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The Trade Effects of Bt Corn

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1.0 Introduction

Commercialization of genetically modified (GM) crops has grown at a rapid pace over the past six years. In the United States and Canada, GM soybeans, corn, canola and cotton were planted on 33.3 million hectares in 2000, representing 75 percent of the global area devoted to commercial plantings of genetically modified crops (James 2000). Throughout the rest of the world, the rise in commercial plantings of GM crops appears to be split along philosophical lines. Those regions that are eager to embrace this new technology like China and much of Latin America have steadily increased plantings, while other regions have chosen to adopt extremely cautious and in some cases, hostile, approaches to the use of GM crops. The European Union, Japan, Australia, New Zealand and many developing countries would fall into the latter category. These regional differences in the level of acceptance of genetically modified organisms (GMOs) reflect the fierce debate that exists between the proponents and opponents of GMOs.

The proponents of biotechnology believe artificial gene technologies are essential for agriculture to meet the challenges of the twenty-first century. Genetically modified crops are seen as the most promising way to increase the global food supply in order to feed an ever-growing human population. Life science companies claim that GMOs lower production costs and as a result promise a cheaper food supply. Herbicide resistant crops that use fewer herbicides are an important step in the process towards lowering pesticide residuals in the environment. To date, there is little scientific evidence that GMOs pose a danger to human health. So why, then, has there been such a backlash against the products of biotechnology, particularly in Western Europe?

Buckwell (1999) puts the arguments against GMOs into four categories: 1) concerns about human health, 2) environmental concerns, 3) ethical issues, and 4) political issues. Diminishing public trust in scientists and technical experts who are relied upon to determine whether new technologies will result in unforeseen and unwanted side effects are a big factor in public resistance to GMOs, particularly in the EU. Recent European health scares like mad cow disease, and the case of dioxin in Belgian chickens, have undermined consumers' faith in government regulators. Some of the opponents of GMOs are concerned about the release of transformed materials into the environment, which might lead to breeding with wild species and to the creation of "superbugs" or "superweeds" resistant to pesticides. Others object to GMO technology based on ethical objections to the transfer of genetic material between species that could not occur naturally. To some people, this represents interference with the "core" of life and should not be permitted. Another important factor in explaining the fierce opposition to the products of biotechnology is a perception among some consumers, in the EU, that the drive to use GMOs in food production comes from a limited number of large transnational companies. GMO opponents fear that these large companies have enough economic power to influence the regulatory process to their commercial advantage.

It is not the goal of this paper to resolve the debate over GMOs. Instead, this study attempts to quantify the economic impact of the introduction of genetically modified corn on the international corn market, as well as looking at the potential impact of various consumer and policy responses to this new crop.

The remainder of the paper is organized as follows. Section 2 provides background information on GMOs including the global distribution of commercial plantings, differing national attitudes towards GMOs, as well as information about international trade agreements affecting trade in GMOs and their products. Section 3 provides an overview of the international corn market including a discussion of Bt corn technology. This is followed by a discussion in section 4 of the empirical model and data employed by the study. Section 5 presents detailed descriptions and results from five different policy scenarios plus a brief discussion of the pre-GMO base scenario. Finally, the paper closes with a section detailing the policy implications and conclusions that can be drawn from the results.

2.0 Genetically Modified Organisms

The definition of what constitutes genetic modification is open to considerable discussion and interpretation. For the purpose of this study genetic modification is defined as a collection of techniques of molecular biology including recombinant DNA techniques (gene isolation, purification and engineering techniques), and enabling technologies (transformation, gene mapping, promoters, regeneration, control of plant functions and some hybridization systems).

Genes determine specific traits like color, height, and tolerance to specific herbicides. The first generation of GMO crops, like Bt corn, feature improved agronomic or input traits valued by farmers. Most commercial genetically engineered crops have been developed to carry genes that confer herbicide tolerance and insect control (e.g. Roundup Ready soybeans and Bt corn). Traits can also provide field crops with value-enhanced qualities for end-users, so called output traits (e.g. high-oil corn and colored cotton) (USDA 1999).

2.1 The Commercial Extent of Genetically Modified Crops

Since the first transgenic crops were introduced commercially in the early 1990s, there has been tremendous growth in the adoption of GMOs on a global basis. James (2000) reports that the global area of transgenic crops grew from 1.7 million hectares in 1996 to an estimated 44.2 million hectares in 2000. While GMOs are grown predominately in industrialized countries, approximately 24 percent of plantings in 2000 occurred in developing countries. Indeed, between 1999 and 2000, there is strong evidence of a tapering off of growth in GM crops in industrialized countries (area up just two percent), while the growth trend for developing countries for the same period is very strong (area up 51 percent).

Table 1 shows the top four GM producing regions in 2000, which account for 99 percent of the global total. The top four commercially grown GM crops in 2000 include soybeans, corn, cotton and canola. Table 2 reports the area planted and the percentage of the global area for each crop that these GM plantings represent. Bt corn is the second most important GM crop by area, equal to about 15 percent of the global transgenic crop, and in 2000 it was planted in the United States, Canada, Argentina, South Africa, Spain, and France.

