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GENETICALLY MODIFIED FOODS, TRADE, AND DEVELOPING COUNTRIES

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Abstract

This paper analyzes price, production and trade consequences of changing consumer preferences regarding the use of genetically modified organisms (GMOs) in food production. The analytical framework used is an empirical global general equilibrium model, in which the entire food processing chain – from primary crops through livestock feed to processed foods – is segregated into genetically modified (GM) and non-GM lines of production. This model is used to analyze the implications of widespread use of genetically engineered crops in some regions whilst consumers in Western Europe and High-income Asia adopt a critical attitude toward GM foods. Two different representations of consumer preference changes are illustrated: (1) a change in price sensitivity: i.e. consumer demand is less sensitive to a decline in the price of GM foods relative to non-GM varieties, and (2) a structural demand shift: for a given price ratio consumers simply demand less of the GM variety relative to the non-GM variety.

This analysis finds that developing countries adjust their trade patterns in response to preference changes in important trading partner countries. Non-GM varieties are diverted to GM-critical regions while GM varieties are sold to countries in which consumers are not sensitive to GM content. Furthermore, the development of segregated GM and non-GM food creates a potential niche market for producers if the non-GM characteristic can in fact be preserved and verified throughout the marketing system at reasonable costs.

This discussion paper will be forthcoming as a chapter in *Leveraging Trade, Global Market Integration, and the New WTO Negotiations for Development*, edited by Merlinda Ingco, The World Bank, Washington D.C., 2001.

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1. INTRODUCTION

The current debate about the use of genetic engineering in agricultural production reveals substantial differences in perception of the risks and benefits associated with this new biotechnology. Farmers in North America and a few large developing countries such as Argentina, Mexico, and China are rapidly adopting the new genetically modified (GM) crop varieties as they become available, and citizens in these countries are generally accepting this development. Growing genetically modified crop varieties provides farmers with a range of agronomic benefits, mainly in terms of lower input requirements and hence lower costs to consumers. However, in other parts of the world, especially Western Europe, people are concerned about the environmental impact of widespread cultivation of GM crops and the safety of foods containing genetically modified organisms. In response to the strong consumer reaction against genetically modified foods in Western Europe, and to a certain extent also in Japan, separate production systems for GM and non-GM crops are emerging in the maize and soybean sectors.[1] To the extent that GM critical consumers are willing to pay a price premium for non-GM varieties there may be a viable market for these products alongside the new GM varieties.

Developing countries – regardless of whether they are exporters or importers of agricultural crops – will be affected by changing consumer attitudes toward genetic modification in the developed world. Some developing countries are highly dependent on exporting particular primary agricultural products to GM critical regions. Depending on the strength of opposition toward GM products in such regions and the costs of

[1] Another response to the growing concerns about GM products has been the agreement on the Cartagena Biosafety Protocol, which was concluded in January 2000, but is yet to be ratified. See Nielsen and Anderson (2000) for a discussion of the relationship between this Protocol and the WTO rules, and an empirical analysis of the world trade and welfare effects of a Western European ban on GM imports.

segregating production, the developing countries may benefit from segregated agricultural markets, which will have different prices. In principle these countries may choose to grow GM crops for the domestic market and for exports to countries that are indifferent as to GM content, and to grow GM-free products for exports to countries where consumers are willing to pay a premium for this characteristic. Such a market development would be analogous to the niche markets for organic foods. Other developing countries are net importers and can benefit from the widespread adoption of GM technology. Assuming consumers in those countries are not opposed to GM products, they will benefit from lower world market prices. If changing consumer preferences have an effect on world agricultural markets, this latter outcome may also be affected.

This paper offers a preliminary quantitative assessment of the impact that consumers' changing attitude toward genetic modification might have on world trade patterns, with emphasis on the developing countries. It extends earlier work described in Nielsen, Robinson and Thierfelder (2001) and Nielsen, Thierfelder, and Robinson (2001). The analytical framework used is an empirical global general equilibrium model, in which the two primary GM crops, soybeans and maize, are specified as either GM or non-GM. This GM and non-GM split is maintained throughout the entire processing chain: GM livestock and GM food processing industries use only GM intermediate inputs; likewise non-GM livestock and non-GM food processing industries use only non-GM intermediate inputs.

The following section provides a concise overview of the current status of genetically modified crops in food production and briefly discusses selected issues related to the segregation of GM and non-GM marketing systems. Section three presents the main features of the multi-regional CGE model and describes the scenarios. The empirical results are examined in section four, and a final section identifies areas for future research and concludes.

2. GENETIC ENGINEERING IN AGRICULTURE[2]

2.1 Background

The most recent research and development advances in modern biotechnology have introduced an ever-widening range of genetically engineered products to agriculture. While traditional biotechnology improves the quality and yields of plants and animals through, for example, selective breeding, genetic engineering is a new biotechnology that enables direct manipulation of genetic material (inserting, removing or altering genes).[3] In this way the new technology speeds up the development process, shaving years off R&D programs. Protagonists argue that genetic engineering entails a more-controlled transfer of genes because the transfer is limited to a single gene, or just a few selected genes, whereas traditional breeding risks transferring unwanted genes together with the desired ones. Against that advantage, antagonists argue that the side effects in terms of potentially adverse impacts on the environment and human health are unknown.

Genetic engineering techniques and their applications have developed rapidly since the introduction of the first genetically modified plants in the 1980s. In 1999,

[2] The first part of this section draws on Nielsen and Anderson (2000).

[3] Definitions of genetic engineering vary across countries and regulatory agencies. For the purpose of this paper a broad definition is used, in which a genetically modified organism is one that has been modified

genetically modified crops occupied 40 million hectares of land – making up 3.4% of the world's total agricultural area and representing a considerable expansion from less than 3 million hectares in 1996.[4] Cultivation of transgenic crops has so far been most widespread in the production of soybeans and maize, accounting for 54% and 28% of total commercial transgenic crop production in 1999, respectively. Cotton and rapeseed each made up 9% of transgenic crop production in 1999, with the remaining GM crops being tobacco, tomato, and potato (James, 1999, 1998, 1997).

To date, genetic engineering in agriculture has mainly been used to modify crops so that they have improved *agronomic* traits such as tolerance to specific chemical herbicides and resistance to pests and diseases. Development of plants with enhanced agronomic traits aims at increasing farmer profitability, typically by reducing input requirements and hence costs. Genetic modification can also be used to improve the final *quality* characteristics of a product for the benefit of the consumer, food processing industry, or livestock producer. Such traits may include enhanced nutritional content, improved durability, and better processing characteristics.

The United States holds almost three-fourths of the total crop area devoted to genetically modified crops. Other major GM producers are Argentina, Canada, and China. At the national level, the largest shares of genetically engineered crops in 1999 were found in Argentina (approximately 90% of the soybean crop), Canada (62% of the rapeseed crop), and the United States (55% of cotton, 50% of soybean and 33% of maize) [James, 1999]. The USDA (2000b) figures for the United States are similar in magnitude: it is estimated that 40% of maize and 60% of soybean areas harvested in 1999 were

through the use of modern biotechnology, such as recombinant DNA techniques. In the following, the terms 'genetically engineered', 'genetically modified' and 'transgenic' will be used as synonyms.

genetically modified.

Continued expansion in the use of transgenic crops will depend in part on the benefits obtained by farmers cultivating transgenic instead of conventional crops relative to the higher cost for transgenic seeds.[5] So far the improvements have been not so much in increased yields per hectare of the crops, but rather by reducing costs of production (OECD, 1999). Empirical data on the economic benefits of transgenic crops are still very limited, however. The effects vary from year to year and depend on a range of factors such as crop type, location, magnitude of pest attacks, disease occurrence, and weed intensity.

In developing countries one of the main reasons for low crop yields is the prevalence of biotic stresses caused by weeds, pests, and diseases. The first generation of improved transgenic crops, into which a single trait such as herbicide tolerance or pesticide resistance has been introduced, can provide protection against several of these. The development of more complex traits such as drought resistance, which is a trait controlled by several genes, is underway and highly relevant for tropical crops that are often growing under harsh weather conditions and on poor-quality soils. There are not many estimates of the potential productivity impact that widespread cultivation of transgenic crops may have in developing countries, but according to James and Krattiger (1999 p.1) "[a] World Bank panel has estimated that transgenic technology can increase rice production in Asia by 10 to 25 percent in the next decade."

