 3.7 billion in scenario 3 with 38 GM events. Adding the aggregated losses from the five scenarios the trade flow value reaches US$ 3.4 billion. However, conclusively the world would be in a better position having more GM events available, even when asynchronicity is present, as the increase in trade flows from new GM events is greater than the reduction in the trade flows caused by asynchronicity. This conclusion is supported by the comparison of results from scenarios 2 and 4. Scenario 4 results in a US$1.4 billion increase in trade flows from the base value for the three crops due to more GM events on the market, even though asyncronicity between them is greater.

By comparison, scenario 2 has reduced asynchronicity but trade flows for the three crops only increase US$84 million from the base value due to fewer GM events on the market.

In the second essay the development of a theoretical real options model is used to analyze the decision approval process of a GMO event in the EU. Defining how the regulation structure can be seen as political risk that can influence the investment decisions of firms that want to bring GM products to the EU market is also discussed. The solution from the model is explained through critical cash flow threshold influenced by regulatory environment x^* and a maximum acceptable level of irreversible sunk cost by the investor K^*. These critical values explain the decision of an investor on whether to invest immediately or wait for future time when additional regulation information is available. Through differentiating the critical values with respect to the regulation uncertainty parameter σ_x and the uncertainty of each step of the EU decision process σ_R, the behaviour of the investor is explained.

The situation where political factors are driving the decision of the EC, Examination Committee and the Appeals Committee regarding whether the GM event will be approved is represented in the model through the increase in uncertainty in the legislative approval process or high values of σ_R and σ_x. This situation results in an increase in the value of the option and thus postpones the decision to invest to a future time. It also decreases the acceptable level of irreversible cost for the investor. When GM products are developed they have a limited time to achieve their maximum economic potential and thus cover the initial investment. However, continually postponing the investment into the future can lead to the investment never occurring. The final outcome is that the presence of political factors in the decision approval process slows the

growth of the biotechnology industry and constrains the accessibility of this technology for developing countries.

In the third essay through the application of the partial equilibrium model we determined that price disparity exists between the two regions when regionalisation is applied. The price disparity leads to an incentive for commercial and casual smuggling between the regions and thus the unwillingness of the importing country to accept the disease free sub-national zone of the exporting country. Therefore, the concept of regionalisation under the WTO fails to be implemented because the incentive to smuggle between regions is not considered. This research, through application of a partial equilibrium model, analyses the regionalization concept accounting for the incentive for commercial and casual smuggling. The essay evaluates the model with the risk of being caught and the risk of not being caught. If there is no risk of being caught the incentive to smuggle will exist as long as the price minus the smuggling costs in the non-infected area exceeds that of the infected area. If we consider the risk of being caught and fined by the governing authorities then the incentive to smuggle will depend on the probability of being caught. The higher the probability of being caught the lower the incentive for smuggling will be, given the losses in revenue in the non-infected market and the additional cost of being fined. These two conditions are important when designing policies to reduce the incentive to smuggle and thus improve the regionalisation concept. Casual smuggling is another important component when designing policies to improve the regionalisation concept. Casual smuggling depends on the distance the consumer has to travel to the low priced region, the cost of transportation and the easiness of avoiding the authorities.

Two policies were discussed in this essay: price support, and enforcement and punishment when commercial smuggling with and without risk, and casual smuggling were considered. Price support was evaluated as a more appropriate policy as it is difficult to estimate the appropriate level of enforcement and punishment under that type of policy that will bring smuggling to zero. While there is always the risk of a single infected animal being smuggled between the regions, implementing a price support policy based on the daily market price from the non-infected region is key to eliminating the incentive to smuggle.

5.2 Policy Implications

The findings of this thesis have implications for the global trade system in the area of biotechnology and when a disease outbreak occurs. Biotechnology is an important factor in the economic growth of agriculture as it increases global food production in environmentally sustainable way through reduction of CO_2 emissions and preservation of soil quality. The benefit that this technology brings to farmers, the environment and consumers results in wide acceptance and development of new GM varieties. The development of new GM varieties with suitable product characteristics for specific market demands should contribute to the food security challenge and doubling of world production by 2050. This research takes into account the development of new GM varieties and measures the global trade flow, while also considering the biotechnology investment decisions of exporters with respect to the biotechnology challenges that have arose in the last decade. The two biotechnology challenges considered in this research were asynchronous approval of new GM varieties among countries and the inefficiency of EU regulation on agricultural biotechnology.

This thesis shows that the EU's regulation inefficiencies regarding GM event approvals can be attributed to the presence of political factors in the decisions of the EC, Examination Committee and the Appeals Committee. Regulating biotechnology is an important component in order for the government to provide human, animal and plant safety and health. However, political interference is putting at risk food safety, creating externalities that an unsafe food product will be allowed on the market while a safe GM product will be rejected (Smyth and Phillips, 2014). The findings in this thesis indicate that the presence of political factors in the EU decision process for approving new GM varieties influences the exporter's decision to export a safe GM product to the EU market. As a result, the exporter postpones their decision to enter the EU market into the future and reduces the level of sunk cost they are willing to invest to enter the market. Since GM products have a limited time until market maturity, the exporter's decision to enter the EU market is delayed and eventually may not occur. Instead the exporting firm may choose to avoid the EU market due to the GM approval process and enter a market where efficient GM approval regulations exist, thereby reducing uncertainty for the exporting firm.

The ability of developing countries to access biotechnology is complicated when regulations are based on political factors rather than scientific evidence. This is evident for developing countries that export to the EU and fear that adoption of biotechnology products will jeopardise EU market access for their conventional crops (Kerr, 2014). This fear stems from the point of view that they will not be able to segregate their supply chain to a degree that will satisfy the EU policy on unintentional comingling of GM and conventional products (Kerr, 2014).