2.2 International Agreements Affecting Trade in Genetically Modified Organisms

The following four international agreements apply to different aspects of biotechnology and trade: 1) the WTO Agreement on the Application of Sanitary and Phytosanitary Measures; 2) the WTO Agreement on Technical Barriers to Trade; 3) the

WTO Agreement on Trade-Related Aspects of Intellectual Property Rights; and 4) the Biosafety Protocol.

For the issues examined in this paper, the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), and the Biosafety Protocol are most relevant. Fears that GMOs may contain hidden allergens, as well as the unknown cumulative effect of toxic substances that might be present in trace amounts in GMOs are the main reasons for the existing health concerns regarding products of biotechnology. At present, no scientific studies have been able to verify any potential health risks from licensed GMOs. However, Article 5.7 of the SPS Agreement recognizes that when urgent problems of safety, health, environmental protection or national security arise, and scientific evidence is unavailable or insufficient a country can “skip” conformity assessment procedures. This article is viewed by some as a potential means under the SPS Agreement to limit imports of GMOs.

The Cartagena Protocol on Biosafety is a part of the Convention on Biological Diversity established in 1992 by the United Nations. As a multilateral environmental agreement, the Biosafety Protocol is not explicitly a trade agreement, but it does condone trade sanctions when environmental conditions warrant their use. With its language on the “precautionary principle”, the proposed Protocol could set the stage for countries to close their markets to genetically modified crops without conclusive scientific evidence of harm. However, this agreement is not to override rights and obligations signatories have made under other international agreements, including the SPS Agreement. In this study, it is assumed, for illustrative purposes, that the European Union is permitted to invoke the precautionary principle to ban imports of Bt corn. It is further assumed that the other regions in the model undertake no retaliatory actions. In reality, however, it seems likely that a WTO challenge to such a ban would occur.

2.3 Trends in Country Attitudes towards Genetically Modified Crops

Besides international agreements that are meant to enhance trade, each country implements its own rules regarding GMOs. These individual regulatory regimes are very important since they mirror consumer attitudes toward GMOs in each country.

The United States and Canada, the first and third largest producers of GMOs in the world, share very similar regulatory environments for these products. Both countries are opposed to the mandatory labeling of foods containing GMOs, and, for the most part, consider modified products to be identical to those containing no GMOs.[1] Although consumer attitudes in North America towards GMOs have been relatively favorable thus far, there are a number of consumer and environmental groups opposed to their use. Fiascos like the case of StarLink corn and increased consumer awareness of the presence of GMOs in many commonly purchased foods may yet result in a stronger negative reaction towards GMOs.[2] In some instances, food processors have become less open to the use of GM ingredients out of fear of alienating their customers.[3] This domestic market uncertainty, plus the difficulty in predicting secure export markets for products containing GMOs have made many producers nervous about the continued profitability of raising GM crops.

In the European Union, the GMO environment is characterized by negative consumer attitudes and strict government regulations. Consumer activists in the EU tend to be very outspoken in their opposition to GMOs and some extremists have resorted to "eco-terrorist" acts including the destruction of GMO test plots. Retailers cater to consumer skepticism about bio-engineered foods by offering GMO-free house brands and clear labeling of products. EU regulations concerning GMOs include a moratorium on approvals of new GMO varieties; rules for monitoring GMOs featuring traceability and liability controls; as well as mandatory labeling of all food products containing GMOs.[4]

Japan, the world's largest food importer, is the leading non-GMO market in Asia. Its government has announced labeling regulations similar to the European Union's, using

[1] If the modification involves a known allergen or significantly changes a product's nutritional content, then labeling is required.

[2] StarLink corn, which contains a potential allergen, was approved for animal feed but not for food consumption in the U.S. In September 2000, traces were found in chips and Taco shells produced by Kraft resulting in a massive recall effort.

[3] For example, in late 1999, McCain's announced that it would no longer buy genetically altered potatoes grown by Canadian farmers. The company made the decision after months of pressure from consumers.

[4] If the production process has eliminated the external DNA or protein resulting from genetic modification, then the product does not need to be labeled.

the tightest standards that are scientifically practical. Similarly, the Korean legislature has adopted mandatory labeling of foods containing GMOs.

Although originally supportive of the United States' position against mandatory labeling of GMOs, Australia and New Zealand have since adopted stringent regulations regarding the labeling of GMOs. This reversal of government policy was in direct response to pressure from consumer, medical and conservation groups.

China was the first developing country to plant large areas of GM crops, but it is still working on regulations concerning food safety, labeling and the environment (USDA 2000). Many other developing countries face the dilemma of how to address the issue of biotechnology. Governments and producers often find the prospects of this new technology appealing given its potential yield improvements. However, consumer acceptance is not always forthcoming; and uncertainty about its impacts on the environment, and a country's ability to trade with the European Union are important considerations in formulating GMO regulations (Pinstrup-Anderson 1999). Tzotzos (1999) categorizes developing countries' biotech regulations into four groups: 1) those which aspire to develop a domestic agri-biotech industry with lax regulation and little monitoring or enforcement; 2) those which have adopted a more defensive stance in an effort to assess the potential impacts of agri-biotechnology imports on the national economy with voluntary or mandatory norms, but little actual monitoring or enforcement; 3) those with market potential but little prospect of developing domestic competence in biotechnology with regulations based on existing or modification of existing trade and phytosanitary norms in anticipation of trade of biotechnology-derived agricultural commodities; and 4) those where GMO activity is taking place (field trials or commercial registrations) with virtually no regulation or oversight mechanisms in place.