[4] Calculations are based on the FAOSTAT statistical database accessible at www.fao.org.

2.2 GM potential crops in world production and trade

The data used in the empirical analysis described below are from version 4 of the Global Trade Analysis Project (GTAP) database, which is estimated for 1995 (McDougall, Elbehri & Truong, 1998). As discussed above, the main crops that have been genetically modified to date are soybeans and maize. The sectoral aggregation of this database therefore comprises a cereal grains sector (which includes maize but not wheat and rice) and an oilseeds sector (which includes soybeans) to reflect these two GM potential crops. The livestock, meat & dairy, vegetable oils & fats, and other processed food sectors are also singled out, since they are important demanders of oilseeds and cereal grains as intermediate inputs to production.

The importance of trade in GM-potential crops varies across the regions. Table 1 shows that the value of oilseed exports relative to total value of production is significant for Cairns group, the United States and the Rest of South America. Cereal grain exports are also moderately large in value terms for the first two regions, but otherwise most of the production value of these two crops is captured on the domestic markets. For Cairns group, the Rest of South America, the United States and Sub-Saharan Africa, the impact of genetic engineering would be much larger if these techniques were applicable to the crops contained in the much larger aggregate 'other crops' sector. On the import side, the value of oilseed imports into Western Europe amounts to almost 40% of the total value of oilseed absorption. High–income Asia is also heavily dependent on imports of oilseeds and to a lesser extent cereal grains.

[5] As long as private companies uphold patents on their transgenic seeds they will be able to extract monopoly rents through price premiums or technology fees.

In general, the trade dependencies for livestock and processed food products are lower than the agricultural sectors described above. However, trade in these products is still important for developing regions. For example, Sub-Saharan Africa exports 16 % of its processed food products and 11 % of is meat and dairy products. Low-income Asia exports 10 % of its processed food products and 13 % of its meat and dairy products. South America exports 11 % of its processed food products.

Table 2 shows data on export market shares. The United States is by far the dominant exporter of both cereal grains and oilseeds and High-income Asia is the main importer of cereal grains and the second largest importer of oilseeds. In terms of processed food trade, countries in Cairns group and Western Europe are large exporters of meat and dairy products and other processed food products. High-income Asia is a major importer of other processed food products. Developing countries account for a small share of global trade in GM-potential crops and processed products.

Bilateral export patterns indicate that Low-income Asia and South America depend on both Western Europe and High-income Asia as markets for their exports (see tables 3 and 4). Sub-Saharan Africa depends primarily on Western Europe, sending 68 % of its other crops, and 93 % of its vegetable oils & fats to that region (see table 5).

3. GLOBAL CGE MODEL AND SCENARIOS

3.1 Global CGE model with segregated food markets

The modeling framework used in this analysis is a multi-region computable general equilibrium (CGE) model consisting of eight regions, which are inter-connected through bilateral trade flows: Cairns group, High-income Asia, Low-income Asia, the United States, the Rest of South America, Western Europe, Sub-Saharan Africa and the Rest of World. We begin from a standard global model and segment the GM-potential sectors – cereal grains and oilseeds. We also segregate intermediate users of GM and non-GM crops.[6]

In order to operate with segregated GM and non-GM sectors in the extended model, the base data must also reflect this segregation. First of all, the base data are adjusted by splitting the cereal grain and oilseed sectors into GM and non-GM varieties.[7] It is assumed that all regions in the model initially produce some of both GM and non-GM varieties of cereal grains and oilseeds. The assumed shares are adapted from estimates provided in James (1999) and USDA (2000a).[8] The Cairns group, Low-income Asia, the United States, and the Rest of South America regions in the model are the extensive GM-adopters.

The structures of production in terms of the composition of intermediate input and factor use in the GM and non-GM varieties are initially assumed to be identical. The destination structures of exports are also initially assumed to be the same, and this determines the resulting import composition by ensuring bilateral trade flow consistency.

The next step is to identify the sectors that use cereal grains and oilseeds as intermediate inputs as GM and non-GM sectors to reflect the concept of identity preservation. The GM/non-GM split is applied to the following sectors: livestock,

[6] The basic model is described in Lewis, Robinson, and Thierfelder (1999) and Nielsen, Thierfelder, and Robinson (2001).

[7] As will be discussed below, the distinguishing characteristic between these two varieties is the level of productivity. Furthermore, there may be environmental risks and hence externality costs associated with GM crops, they are impossible to estimate at this time and this paper makes no attempt to incorporate such effects in the empirical analysis.

vegetable oils and fats, meat and dairy, and other processed foods. In the base data the GM/non-GM split for these four sectors is determined residually, based on the share of GM inputs of cereal grains and oilseeds in total (GM plus non-GM) inputs of cereal grains and oilseeds for each sector. These shares are then used to split the data into GM and non-GM varieties of the four processing sectors. At this stage, the described procedure leaves all agricultural and food sectors using some of both GM and non-GM inputs. The input-output table is then adjusted so that GM sectors only use GM inputs and non-GM sectors only use non-GM inputs.[9]

In the model the decision of consumers to place GM versus non-GM varieties in their consumption bundle is endogenized. Final demand for each composite good (i.e. GM plus non-GM) is held fixed as a share of total demand, while introducing an endogenous choice between GM and non-GM varieties. In this way, all the initial expenditure shares remain fixed, but for six of the food product categories (oilseeds, cereal grains, livestock, vegetable oils and fats, meat and dairy, and other processed foods), a choice has been introduced between GM and non-GM varieties. All other expenditure shares remain fixed, as illustrated by Figure 1.[10]

3.2 GM and non-GM production technologies

As mentioned above, the distinguishing characteristic between the GM and non-GM maize and soybean sectors is the level of productivity. The GM cereal grain and

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[8] See Nielsen, Thierfelder, and Robinson (2001) for the breakdown of GM shares by country and commodity.

[9] Intermediate use in the GM sectors is restricted to only GM inputs and intermediate use in the non-GM secctors is restricted to only non-GM inputs. This is an important difference compared to the authors' earlier work (Nielsen, Robinson, and Thierfelder, 2001) where intermediate users of oilseeds and cereal grains had a choice between GM and non-GM varieties.

oilseed sectors are assumed to benefit from increased productivity in terms of primary factor use as well as a reduction in chemical use.[11] The available estimates of agronomic and hence economic benefits to producers from cultivating GM crops are very scattered and highly diverse (see e.g. OECD, 1999 for an overview of available estimates). Nelson, Josling, Bullock, Unnevehr, Rosegrant, & Hill (1999), for example, suggest that glyphosate-resistant soybeans may generate a total production cost reduction of 5%, and their scenarios have genetically modified corn increasing yields by between 1.8% and 8.1%. For present purposes, the GM-adopting cereal grains and oilseed sectors are assumed to make more productive use of the primary factors of production as compared with the non-GM sectors. In other words, the same level of output can be obtained using fewer primary factors of production, or a higher level of output can be obtained using the same level of production factors. In our scenarios, the GM oilseed and GM cereal grain sectors in all regions are assumed to have a 10% higher level of factor productivity as compared with their non-GM (conventional) counterparts. Furthermore, there seems to be evidence that cultivating GM varieties substantially reduces the use of chemical pesticides and herbicides (see e.g. Pray et al. 2000). Hence the use of chemicals in the GM oilseed and GM cereal grain production is reduced by 30% to illustrate this cost saving effect.

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[10] See Nielsen, Thierfelder, and Robinson (2001) for details on how to calibrate the constant elasticity of substitution (CES) aggregate of the GM and non-GM varieties.

[11] Note that this is an asymmetric shock and that it will therefore have different effects in different regions because of different cost structures: the shares of primary factor costs and chemical costs in total production costs are different.

3.3 Consumer preferences

There are many ways to formally model changes in consumer preferences. This paper illustrates how two such ways can be implemented in a computable general equilibrium model. This is done by shifting and altering the curvature of the indifference curve between GM and non-GM commodities. Each alternative has a different interpretation of what consumers might mean when they say they disapprove of GM foods.

The starting point for the consumer preference experiments is that food products come in two varieties, distinguished by their method of production: GM and non-GM. The model has the representative consumer who views these two varieties as imperfect substitutes. Three different consumer response scenarios are examined. In the base case consumers in all countries are relatively indifferent with respect to the introduction of GM techniques in food production, and so they find GM and non-GM food varieties highly substitutable.