The analysis in this thesis indicates that inefficient EU regulations regarding GM approval cause the individual firm to postpone their decision on EU market entrance. These inefficiencies also cause some developing countries to hesitate on accepting the technology because of the fear of losing the EU market. This inefficiency in regulations slows down growth and the contribution of the technology to increasing global food security. This creates externalities in the global trade system with the EU leading the global trend of asynchronous approval of GM events and implementation of a zero policy for unintentional presence of unapproved GM products in the shipment of conventional crops.

The findings of this research indicate that the asynchronous approval did impact global trade for the three crops in question, maize, soybeans and rapeseed, where agricultural biotechnology is extensively applied. The impact is felt through the reduction of benefits that biotechnology can bring to the global trade system, more specifically by reducing both the exports of countries accepting biotechnology and imports of countries rejecting biotechnology. The loss of trade also affects industries where these three crops are crucial inputs, such as meat products and vegetable oils, bringing the total loss to US$4.4 billion. However, the findings also indicate that the world is better off having more new GM varieties since the benefit of the technology surpasses the cost of asynchronous approval on the global supply chain. Knowing these outcomes allows us to propose certain policy implications.

First, the growth of biotechnology is limited by the inefficient EU regulations around the GM approval process and the asynchronous approval of GM products internationally. The limitation of inefficient EU regulation, as indicated in this analysis, is not expected to be changed or eased

in the coming years. Rather, the regulations are likely to see more political factor manipulation as the MS become more involved in the decision process and science becomes increasingly less important. As a result, certain negative externalities will continue to happen while new ones are expected to rise in response to the ongoing presence of uncertainty that the agricultural biotech industry continues to face in the EU market. Therefore the firms' decision will be to postpone the approval of the GM event in the EU market and redirect their products and R&D capacities to markets that employ science based regulation. As a result the number of biotechnology companies participating in the EU market is explicably low. For example, BASF's decision in January 2012 to relocate all of its plant biotechnology R&D capacity from Europe to the US was the result of lengthy regulatory decisions (Smyth, et al. 2014). Overall, negative externalities are expected to rise in the global trade system given international asynchronous approval and as more unapproved GM events are found in the shipments of conventional crops and approved GM products. As previously stated, the trade flow losses from asynchronous approval are calculated to reach US$4.4 billion.

Synchronising the international approval process of GM products using science-based evidence as the determining factors in the approval of new GM varieties is the ideal theoretical policy. If such a biotechnology policy were in place, it would be a leading factor in reaching the goal of doubling world production by 2050 and in solving the food security issue. However, synchronicity is currently not a possible option but some improvements can be completed by lobbying developing countries to accept biotechnology and implement a science-based approval process that would be synchronised with countries that have already adopted the technology.

Second, despite the setbacks generated by asynchronicity, the world is better off with more new GM varieties on the world market. The findings show that the benefits of biotechnology exceed the cost that asynchronous approval has on the global supply chain. As such, international organisations, governments and research organisations in developed countries that apply science based regulations regarding biotechnology need to encourage and continue to support the development of new GM varieties.

Other important implications that can be discussed from the results of this research are incorporating the incentive for commercial and casual smuggling into the regionalisation concept. Regionalisation as a concept can bring significant economic and trade benefits if appropriately implemented, this inference arises from the point that there will be no disruptions in the global trade system when disease outbreaks occur. The current policy focus of countries when a disease outbreak occurs is to physically constrain the infected zone and invest in strict control and monitoring measures to contain the disease. This application allows the non-infected region to freely continue exporting. However, the results of this research indicate that the incentive to smuggle is present when a disease outbreak occurs and regionalisation is implemented. The incentive to smuggle originates from the price disparity that arises between the regions. The disease free region is able to export at the resulting higher price while the diseased region is in autarky as market supply is greater than demand which results in lower prices. The research in this thesis also contributes by showing that strict control and monitoring measures are not a suitable policy to bring the incentive to smuggle to a zero level. This research also found that zero smuggling is a key component for stopping the spread of disease into the

non-infected region, the acceptance of the disease free region by the importing countries and making the regionalisation concept more efficient under the SPS regulations.

Recognizing these key pieces of information led to the price support policy proposal as a method of improving the regionalisation concept in the international trade system. When the price support policy is implemented, the prices in the two regions will be equalised creating a very effective policy tool in eliminating casual and commercial smuggling at the same time. Under this policy, the government will be required to increase the price in the infected region to the level of the non-infected region and buy the excess supply that will arise from this policy program. With this policy program the incentives to smuggle are reduced as the price disparity between the regions will be smaller, thereby decreasing the likelihood that the size of the infected region will grow and lower costs for the government.

The implications from the incentive to smuggle can also be analysed in the biotechnology global trade system. In some countries the cultivation of GM products takes place even though the cultivation of them is prohibited. This is because the producers are able to achieve an improved outcome through illegal cultivation of the technology. Producers are able to achieve a higher profit level through reduced production cost if they plant GM seed. This is particularly evident in Ukraine where GM cultivation is officially prohibited, however, USDA reports suggest that around 80% of Ukraine soya and 10% of the corn planted is genetically modified (USDA, 2016). In certain developing countries the technology was used prior to approval by governing institutions as producers were able to achieve a higher profit level through illegal cultivation. This was the case in Argentina, Brazil and Pakistan. For example, in Pakistan Bt cotton was

approved in 2010, however evidence of its cultivation was found in 2002 (Ma et al., 2016). As discussed in this research, a policy of prohibiting the technology with strict control and monitoring measures will not be able to prevent the illegal cultivation of the technology as long as there is an incentive. The way to eliminate the incentives regarding illegal cultivation is through approval of the technology on science based evidence.

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