3.0 The International Corn Market

Corn is the third most important cereal crop grown in the world after rice and wheat with over 590 million tonnes produced, in 2000, on nearly 140 million hectares (FAO). The main use for corn is as an animal feed. While more than one-half of total corn usage is for animal feed, in some Asian, African and Latin American countries corn is a staple food. Corn has also found an important place in food and industrial processing with such end uses as cereals, starches, ethanol, sweeteners, lysine, pharmaceuticals, and industrial chemicals.

Table 3 summarizes global corn production by region for 2000. While some corn is grown on every continent, by far the largest producer is the United States. U.S. farmers produced over 253 million tonnes of corn in 2000, representing about 43 percent of the global total. China is the next largest individual producing nation followed by Brazil, at 105.2 and 32 million tonnes, respectively. The Western Hemisphere dominates world corn production accounting for 57 percent of the global total. Asian and African production account for 25 and 7.5 percent of the global total, respectively. The European Union is not a significant corn producing region with just 6.5 percent of the worlds production.

Table 4 shows the major corn exporting and importing regions in 1999. The United States is by far the largest exporter of corn at 52 million tonnes or 66 percent of global exports. The next two most important exporters are Argentina and China at 7.9 and 4.3 million tonnes, respectively. Although China exports 4.3 million tonnes of corn, it is actually a net importer with imports of 4.9 million tonnes. While the U.S. dominates corn exports, imports of corn are spread out more evenly. The two largest importing regions are Japan with 22 percent of global imports, and Korea with 10 percent of total imports (16.6 and 8.1 million tonnes, respectively). The EU is a net importer of 2.1 mmt of corn. Considering the regional aggregation employed in this study, the Western Hemisphere is a net exporter of corn while the EU and the rest of the world are net importers.

3.1 European Corn Borer And Bt Corn

The European Corn Borer (*Ostrinia Nubilalis)* is a major pest of corn in many parts of North America (Gianesi and Carpenter 1999), as well as Europe (Melchinger et al. 1998). European Corn Borer (ECB) moths deposit their eggs on the corn plant and its larvae feed on leaves and pollen before entering the stalk. The main damage caused by ECB is the tunneling of larvae in the stalk and ear shank, resulting in reduced plant growth and grain yield (Hyde et al. 1999). Damaged plants show increased susceptibility to secondary infections and are more prone to lodging.

Few economically feasible ECB control methods exist. In the past, farmers have used cultural practices (i.e. moldboard plowing and crop rotation) to protect their fields against infestation (Rice and Pilcher 1998). Today farmers have three more “tools” to manage ECB including granular insecticides, liquid insecticides and Bt corn. Neither liquid nor granular insecticides have proven to be 100 percent effective in killing ECB. In order for a pesticide treatment to be effective, the timing of its application must be precise. The high cost of scouting – especially for second-generation borers – makes it uneconomical for the great majority of corn farmers to spray against ECB (Hyde et al. 1999). As a result, for most farmers Bt corn is the most effective means available to control ECB.

4.0 The Model

In order to examine the impact of the introduction of Bt corn on the international corn market it is necessary to develop an empirical model that captures regional supply and demand relationships and international trade in corn. The demand and supply relationships, the regional aggregation and the international trade model are described in this section. This is followed by a discussion of the data and the parameter values used in the study.

The two main uses of corn are for human food products and in animal feed. Both the demand for corn for food processing (DFO) and for animal feed (DFE) are assumed to be linear with the general form:

$$DFO_{ti} = \alpha_{1i} + \beta_{1i} P_{ti} \quad (1)$$

$$DFE_{ti} = \alpha_{2i} + \beta_{2i} P_{ti} \quad (2)$$

where: P_{ti} = the market price of corn, α's = intercept parameters, β's = slope parameters and i = 1, 2, 3 indicates the three regions in the model the Western Hemisphere, European Union and rest of world (ROW), respectively.

Regional corn production (Q_{ti}) is determined as the product of the area planted (L_{ti}) and the corn yield (YLD_{ti}):

$$Q_{ti} = L_{ti}\ YLD_{ti} \quad (3)$$

The amount of land allocated to the production of corn in each region is modeled as a double logarithmic function:

$$\ln(L_{ti}) = \ln(\alpha_{3i}) + e_i \ln(\pi_{ti}) \quad (4)$$

where ε_i = the elasticity of land supply with respect to gross margin, and π_{ti} = gross margin per hectare.

In deciding how much land to allocate to the production of corn, producers are assumed to respond to changes in their gross margin per hectare:

$$\pi_{ti} = P_{ti}\ YLD_{ti} - W_{ti}\ X_{ti} - WS_{ti}\ G_{ti} \quad (5)$$

where X_{ti} = a vector of inputs used excluding seed (quantity/ha), W_{ti} = a vector of variable input prices excluding the price of seed ($/ha), WS_{ti} = the price of seed ($/ha), and G_{ti} = seed use (quantity/ha).