The next two experiments then attempt to reflect the fact that citizens in Western Europe and High-income Asia dislike the idea of genetically modified foods. In the second experiment this is illustrated by lowering the elasticities of substitution between the GM and non-GM varieties for consumers in these two regions. Consumers in these regions are assumed to be less sensitive to a given change in the ratio of prices between GM and non-GM varieties. They are seen as poor substitutes in consumption in these particular regions. Citizens in all other regions are basically indifferent, and hence the two varieties remain highly substitutable in consumption in those regions.

The change in consumer preferences described in experiments 1 and 2 corresponds to altering the curvature of the indifference curves of consumers in Western Europe and High-income Asia as illustrated in Figure 2. The two curves in the figure correspond to the same level of utility, U_0. When the relative prices of GM and non-GM foods change, consumers in Western Europe and High-income Asia are in the second experiment assumed to be less inclined to shift consumption toward GM varieties as they were in the base case, where substitutability was high. The representative consumer is on the same budget line (same expenditure on the composite food product, i.e. GM plus non-GM, and hence same level of utility).

It is not clear, however, whether reduced price sensitivity is an appropriate interpretation of consumers' critical approach to GM foods. In some rich countries, where consumers can indeed afford to be critical of these new techniques in food production, irrespective of how cheap these products may become (relative to non-GM foods), some consumers may simply not want to consume them. In this case, we are changing the ratio of GM to non-GM foods demanded at a given (constant) price ratio, holding utility constant. This is illustrated in Figure 3, where the representative consumer in Western Europe and High-income Asia is as well off as before but now with a lower share of GM foods in his/her consumption bundle. The total value of expenditure on each composite food item remains the same. In other words, consumers still spend the same amount on their consumption of food, but the composition is changed in favor of non-GM varieties. In the experiment we reduce the GM share of foods in consumption in Western Europe and High-income Asia to 2%.

4. RESULTS OF EMPIRICAL ANALYSIS

4.1. Price and trade results

Base case experiment

The increase in factor productivity and the reduced need for chemicals in the GM cereal grain and oilseed sectors causes the cost-driven prices of these crops to decline. The magnitude of this price decline in the different sectors and regions will differ, depending on the shares of primary production factors and chemicals in total production costs. In sectors and regions where these costs make up a large share of total costs, the impact of the productivity shock in terms of lower supply prices will be greater than in sectors and regions where the share is smaller. Intermediate users of GM inputs (the GM livestock and GM processed food producers) will benefit from lower input prices.

The non-GM product markets will be affected by the productivity gain in the GM sectors in three ways. First, there will be increased competition for primary factors of production and intermediate inputs because GM production will increase. Second, consumers domestically might change their consumption patterns in response to the new relative prices depending on their initial consumption pattern and substitution possibilities. Third, importers will change their import pattern depending on the relative world prices, their initial absorption structures and the substitution possibilities between suppliers. In all three cases, the initial cost, consumption and import structures on the one hand, and the substitution possibilities between products for input use, final consumption and imports on the other, will determine the net impact of the productivity experiment.

The net effects are theoretically ambiguous and hence must be determined empirically.

Figures 4a and 4b depict for developing and developed countries, the price wedges that arise between the non-GM and GM varieties in the base case experiment, where GM and non-GM foods are considered to be good substitutes in consumption in all regions. Generally, the relative price of non-GM to GM commodities rises, and the percentage point differences between the prices of non-GM and GM varieties of cereal grains and oilseeds are between 6.3 and 9.4. As described above, the price wedges vary across the regions in part because they have different shares of primary factor and chemical costs in total production costs. Hence the extent to which the individual regions benefit from the productivity increase differs.

The lower GM crop prices in turn result in lower production costs for users of GM inputs, thereby reducing those product prices relative to the non-GM varieties as well. As can be seen in Figures 4a and 4b, the price wedges that arise between the GM and non-GM livestock and processed food products are much smaller than the price wedges between GM and non-GM primary crops because the cost reduction concerns only a part of total production costs. Relatively speaking, oilseeds constitute a large share of production costs in vegetable oils and fats production (compared with oilseed and cereal grain use in other food production), and hence the spillover effect is largest.

The lower GM crop prices mean improved international competitiveness for exporters of these crops. Hence, as Table 6 shows, the United States, a large exporter of cereal grains and oilseeds, increases its exports of GM crops in this base case by 9.0%. There are also large percentage increase in exports from the developing countries that are

GM-adopters, but the improvement is from a lower base. Due to the reduced relative competitiveness of non-GM crops, exports of this variety decline somewhat. The large importers of these crops, High-income Asia and Western Europe, increase their imports of the cheaper GM varieties. This is particularly so in the case of oilseeds because these two regions are highly dependent on imported oilseeds from countries that are enthusiastic GM adopters. Imports of the non-GM varieties decline slightly due to the reduced relative price competitiveness of non-GM products in an environment where consumers find GM and non-GM food varieties to be good substitutes.

Price sensitivity experiment

As can be seen by Figures 5a and 5b, the price wedges resulting from the price sensitivity experiment are not markedly different from the ones reported in the base case experiment. It may be mentioned, however, that the prices for GM cereal grains and especially oilseeds are slightly lower on the Western European and High-income Asian markets when consumers are critical (less price sensitive): larger price reductions are required in order to sell GM-varieties in GMO-critical markets. Conversely, demand for non-GM crops is relatively stronger, and hence the prices of non-GM oilseeds, for example, are higher. Hence we find that the price wedges for especially oilseeds, but also cereal grains, are larger in High-income Asia and Western Europe in the price sensitivity experiment. In large oilseed producing markets such as the United States, the price of the non-GM variety falls slightly more and the price of the GM variety falls less as compared with the base case – the price wedges are smaller.

Compared with the base case, the increase in GM oilseed and cereal grain exports from the United States is smaller when consumers in their important export markets are less responsive to the GM/non-GM price difference. Consequently, on the import side, the results show that the declines in imports of the more expensive non-GM oilseeds into High-income Asia and Western Europe are smaller. The decreases in non-GM cereal grain imports have even turned into minor increases. High-income Asia and Western Europe still increase their GM oilseed imports in this price sensitivity experiment (although at lower rates) because of their high dependence on importing from GM-enthusiastic regions. This result is due to the fact that there is a symmetry in the trade dependence concerning oilseeds: U.S. oilseeds make up a large share of oilseed imports into High-income Asia and Western Europe, and exports for High-income Asia and Western Europe make up a large share of U.S. exports. For this reason changes in consumer preferences in these countries will have an impact on the trading conditions for U.S. producers.

A similar pattern holds for the developing countries that are GM-adopters. Exports of GM varieties do not expand as much, and exports of the non-GM varieties do not decline as much, in the price sensitivity experiment compared to the base case. In absolute terms, the changes in the U.S. are larger because that country is a larger exporter on world markets. Also, Low-income Asia and the Rest of South America are less dependent than is the U.S. on Western Europe and High-income Asia for sales of cereal grains and oilseeds. These developing countries are also dependent on the Cairns group as a market for exports.

Structural change experiment

In this final experiment consumers in Western Europe and High-income Asia simply turn against genetically modified foods. Compared with the previous experiment, final demand in these regions is very insensitive to relative price differences between GM and non-GM food varieties. Consumers in Western Europe and High-income Asia are assumed simply to shift their consumption patterns away from GM varieties in favor of non-GM varieties, regardless of the relative price decline of GM foods. This shift is measured relative to the experiment in which price sensitivity in these regions is low to begin with. Hence the effects of this structural shock are an addition to the second experiment.

The results show that this rejection is clearly a much more dramatic change compared with reduced price sensitivity. Critical consumers simply do not want GM-products. The price of GM varieties in the GMO-critical countries declines further because of the almost complete rejection of these products, whereas the price of non-GM foods increases. This leads to substantially larger price wedges in the GM-critical regions as compared with the previous experiments, as is evident from Figures 6a and 6b. The larger price wedges between GM and non-GM primary crops follow through the entire food processing chain. The price increase for non-GM foods is, however, moderated by the fact that there are markets for non-GM products in all regions in the model. All countries can produce both varieties and hence supply both GMO-indifferent and GMO-critical consumers.

Total U.S. GM cereal grain and oilseed exports fall by 17% and 33%, respectively (Table 8), while exports of the non-GM varieties increase by 8% and 15%, respectively. These changes are a direct reaction to the relative prices obtainable on their key export markets, namely High-income Asia and Western Europe. The prices of GM cereal grains and oilseeds on these markets plummets and the prices of non-GM varieties increase slightly.