The introduction of Bt corn influences both the yield per hectare and input costs. The assumptions with respect to yield and cost changes with the introduction of Bt corn, are discussed in the next section. However, given the yield assumptions, the corn yield in the base period (YLD_{0i}) is adjusted to reflect the yield increase ($YLDINC_{Bti}$), in percent, from Bt corn:

$$YLD_{ti} = YLD_{0i} + (1 + YLDINC_{Bti}) \quad (6)$$

A three-region, non-spatial, partial equilibrium model of trade is employed in this study. It is necessary to include at least the three regions (Western Hemisphere, European Union, and ROW) in order to capture the essence of international trade in corn. This aggregation is based on both corn production and trading patterns; and to a lesser extent, consumer attitudes towards GMOs.

A non-spatial model provides a market clearing solution for each region's net trade and the international price of corn. It is also capable of handling the impact of border measures on trade, which in this case is an important consideration for the European Union.

Since global corn trade is dominated by the United States, the world reference price of corn is the U.S. price (P_{t1}). The domestic price of corn in the EU (P_{t2}) is obtained by adding the value of its border measures plus shipping costs (T_0), in the base period, to the world price, yielding:

$$P_{t2} = P_{t1} + T_0 \qquad (7)$$

The price of corn in the ROW (P_{t3})is assumed to equal to the world price:

$$P_{t3} = P_{t1} \qquad (8)$$

Net trade (NT_{ti}), in each region, is calculated as the difference between total production and total demand for corn:

$$NT_{ti} = Q_{ti} + I_{t-1i} - DFO_{ti} - DFE_{ti} - I_{ti} \qquad (9)$$

where I_{ti} = ending stocks (tonnes).

The sign of the net trade variable shows whether a region is a net exporter (positive) or a net importer (negative). In order to close the model the sum of net trade across the three regions is set equal to zero.

This partial equilibrium model focuses entirely on the corn market. All non-corn prices are assumed exogenous, as are corn stocks. The model is calibrated to data for 1995, prior to the introduction of Bt corn, and medium-run elasticities are used to represent the response parameters. The model contains 25 equations solving for 25 endogenous variables. The model and solution values can be used to determine producer surplus, consumer surplus, tariff revenue in the EU and regional welfare. A major simplifying assumption in the analysis is that no economic surplus is generated in the life science companies producing Bt corn. Recent, work by Moschini, Lapan and Sobolevsky (2000) show how this limitation can be tackled.

4.1 Data

Data on corn area planted, yield, production, food and feed demand and net trade, for the base year, 1995, are shown in table 5. In order to simulate the model, parameters for the regional demand and area planted equations are needed. This is accomplished by using elasticity estimates from the literature and then calibrating the model to the base year data (table 6).

The price elasticity of demand for corn in food processing is assumed to be very inelastic. A value of -0.10 is assumed for the Western Hemisphere and the European Union, while a slightly larger value of –0.20 is employed for the ROW. This assumption is based on the fact that consumers in developing countries (which dominate the rest of world region) consume corn in less processed forms and are more responsive to changes in corn prices.

In general, the demand for corn used in animal feed is more price elastic because it has more substitutes than corn used in food processing. The price elasticity of feed demand is assumed to be -0.40 in the Western Hemisphere, and -0.60 in the European Union and the ROW. Both the European Union and the ROW are net corn importers.

Whittaker and Bancroft (1979) estimate the U.S. corn area elasticity to be 0.22 using double logarithmic functional forms. Reed and Riggins (1981) report U.S. elasticities for corn area, with respect to the relative price of corn, ranging from 0.34 to 0.56 in the short run, and from 0.93 to 2.07 in the long run. These are all higher than some earlier estimates by Ryan and Abel (1972), which lie in the range of 0.12 to 0.17. After considering these estimates of the elasticity of corn area the price elasticity of supply is set equal to 0.50 in all three regions.

The main characteristic of Bt corn is that it increases corn yields in the case of a European Corn Borer infestation. The average yield loss due to ECB infestation is based on data from numerous U.S. extension service surveys conducted between 1943 and 1997 (Nelson et al. 1999). This data reveals that ECB larvae of first generation decrease corn yields by about five percent, and ECB larvae of second generation decrease corn yields by about three percent. The authors determine that corn borer larvae infestation reduces per-acre corn yields, on average, by 3.53 percent. This estimate of a 3.53 percent yield increase, as a result of adopting Bt corn, is used as an average value for the Western

Hemisphere, although ECB is not as significant a pest in South America as it is in the U.S. and Canada.

In Europe, there are some areas that have a history of high ECB populations and damage, and other areas that receive little damage. Overall, the average yield loss is similar to that in North America. Based on this, a value of 3.53 percent is used as an average yield increase as a result of adopting Bt corn in the EU.

In tropical regions, ECB is not a significant pest but there are other insects such as fall armyworm, corn earworm and other corn borers that adversely affect corn yields. Bt corn is very effective against the latter, but offers only moderate protection against the first two insects. Given the available information on pest damage, an average yield increase for Bt corn in the ROW of 2.53 percent is used.

An Ontario corn budget for 1999 is used as a benchmark for the cost of corn production in the Western Hemisphere (OMAFRA). The estimated cash costs of producing corn are $291/ha.

A EU corn budget could not be found. Given the fact that the EU has higher prices for some agricultural inputs, the cost of producing corn in this region is assumed to be 10 percent higher than in the Western Hemisphere. This gives $320/ha as the cost of variable inputs in the European Union.

The ROW is extremely diverse. China is the biggest producer of corn in this region but cost data, for China, were not available. However, a corn budget for Thailand was located and it was used to estimate the production costs for corn in the ROW. The Thai budget shows cash costs about 30 percent below those in the Western Hemisphere at $200/ha.

In the Western Hemisphere the price of traditional seed corn is about $77/ha. Estimates of the additional cost of Bt seed over and above regular seed are from $15 - 30/ha, with $20/ha being a commonly quoted figure. This study also assumes Bt seed costs $20/ha more than non-Bt seed (table 6).

The price of seed corn varies across the EU. In France, seed corn costs about the same as in the United States. The prices in Italy, Spain and Portugal are 20-30 percent higher. Therefore, the cost of seed for both Bt and non-Bt corn are assumed to be 10 percent higher than in the Western Hemisphere. Given the lack of data for the ROW the cost of corn seed of both types is assumed to be 30 percent lower than in the Western Hemisphere.

The average Chicago spot price of corn is used as the base value for the Western Hemisphere and as the world reference price. Its average value, in 1995, was $109.4 per tonne (USDA 1996). The European corn price is a weighted average of selling prices in its member countries that have a corn market. Its value for 1995 is $200.2 per tonne. The difference between the price in the EU and the world price includes both border measures and shipping costs. The world price is assumed to be the price prevailing in the ROW. Table 6 summarizes all of the economic assumptions used in the analysis.

5.0 Policy Analysis

The first scenario establishes the pre-GMO baseline with which to compare all other production and policy scenarios.[5] It depicts the situation in the international corn market in 1995 prior to significant commercial planting of Bt corn. It is assumed that none of the regions in the model produces GM corn and trade in corn among the three regions is free with the exception of EU border measures.

Table 7 summarizes the benchmark values obtained under the baseline scenario. The Western Hemisphere is a large net corn exporter (51 mmt) while the remaining regions are net importers. Consumers surplus from the consumption of corn in the food processing and animal feed sectors are shown in table 7, as well as producers surplus and total regional welfare which is equal to the sum of the consumer and producer surplus values. In the EU, tariff revenue is also included in the calculation of regional welfare.

5.1 The Impact of the Introduction of Bt Corn

Commercial plantings of Bt corn have grown considerably since 1996. In this scenario it is assumed that all three regions embrace this yield improving technical innovation with no consumer backlash. Average yield increases of 3.53 percent are assumed for both the Western Hemisphere and the European Union, and 2.53 percent for the rest of world region. The technical innovation has the effect of shifting the corn supply curve to the ROW.

[5] Pekaric-Falak evaluates a number of policy scenarios not reported in this paper.

The increase in cash costs in all GMO scenarios is assumed to be 30 percent of the additional cost of Bt corn seed. This is based on the fact that the probability of having European Corn Borer infestation is about 25 percent in the U.S. Since farmers are risk averse, 30 percent of the total corn area is assumed to be planted to Bt corn varieties. It is important to point out that Bt corn is not profitable for all farmers. Therefore, there will always be a significant area planted with non-Bt hybrids.

The introduction of Bt corn results in increased output in both the Western Hemisphere (2.5 percent) and the EU (4.6 percent) as shown in table 8. Due to the increased cost of purchasing Bt seed and a smaller yield increase, output in the ROW falls (-0.9 percent), despite the positive effect of Bt technology on yield. Overall, global output rises, resulting in a drop in the world price of 2.8 percent. Imports fall in the EU (-1.6 percent) as a result of increased domestic output, while exports from the Western Hemisphere rise (8.6 percent) accompanied by an increase in imports in the ROW (11.4 percent).

As a result of the fall in corn prices, the consumption of corn increases having a positive impact on consumers surplus in every region (table 8). The drop in the world price results in welfare losses for producers in the Western Hemisphere (-3.0 percent) and the ROW (-9.8 percent). In the EU, producer surplus increases (3.1 percent). This results from the assumption that the yield increase resulting from Bt corn is a percent of base period yield. The change in corn yield/ha in the U.S., EU and ROW, from the introduction of Bt corn, is 0.17 mt/ha, 0.27 mt/ha and 0.11 mt/ha, respectively

5.2 The Impact of the Rejection of GMO Technology in the European Union

The previous scenario assumes that producers in every region adopts Bt technology. However, regional attitudes towards GMO technology has not been embraced by either producers or consumers in the EU. In this scenario, it is assumed that producers in the EU do not adopt Bt corn, while those in the Western Hemisphere and the ROW do. Additionally, given the uncertainty about the presence of GMOs in imported corn, which cannot be distinguished from the locally grown non-GMO corn, it is assumed EU consumers will purchase less corn. This is modeled as a 20 percent reduction in the quantity of corn demanded for use in food processing and animal feed in the EU, at all price levels. EU corn production costs remain unchanged from the base scenario, while those for the Western Hemisphere and the ROW reflect the use of Bt corn.