For Low-income Asia and South America, exports of GM oilseeds decline, similar to the export response in the U.S. However, exports of GM cereal grains still expand. These countries are less dependent on GM-critical regions for cereal grains than is the U.S. For example, South America sends 92 % of its cereal grain exports to the Cairns Group.

Changing consumer attitudes in Western Europe and High-income Asia also affect Sub-Saharan Africa's trade patterns. While that region is not a GM-adopter, it does have strong trade ties to Western Europe. Its imports of GM processed products declines, despite the fact that it is not a GM-critical region. Instead, its major import source changes its production patterns and therefore the structure of its exports.

Table 8 shows that imports of GM cereal grain and oilseeds into Western Europe and High-income Asia decline substantially (between –57% and –71%). Conversely, imports of non-GM crops increase substantially, at slightly higher prices. The sourcing of these non-GM crop imports is spread across all regions, because in the model all regions are assumed to be able to produce both varieties and to be able to credibly verify this characteristic to importers. Clearly, this is a simplification of reality, and one can easily imagine that for some regions, living up to the principles of identity preservation and verification would be very costly, thereby putting them at a cost disadvantage. Such effects are not captured in this model. The increases in non-GM cereal grain and oilseed imports are supplemented by increases in own production in both High-income Asia and Western Europe.[12]

4.2. Production results

Being a major exporter of both crops, the increased demand for GM cereal grains and oilseeds in the base case experiment filters through to an increase in production of these crops in the U.S. The effect is dampened, however, by the fact that its major destination regions (High-income Asia and Western Europe) have much larger non-GM sectors (relative to their GM sectors), which are required to use only non-GM inputs.[13] This also means, for example, that the production of non-GM crops does not fall as markedly in the U.S. as it does in e.g. Low-income Asia, a region that is not very heavily engaged in international trade in these particular crops. Figure 7 compares the impact on production in the United States of the different and changing assumptions made about consumer preferences in Western Europe and High-income Asia. Since exports make up a relatively large share of the total value of production in these sectors, particularly for oilseeds, we see that there is a marked effect on the composition of

[12] Note that Western Europe might be restricted by the Blair House agreement in terms of increasing acreage for oilseed production and so the reported production increase may not be allowed.
[13] Comparing these production effects with the results of our previous analysis, which did not have the identity preservation (IP) requirement in place (Nielsen, Robinson and Thierfelder, 2000), we see that the effects reported here are substantially smaller. This is precisely because the IP requirement introduces much stronger restrictions on intermediate input choice for livestock producers and food processors. In our previous analysis intermediate users had a free choice between GM and non-GM varieties and could

production. Production of GM crop varieties increases in the first two experiments, whilst production of non-GM varieties declines somewhat. The impact is slightly less when consumers in High-income Asia and Western Europe are less sensitive to the GM/non-GM price difference.

In the structural shift experiment, however, the production of GM oilseeds in the U.S. declines by 15% in spite of the factor productivity gain and the reduced chemical requirements. This is because the U.S. is so highly dependent on exporting especially oilseeds to the GM-critical markets and because a structural consumer preference change has much more of an impact on this region's trading opportunities compared with the reduced price sensitivity experiment. The production of non-GM oilseeds, on the other hand, increases by 10% - another direct reflection of the importance of the GMO-critical export markets is relatively less dependent on exports of these particular crops.

An interesting question is whether these changing preferences in Western Europe and High-income Asia can open opportunities for developing countries to export non-GM varieties of cereal grains and oilseeds to these regions. Sub-Saharan Africa has some production of oilseeds, for example, and although exports of these crops do not account for a significant share of total production value at present, they might if niche markets for non-GM crops develop in Western Europe. Similarly, Low-income Asian countries might look into expanding their production of e.g. non-GM oilseeds if nearby niche markets in High-income Asian countries develop.

Although the differences are very small, comparing the trade and production

therefore benefit fully from the lower GM prices. In this model, however, intermediate users are required to results of the three experiments indicates that this might be a path to follow if the price premia obtainable for non-GM varieties are large enough to outweigh the relative decline in productivity and any identity preservation and labeling costs. But even more significant in value terms for these countries are exports of processed foods, i.e. vegetable oils and fats, meat and dairy products, and other processed foods. Factors such as existing trade patterns, proximity of markets, historical ties, etc. will determine whether or not producers will choose to forego productivity increases and lower costs in GM production in order to retain access to their traditional export markets by selling non-GM products. For a region like Sub-Saharan Africa, with strong ties to Western Europe, changing consumer attitudes toward genetically modified foods are expected to be an important determinant of future decisions regarding genetic engineering in food production. As seen in figure 9, production of GM processed food products expands in the first two experiments but declines in the structural shift case. There, Western Europe's increase in demand for non-GM processed foods changes the pattern of production.

4.3. Absorption results

In this modeling framework, where we are operating with a representative consumer, we are implicitly aggregating over two consumer types – those who are indifferent about GM products and those who are concerned about potential hazards of consuming GM products. We have considered two changes in preferences concerning GM inclusive foods. First, attitudes harden. The size of the two groups does not change, but those who are concerned about GM products become more price sensitive. As described above, this changes the curvature of the indifference curve, as shown in Figure

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use only GM or non-GM inputs.

2. Second, we have considered the effects of a structural preference shift – more people believe that there are health hazards from consuming GM foods and choose to consume less, and the share of consumption of GM foods drops, regardless of relative price changes. In essence, the group of GM sensitive consumers expands, which causes the indifference curve to shift, as depicted in Figure 3.

As discussed above, the level of utility is assumed to stay the same when the indifference curve shifts. The representative consumer is on the same budget line with a different combination of GM and non-GM foods, and we do not assume that the consumer obtains additional utility from his decision to increase the share of non-GM products he consumes. With this assumption, real absorption is an appropriate welfare measure. It indicates the change in the total amount of goods and services consumed following a change in preferences. The results of the experiments show that global absorption increases by USD 7.4 billion in the base case, where consumers are assumed to find GM and non-GM foods to be good substitutes. Increasing the price sensitivity of GM-critical consumers in High-income Asia and Western Europe lowers this gain in total absorption marginally to USD 7.2 billion. As the previous results have shown, the structural shift experiment represents a much more dramatic change in preferences, and hence we find that the global absorption gain is only USD 0.02 billion in that experiment.

The absorption results are reported for selected regions in Figure 11 for the three experiments. The changes are reported in billions of USD and it should be noted that the percentage changes are very small. It is clear from this figure that Cairns group, Low-income Asia, and the United States are the main beneficiaries of the productivity increase given that these are the regions assumed to be intense adopters of the GM crop varieties.

All other regions also experience an increase in total absorption, albeit at a lower absolute level. Reducing the price sensitivity of consumers in High-income Asia and Western Europe reduces the increase in global absorption only marginally and does not change the distribution of the gains across regions. Most importantly, all regions still gain in terms of aggregate absorption from the productivity increase and hence lower product prices in spite of the increased aversion towards GM foods in High-income Asia and Western Europe.

Interpreting consumer preference changes as a structural shift, however, alters the absorption results dramatically. Because our model has completely segregated GM and non-GM production systems, restricting input use to either GM or non-GM varieties, the structural preference shift has a strong effect on the demand for non-GM intermediates, and not all regions experience increases in total absorption in this experiment. Despite the productivity gain in the large GM crop sectors in the United States, these results reveal that aggregate absorption declines in these regions when consumers in important export markets turn against their main product and there is little diversion to other markets. Total absorption declines by USD 0.9 billion in the United States. Although this decline amounts to a percentage change of only 0.007%, it illustrates how different types of preference changes will have very different impacts on total absorption results.

It is particularly interesting that the increases in total absorption in *all* the developing country regions are *not* affected when GM critical regions become more price sensitive (comparing the base case to the price sensitivity experiment). Low Income Asia is the major beneficiary in absolute terms, being both a net importer of the two crops and basically indifferent as to GM content. Hence the region benefits from substantially lower import prices on GM crops. Despite the high dependence on the GM critical regions for its exports of oilseeds, the increase in total absorption in South America is unaffected by the preference changes there because bilateral trade flows adjust well – trade diversion offsets the effects of demand shifts in the GM critical regions. In Sub-Saharan Africa the gains are small in absolute terms, mainly due to the small share of these particular crops in production and trade, but they are also unaffected by preference changes in GM critical regions.