Corn output in the Western Hemisphere rises (1.7 percent) once again due to the yield improving qualities of Bt corn (table 9). Given the large share of world corn production that is located in this region, this increase in output lowers the world price of corn and hence the domestic price in all three regions. Output in the EU falls by 1.2 percent given its continued use of traditional corn varieties in the face of lower corn prices. In the ROW, corn production also falls in response to corn prices 3.2 percent lower than in the base period. However, with the sharp fall in the demand for corn in the EU it becomes a net exporter of 3.0 mmt of corn. To maintain the gap between EU and world corn prices and export subsidy of $271 million is required. Imports by the ROW increase significantly (16.6 percent) in response to the decline in world price and decrease in domestic production. This is matched by an increase in Western Hemisphere exports of 4 percent.

Consumers in the Western Hemisphere and the ROW are better off due to the decrease in corn prices (table 9). In the EU, consumers surplus falls significantly as a result of the inward shift of the corn demand curves resulting from assumed backlash against the presence of GMOs. Corn producers are worse off, in all three regions, in comparison to the pre-GMO situation. There are small total welfare improvements in the Western Hemisphere and ROW compared to the base, while European Union total welfare is down significantly (29.6 percent) due to the demand shift and the cost of export subsidies to maintain domestic corn prices.

5.3 The Impact of a Corn Import Ban in the European Union

The previous scenario demonstrates the potential negative effects of reduced consumer confidence in the quality of the domestic corn supply in the EU when imports of GMO corn are allowed. In this scenario, it is assumed that EU legislators invoke a ban on all corn imports. Demand in the EU is not assumed to shift in this scenario, given that all domestically produced corn is non-GMO and no imports are allowed.

Corn output in the Western Hemisphere rises (2.2 percent) due to the yield improvements of Bt corn, while in the rest of the world output declines by 1.3 percent in the face of prices three percent lower than in the base simulation (table 10). In the EU, producers increase production significantly (5.6 percent) in order to satisfy demand for the entire domestic market. Without competition from imports, the EU price is no longer linked to the world price and it increases by 8.5 percent. Trade falls to zero in the EU, while the Western Hemisphere increases (6.8 percent) its exports to the ROW whose imports rise (13.4 percent) accordingly.

Despite the EU import ban, welfare in the Western Hemisphere increases relative to the base scenario, but by less than when there is no EU corn import ban.. This is due entirely to the fact that domestic consumers benefit from lower corn prices. Producers in the Western Hemisphere lose slightly more than in the GMO scenario with no import ban. Consumers in the ROW benefit considerably from the lower world corn price while producers are worse off relative to the base. In the EU, consumers are worse off compared to the pre-GMO scenario because of the higher prices caused by the import ban. EU corn producers benefit from the import ban. Overall, the Western Hemisphere and ROW are better off than under the base (non-GMO) scenario, while the EU is slightly worse off.

5.4 The Combined Impact of a European Union Import Ban and Consumer Backlash against GMOs in the Remaining Regions

A troubling scenario for life science companies and government regulators would be widespread negative consumer reaction to GMOs in the Western Hemisphere and ROW. If consumers in these regions adopted attitudes towards GMOs similar to those of European consumers, final demand for products containing corn could fall significantly. There has already been some negative reactions by some vocal consumers in Japan, Australia, and New Zealand. In this scenario, it is assumed that the European Union maintains its ban on corn imports and consumers in the other two regions shift consumption away from products containing Bt corn. It is assumed that the demand for corn in food processing in the Western Hemisphere and the ROW decreases by 20 percent from its base level, while the demand for corn in animal feed is unaffected by negative attitudes towards GMOs.

The decline in the world price (-4.4 percent) is significant under this scenario (table 11). This results from the inward shift of the food demand curves combined with the yield increasing Bt corn in the Western Hemisphere and ROW. Once again the EU corn price is determined internally, and it rises due to the ban on imports. Output in the Western Hemisphere (-0.4 percent) and ROW (-4.4 percent) fall in response to the lower world price. EU trade is zero because of the import ban, while exports and imports in the Western Hemisphere (5.1 percent) and the ROW (11.6 percent) rise.

The welfare results summarized in table 11 show that the presence of negative consumer attitudes towards GMOs in the regions outside the EU reduces consumer benefits from Bt corn significantly in both the Western Hemisphere and the ROW. As a result, there are overall welfare losses in each region under this scenario.

5.5 The Impact of the Introduction Bt Corn with a Segregation Scheme

If the consumer backlash against food products containing GM corn is a result of their inability to distinguish between products containing GMOs and those free of GM ingredients, some sort of quality signal should result in improved demand. In this case, either labeling products that may contain GMOs or those that are GMO-free might accomplish this objective. In order for the labels to be accurate, some method of product segregation and identity preservation is needed.[6] In this scenario, it is assumed that each region segregates GMOs from non-GMOs and each region satisfies its own demand for corn in food processing with domestically produced non-GMO corn. Imports are not labeled, but they are only used in the feed market where it is assumed the presence of GMOs is accepted for the feed market in all three regions. Feed demand is satisfied with corn that may contain GMOs and this corn is traded among the three regions. The cost of segregation is assumed to be 15 percent of the corn price. Producers in all three regions are assumed to receive $5 per tonne as an incentive (price premium) to produce non-GMOs resulting in separate prices for GMOs and non-GMOs. It is assumed that EU producers have access to Bt corn technology for the purposes of producing corn destined for the animal feed market. Yield improvements and all other costs are identical to the full GMO scenario.

[6] There is a large literature on the costs and benefits of labeling.

Output in the Western Hemisphere (1.5 percent) and the EU (3.6 percent) increase as a result of the Bt corn technology, while in the ROW, the price decline (-2.8 percent) and the additional cost of Bt seed more than off-set the yield increase and output falls by 2.0 percent. In this scenario, the Western Hemisphere increases its exports (6.4 percent), while the EU reduces its imports by 32.0 percent. Imports rise in the ROW by 8.7 percent.

Reduced corn prices result in increases in consumers surplus in all three regions. Producers surplus in the Western Hemisphere and the ROW fall as a result of the lower world price but by roughly one-half as much as in the GMO with no segregation scenario. Total welfare in each region is higher than under the base scenario, and except for a miniscule decline in the EU, higher than under the complete adoption of GMOs with no segregation.

6.0 Implications and Conclusions

The results of the various scenarios, including the base period pre-Bt corn scenario, are compared and ranked in table 13. A ranking of one indicates the best scenario and a ranking of six the worst scenario. Many of the results are straightforward. Consumers prefer policies that lower market prices, in their region, as is the case with Bt corn. Consumers in the U.S. and the ROW like lower corn prices even if they result from the EU banning corn imports. Corn producers in the EU benefit from an EU import ban that strengthens their prices significantly, but at the same time lowers consumer welfare relative to the base situation.

There are three general conclusions that emerge from a careful analysis of the results of the policy scenarios. First, the introduction of Bt corn is one of the top three policy choices for all economic agents in all regions. Somewhat surprisingly it is the top ranked policy alternative for EU consumers and the second ranking policy alternative for EU corn producers. Bt corn is the third ranking alternative for Western Hemisphere and ROW producers. However, these results are sensitive to the choice of parameter estimates, especially the assumed increase in average yields resulting from Bt corn and the cost of Bt seed.

Second, the welfare changes resulting from a ban on corn imports by the EU or consumer backlash against Bt corn in the EU have only small, albeit negative, impacts on Western Hemisphere and ROW corn producers. Conversely, there are small gains by Western Hemisphere and ROW consumers from these reactions in the EU. The only large welfare changes occur when the backlash against Bt corn is "exported" from the EU to Western Hemisphere and ROW consumers. If consumers in the Western Hemisphere and the ROW should reduce their consumption of food corn products by 20 percent then producer welfare in the Western Hemisphere falls by 11 percent and in the ROW by 19 percent.

Third, a scenario where each country supplies its own (non-Bt) food corn products, and producers are paid a premium over Bt corn prices for this product appears an attractive scenario. Again, this policy option ranks in the top three for all economic agents in all regions. This result is sensitive to the assumed cost of about $15/mt for identity preservation and segmentation.

Many countries in the world and the World Trade Organization are struggling with how to handle the problems associated with trading products of agricultural biotechnology. This study suggests that if consumer backlash against the products of biotechnology can be isolated in the EU, it will have little impact on the world corn market. In addition, there are "segregation" schemes that appear attractive from a welfare perspective, as long as Bt corn destined for the animal feed market continues to be traded and consumers do not reduce their consumption of meat as a result. However, if consumer backlash against Bt corn becomes widespread it could have devastating effects on Western Hemisphere farmers.

Table 1: The Top Four Producing Regions of Genetically Modified Crops in 2000

Country	Area Planted (millions of hectares)	Percent of Global Area Planted to GMOs
United States	30.3	68
Argentina	10	23
Canada	3	7
China	.5	1
Total	43.8	99

Table 2: The Top Four Commercially Grown, Genetically Modified Crops in 2000

Crop	Area Planted (millions of hectares)	Percent of Global Total Planted for Each Crop
Soybeans	25.8	36
Corn	10.3	7
Cotton	5.3	16
Canola	2.8	11

Table 3: World Corn Production in 2000 (millions of tonnes)

Region	Corn Production
United States	253.2
Canada	6.9
Brazil	32.0
Mexico	18.8
Argentina	16.2
Rest of Latin America and Caribbean	9.4
China	105.2
India	11.5
Rest of Asia	30.0
Africa	44.6
European Union	38.7
Rest of World	24.3
Global Total	590.8

Source: FAO.

Table 4: World Corn Exports and Imports in 1999 (millions of tonnes)

Region	Corn Exports	Corn Imports	Net Exports
Argentina	7.9	0.0	7.9
China	4.3	4.9	-0.6
Egypt	0.0	3.6	-3.6
European Union(15)	0.1	2.2	-2.1
Hungary	1.7	0.0	-1.7
Japan	0.0	16.6	-16.6
Korea	0.0	8.1	-8.1
Mexico	0.0	5.5	-5.5
United States	52.0	0.5	51.5
Rest of World	12.5	35.3	-22.8
Global Total	78.5	76.7	N/A.

Source: FAO.