When consumers in Western Europe and High-income Asia reject GM varieties, the developing countries that are GM adopters (Low-income Asia and South America) have less of an absorption gain. Interestingly, Sub-Saharan Africa has the biggest absorption gain in the structural shift scenario. In this case, the effective improvement in its international terms of trade leads to increased imports and a gain in absorption (and an appreciation of its real exchange rate).

5. CONCLUSIONS

The very different perceptions – particularly in North America and Western Europe – concerning the benefits and risks associated with the cultivation and consumption of genetically modified foods are already leading to the segregation of soybean and maize markets and production systems into GM and non-GM lines. By using a global CGE model, this analysis has shown that such a segregation of markets may have substantial impacts on current trade patterns. The model distinguishes between GM and non-GM varieties in the oilseed and cereal grains sectors, as well as in the processing sectors that use these crops as inputs. GM crop production is assumed to have higher factor productivity as compared with conventional production methods. It is also assumed that the non-GM processing sectors can verify that they use only non-GM intermediate inputs.

The effects of a factor productivity increase in the GM sectors are then investigated in an environment where there are increasingly strong preferences *against* GM crops in Western Europe and High Income Asia. The change in preferences is modeled two ways. First, as a change in substitution elasticity–consumers perceive GM and non-GM crops to be poor substitutes in these regions. Alternatively, as a reduction in the share of the GM variety consumed – consumers reject GM varieties, regardless of the price differential.

The empirical results indicate that trade patterns adjust to changes in consumer attitudes when markets are segregated. Non-GM exports are diverted to the GM critical regions, while GM exports are diverted to the indifferent regions. Historical trade patterns matter as well. We find that when consumers in Western Europe reject GM varieties, they produce and export more non-GM varieties. This affects the non-GM composition of Sub-Saharan Africa's imports because that region depends strongly on Western Europe.

An important question for developing countries is whether genetic engineering in agriculture is an opportunity or a dilemma. The results of this empirical analysis offer some insights into the trade and welfare effects of adopting the new technology in a market with GM-critical regions. All of these results, it should be noted, are based on the heroic (and controversial) assumption that any environmental risks and hence externality costs associated with GM crops are manageable. To the extent that adopting genetically modified crops provides farmers with productivity benefits that outweigh the additional costs of GM seeds, the results seem to suggest that there are large welfare gains to be made for developing countries that adopt such a technology. Furthermore, changing GM preferences in Western Europe and High Income Asia do not affect these gains because markets adjust, and trade flows of GM and non-GM products are redirected according to preferences in the different markets.

The underlying assumption of this finding is, however, that production and marketing systems are indeed capable of dealing with the separation of GM and non-GM crop handling systems – certainly a challenge for countries in the developing world. The difficulties and costs involved in separating GM and non-GM marketing and handling systems present the developing countries with a dilemma: They must decide whether or not to use their limited resources on developing such a capacity. For Sub-Saharan Africa, for example, current exports of GM-potential crops do not constitute a large share of total production, and so there may well be benefits to adopting GM crop varieties since consumers in the domestic market are indifferent, and this is the major market to be served.

On the other hand, in order to ensure future export markets, it may well make sense to establish identity preservation systems so that guaranteed non-GM products can serve GM critical consumers in Western Europe – Africa's major export market for agricultural products. Indeed, a market for non-GM processed foods for exports can coexist with the production of GM processed foods for domestic consumption, allowing producers to exploit a niche market in GM-critical regions. Furthermore, GM technology may expand to other crops that are a large share of total production. The technology is evolving rapidly, and agricultural producers and policy makers in Sub-Saharan Africa and other developing countries must closely follow the development of the international GM debate.

6. REFERENCES

Buckwell, Allan, Graham Brookes & Dylan Bradley (1999) *Economics of Identity Preservation for Genetically Modified Crops*. Final report of a study for Food Biotechnology Communications Initiative (FBCI). With contributions from Peter Barfoot, Stefan Tangermann and Jan Blom. Mimeo.

Frandsen, Søren Elkjær & Chantal Pohl Nielsen (1999), *Derfor skal de GMO-frie varer mærkes* (This is why non-GMO products should be labeled), Chronicle (in Danish), *Jyllandsposten*, Monday 20.12.99.

Hertel, Thomas W. (1997) (ed.) *Global Trade Analysis: Modeling and Applications*. Cambridge University Press. Cambridge and New York.

James, Clive (1999) *Global Status of Commercialized Transgenic Crops: 1999*. ISAAA Briefs No.12: Preview. International Service for the Acquisition of Agri-biotech Applications. Ithaca, New York.

James, Clive (1998) *Global Review of Commercialized Transgenic Crops: 1998*. ISAAA Briefs No.8. International Service for the Acquisition of Agri-biotech Applications. Ithaca, New York.

James, Clive (1997) *Global Status of Transgenic Crops in 1997*. ISAAA Briefs No.5. International Service for the Acquisition of Agri-biotech Applications. Ithaca, New York.

James, Clive & Anatole Krattiger (1999) 'The Role of the Private Sector.' Brief 4 of 10 in Persley, Gabrielle J. (ed.) "Biotechnology for Developing/Country Agriculture: Problems and Opportunities'. *Focus 2: A 2020 Vision for Food, Agriculture, and the Environment*. International Food Policy Research Institute, Washington, D.C.

Lewis, Jeffrey D., Sherman Robinson & Karen Thierfelder (1999) *After the Negotiations: Assessing the Impact of Free Trade Agreements in Southern Africa*. TMD Discussion Paper No. 46. September. International Food Policy Research Institute, Washington, D.C.

McDougall, Robert A., Aziz Elbehri & Truong P. Truong (1998) (eds.) *Global Trade, Assistance, and Protection: The GTAP 4 Data Base*. Center for Global Trade Analysis, Purdue University, West Lafayette.

Nelson, Gerald C., Timothy Josling, David Bullock, Laurian Unnevehr, Mark Rosegrant & Lowell Hill (1999) *The Economics and Politics of Genetically Modified Organisms: Implications for WTO 2000*. With Julie Babinard, Carrie Cunningham, Alessandro De Pinto and Elisavet I. Nitsi. Bulletin 809. College of Agricultural, Consumer and Environmental Sciences, University of Illinois at Urbana-Champaign, November.

Nielsen, Chantal Pohl & Kym Anderson (2000) *GMOs, Trade Policy, and Welfare in Rich and Poor Countries*. Paper prepared for a World Bank Workshop on Standards, Regulation and Trade, held in Washington, D.C., 27 April 2000. Downloadable as CIES Discussion Paper No. 0021 at www.adelaide.edu.au/CIES/publcns.htm. Centre for International Economic Studies, University of Adelaide.

Nielsen, Chantal Pohl, Sherman Robinson and Karen Thierfelder (2001) *Genetic engineering and trade: Panacea or dilemma for developing countries*. World Development, Vol 29 no. 8, pp. 1307-1324.

Nielsen, Chantal Pohl, Karen Thierfelder, and Sherman Robinson (2001) *Consumer Attitudes Towards Genetically Modified Foods, The Modelling of Preference Changes*. SJFI Working Paper no. 1/2001, Danish Institute of Agricultural and Fisheries Economics, Copenhagen, Demark.

OECD (1999) *Modern Biotechnology and Agricultural Markets: A Discussion of Selected Issues and the Impact on Supply and Markets.* Directorate for Food, Agriculture and Fisheries. Committee for Agriculture. AGR/CA/APM/CFS/MD(2000)2, Paris: OECD.

Pray, Carl E., Danmeng Ma, Jikun Huang & Fangbin Qiao (2000) *Impact of Bt Cotton in China*. Paper presented at a seminar at the International Food Policy Research Institute (IFPRI), May 9, 2000.

Runge, C. Ford & Lee Ann Jackson (1999) *Labeling, Trade and Gentically Modified Organisms (GMOs): A Proposed Solution*. University of Minnesota, Center for International Food and Agricultural Policy, Working Paper WP99-4, November 1999

USDA (2000a) *Biotech Corn and Soybeans: Changing Markets and the Government's Role*. April 12, 2000. http://ers.usda.gov/whatsnew/issues/biotechmarkets/

USDA (2000b) *Biotechnology: U.S. Grain Handlers Look Ahead*. Agricultural Outlook, April 2000. Economic Research Service/USDA.