Table 5: Corn Supply and Utilization, by Region, 1995

Variable	Units	Western Hemisphere	European Union	Rest of World
Area Harvested	'000 ha	56.3	3.7	74.2
Yield	mt/ha	4.7	7.8	3.0
Production	mmt	265.3	29.2	222.6
Food Demand	mmt	70.6	8.2	94.7
Feed Demand	mmt	176.4	24.5	168.1
Net Exports	mmt	50.9	-2.9	48.0

Source: USDA

Table 6: Parameters Used in the Empirical Analysis

Variable	Western Hemisphere	European Union	Rest of World
Elasticity of supply	0.5	0.5	0.5
Elasticity of food demand	-0.1	-0.1	-0.2
Elasticity of feed demand	-0.4	-0.6	-0.6
Average yield increase due to Bt corn	3.53 %	3.53 %	2.53 %
Cash cost of non-seed inputs	$291.5/ha	$320.6/ha	$200/ha
Cost of non-Bt seed	$77/ha	$84.7/ha	$50/ha
Cost of Bt corn seed	$97/ha	$106.7/ha	$63/ha
Price ($U.S./mt)	$109.4	$200.2	$109.4

Table 7: Variable Values for the Pre-Bt Corn, Base Scenario

Variable	Units	Western Hemisphere	European Union	Rest of World
Corn Price	$US/mt	109.4	200.2	109.45
Corn Output	mmt	265.3	29.2	222.602
Net Trade	mmt	51.0	-2.9	-48.0
Consumer Surplus	mil. $US	62,792	12,328	41,232
Producer Surplus	mil. $US	8,308	4,339	5,803
Tariff Revenue	mil. $US	0	235	0
Total Welfare	mil. $US	71,100	16,902	47,035

Table 8: The Impact of the Introduction of Bt Corn Relative to the Base Scenario

	Western Hemisphere	European Union	Rest of World
	percent change from base		
Corn Price	-2.8	-1.6	-2.8
Corn Output	2.5	4.6	-0.9
Net Trade	8.6	-1.6	11.4
Consumer Surplus	1.2	0.8	2.0
Producer Surplus	-3.0	3.1	-9.8
Tariff Revenue	N/A.	-37.0	N/A.
Total Welfare	0.7	0.9	0.6

Table 9: The Impact of the EU Rejecting Bt Corn Relative to the Base Scenario

	Western Hemisphere	European Union	Rest of World
	percent change from base		
Corn Price	-3.2	-1.8	-3.2
Corn Output	1.7	-1.2	-1.8
Net Trade	4.0	-201.7	16.6
Consumer Surplus	1.4	-55.2	2.3
Producer Surplus	-5.2	-3.6	-12.2
Tariff Revenue	N/A.	-215.4	N/A.
Total Welfare	0.6	-29.6	0.5

Table 10: The Impact of a EU Ban on Corn Imports Relative to the Base Scenario

	Western Hemisphere	European Union	Rest of World
	percent change from base		
Corn Price	-3.0	8.5	-3.0
Corn Output	2.2	5.6	-1.3
Net Trade	6.8	-100.0	13.4
Consumer Surplus	1.3	-4.4	2.1
Producer Surplus	-3.8	17.6	-10.7
Tariff Revenue	N/A.	-100.0	N/A.
Total Welfare	0.7	-0.1	0.5

Table 11: The Impact of a EU Ban on Corn Imports Combined with Consumer Backlash in the Western Hemisphere and Rest of World Relative to the Base Scenario

	Western Hemisphere	European Union	Rest of World
	percent change from base		
Corn Price	-4.4	8.5	-4.4
Corn Output	-0.4	5.6	-4.4
Net Trade	5.14	-1000	11.6
Consumer Surplus	-9.9	-4.4	-9.0
Producer Surplus	-11.0	17.6	-19.0
Tariff Revenue	N/A.	-100	N/A.
Total Welfare	-10.0	-0.1	-10.2

Table 12: The Impact of the Introduction of Bt Corn with a Segregation Scheme Relative to the Base Scenario

	Western Hemisphere	European Union	Rest of World
	percent change from base		
Corn Price	-2.8	-1.6	-2.8
Corn Output	1.5	3.6	-2.0
Net Trade	6.4	-32.0	8.7
Consumer Surplus	1.2	0.8	2.0
Producer Surplus	-1.6	2.6	-4.4
Tariff Revenue	N/A.	-31.7	N/A.
Total Welfare	0.9	0.8	1.2

Table 13: Policy Scenarios Ranked by Consumer Surplus, Producer Surplus and Overall Welfare

Scenario	WH Consumer Ranking	EU Consumer Ranking	ROW Consumer Ranking	WH Producer Ranking	EU Producer Ranking	ROW Producer Ranking	WH Overall Ranking	EU Overall Ranking	ROW Overall Ranking	Global Ranking
1	4	2	4	1	4	1	5	3	5	4
2	3	1	3	3	2	3	2	1	2	2
3	1	4	1	5	5	5	4	5	4	5
4	2	3	2	4	1	4	3	4	3	3
5	5	3	5	6	1	6	6	4	6	6
6	3	1	3	2	3	2	1	2	1	1

Scenario 1: No Bt corn.
Scenario 2: Adoption of Bt corn.
Scenario 3: No Bt corn planted in the EU, Bt corn imported by the EU and consumer backlash against Bt corn in the EU.
Scenario 4: Corn import ban in the EU.
Scenario 5: Corn import ban in the EU and consumer backlash against Bt corn in the U.S. and ROW.
Scenario 6: Adoption of Bt corn with a segregation scheme.

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