FIGURE 1. **Endogenous choice between GM and non-GM foods**

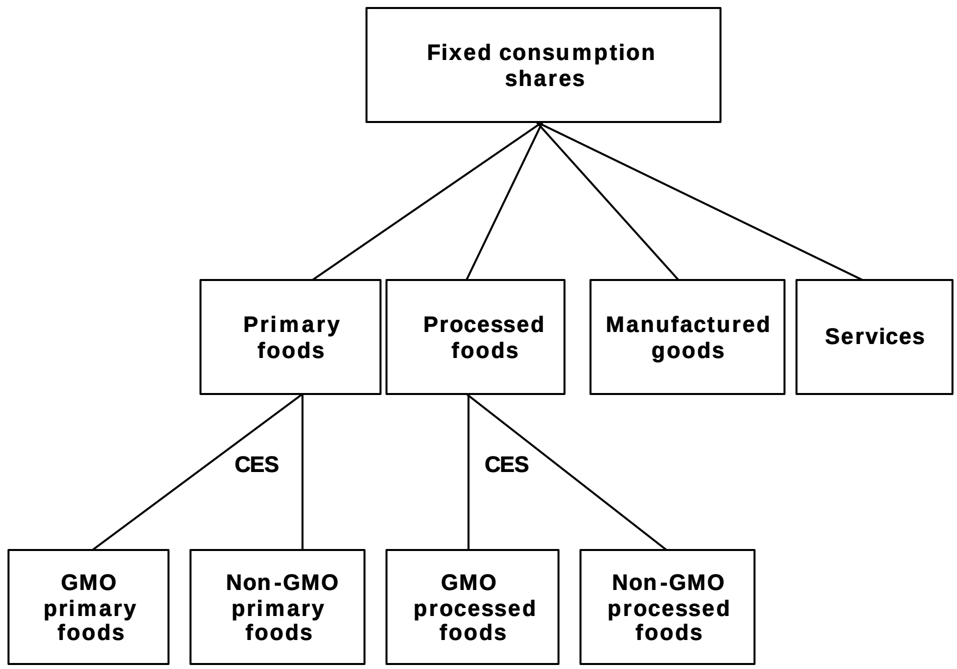

FIGURE 2. **Consumer preferences modeled as different degrees of price sensitivity**

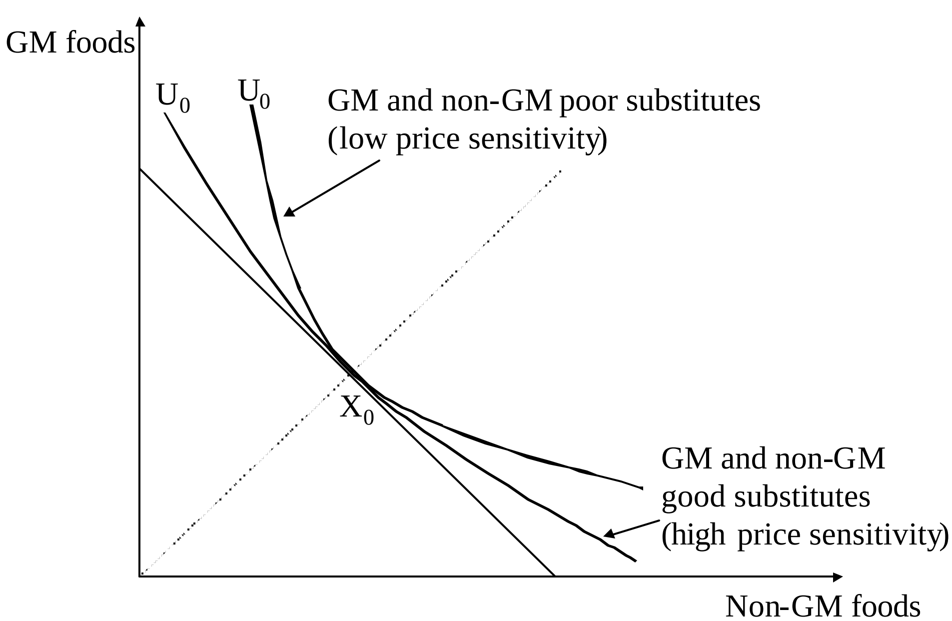

FIGURE 3. **Consumer preferences modeled as a structural change**

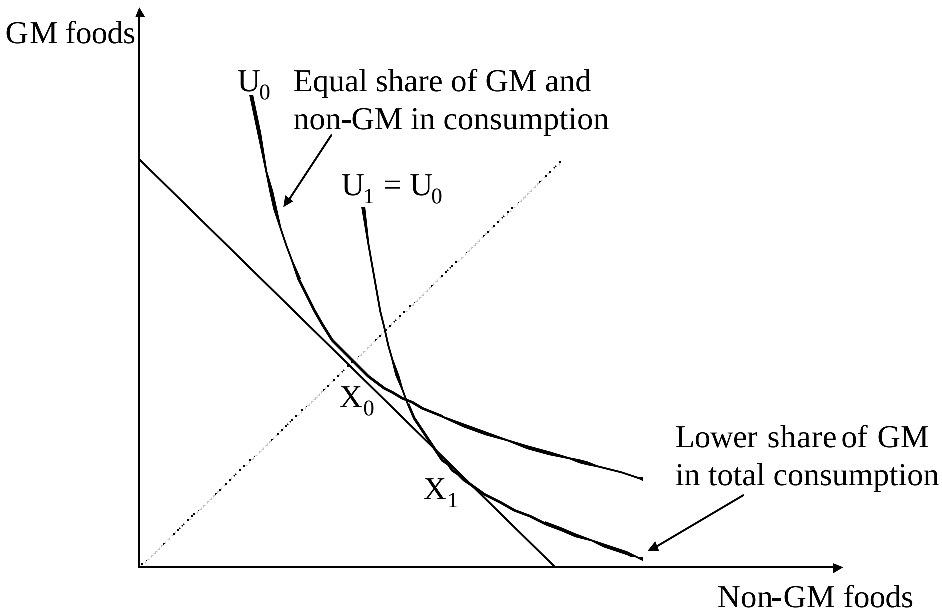

FIGURE 4A. **Base case experiment: Price wedges between non-GM and GM products in developing countries**

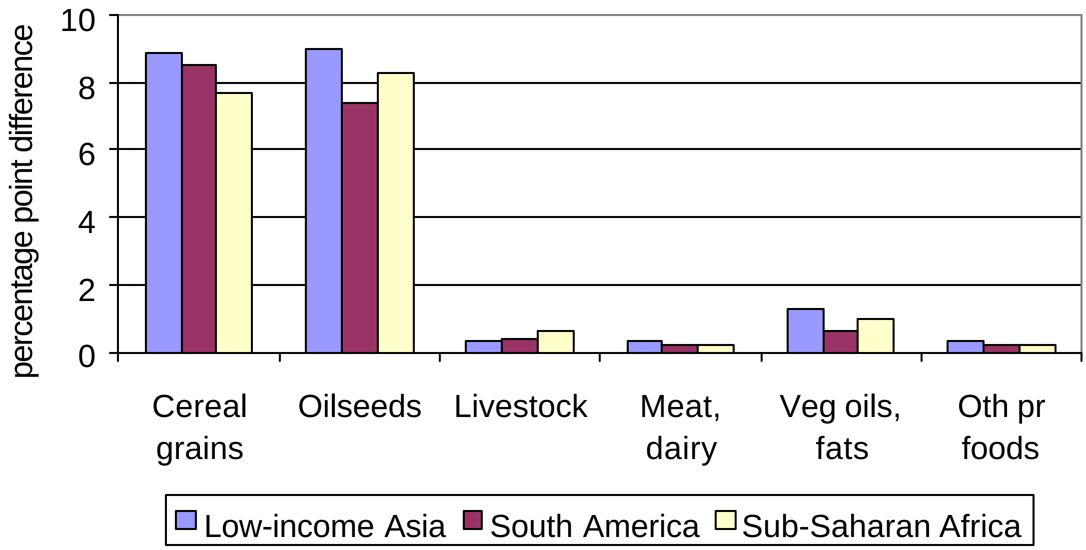

FIGURE 4B. **Base case experiment: Price wedges between non-GM and GM products in developed countries**

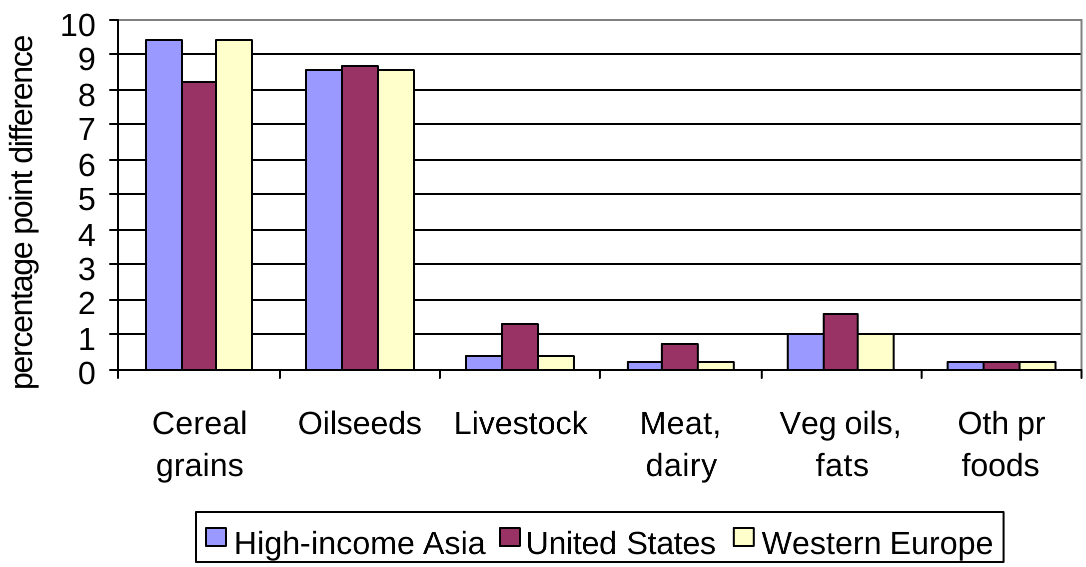

FIGURE 5A. **Price sensitivity case: Price wedges between non-GM and GM products in developing countries**

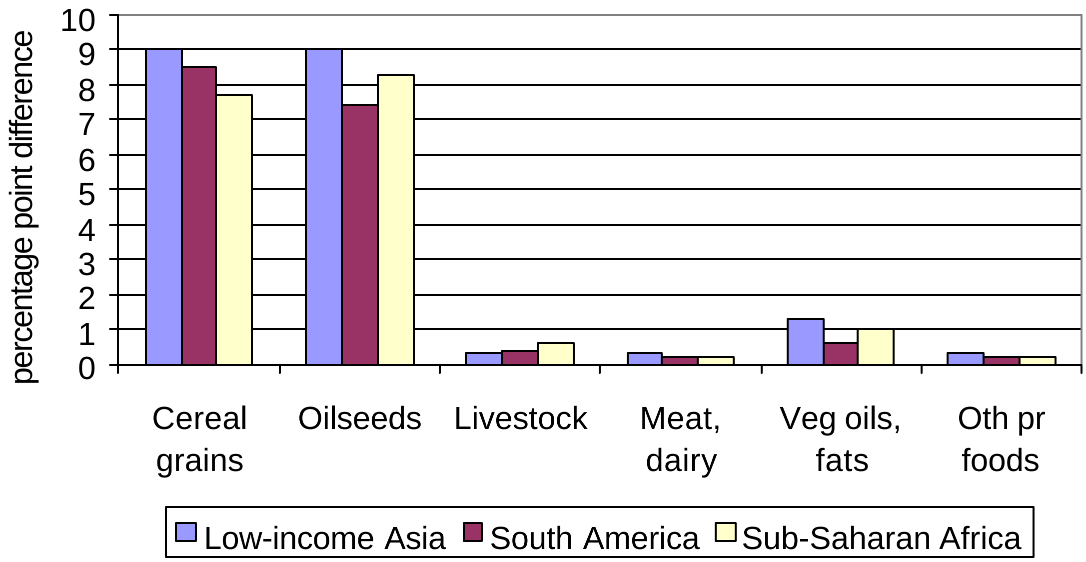

FIGURE 5B. **Price sensitivity case: Price wedges between non-GM and GM products in developed countries**

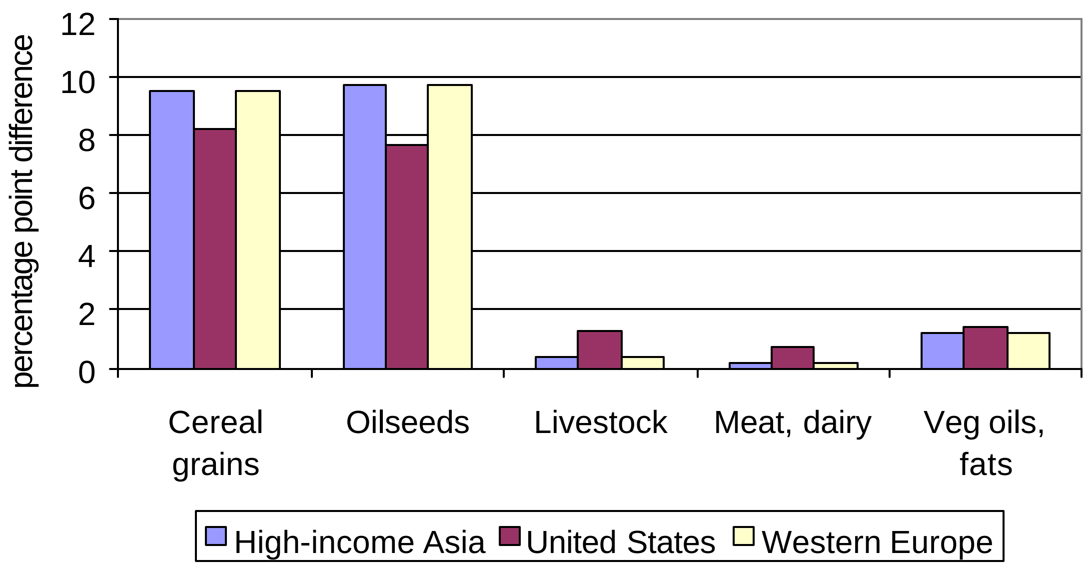

FIGURE 6A. **Structural change case: Price wedges between non-GM and GM products in developing countries**

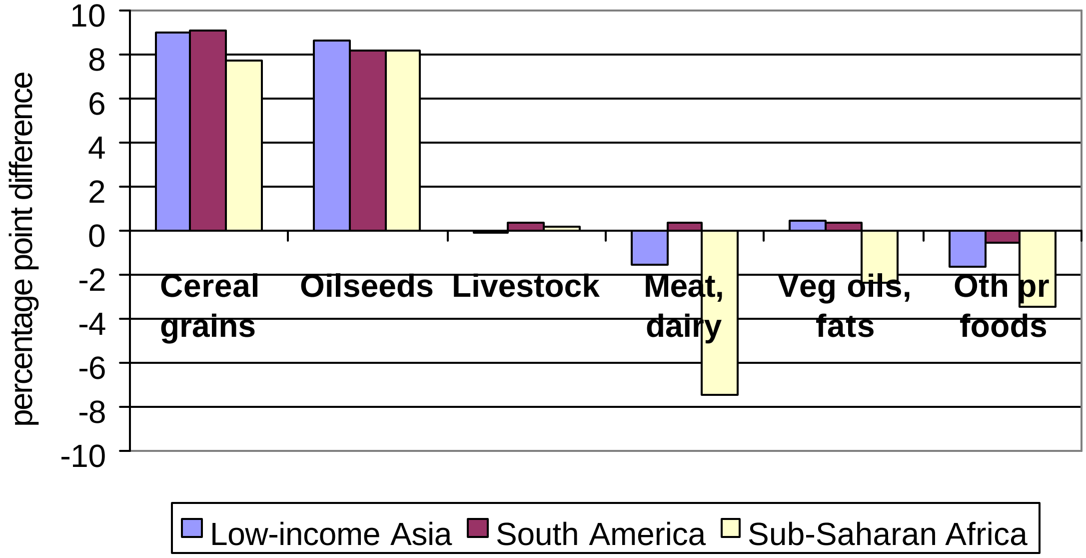

FIGURE 6B. **Structural change case: Price wedges between non-GM and GM products in developed countries**

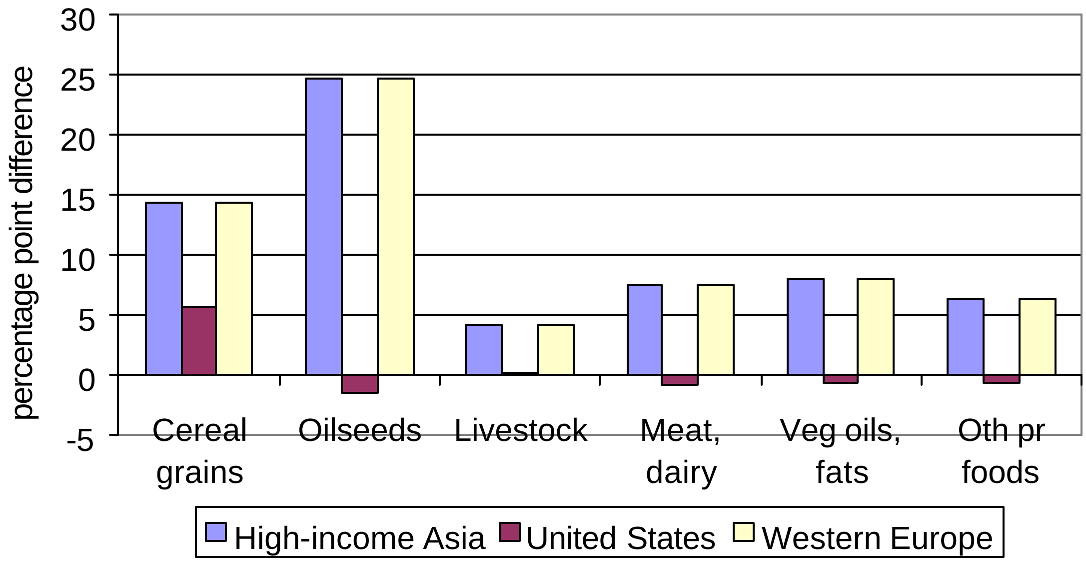

FIGURE 7. **Production effects in United States**

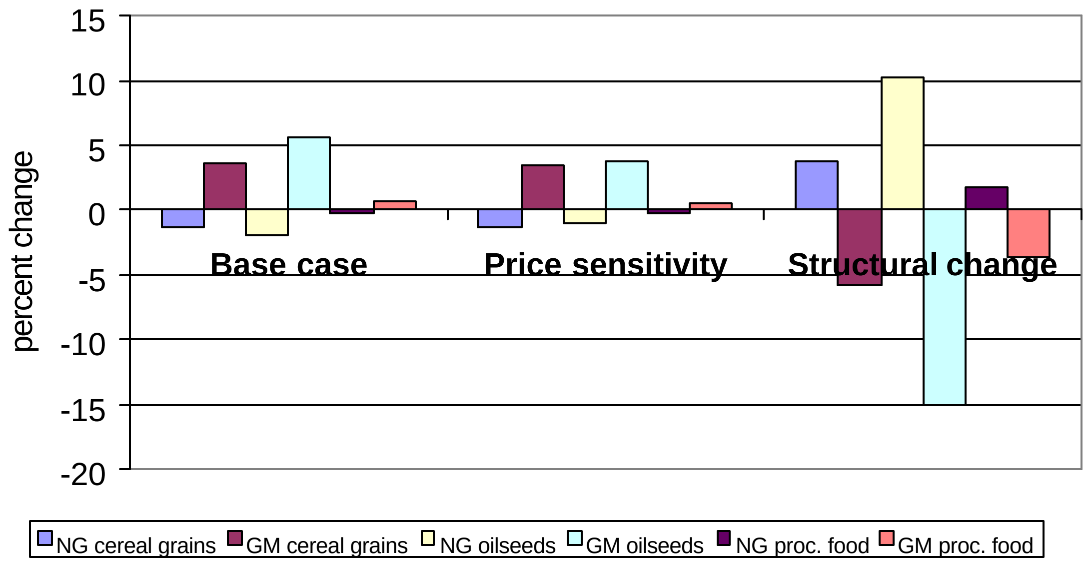

FIGURE 8. **Production effects in Low-income Asia**

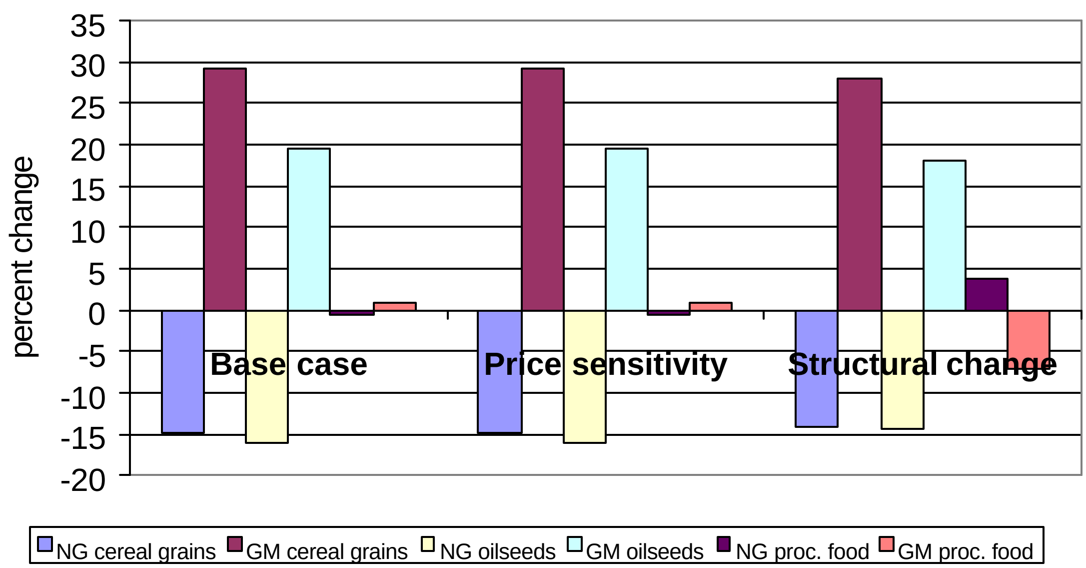

FIGURE 9. **Production effects in South America**

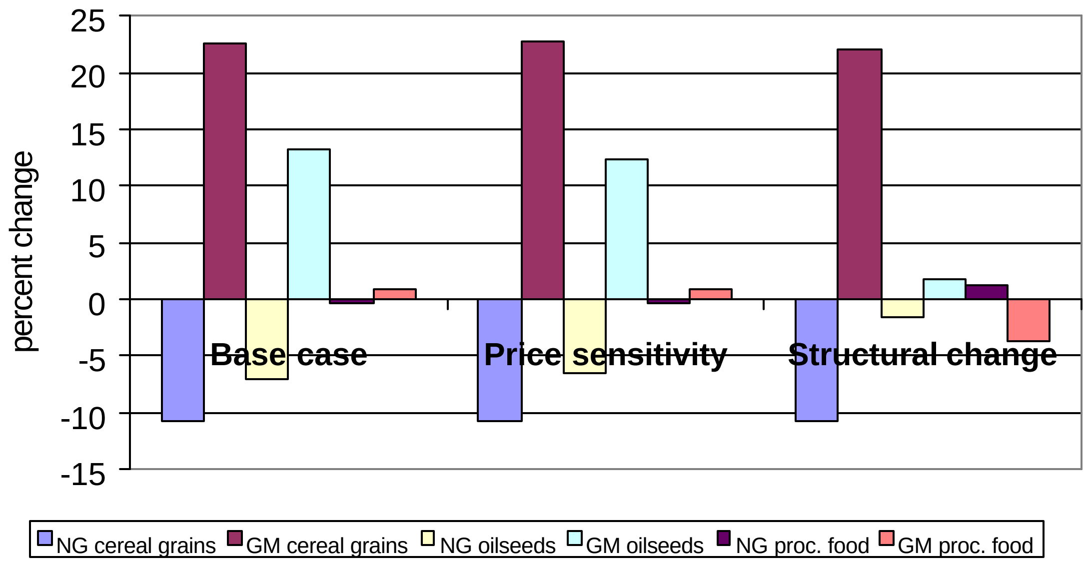

FIGURE 10. **Production effects in Sub-Saharan Africa**

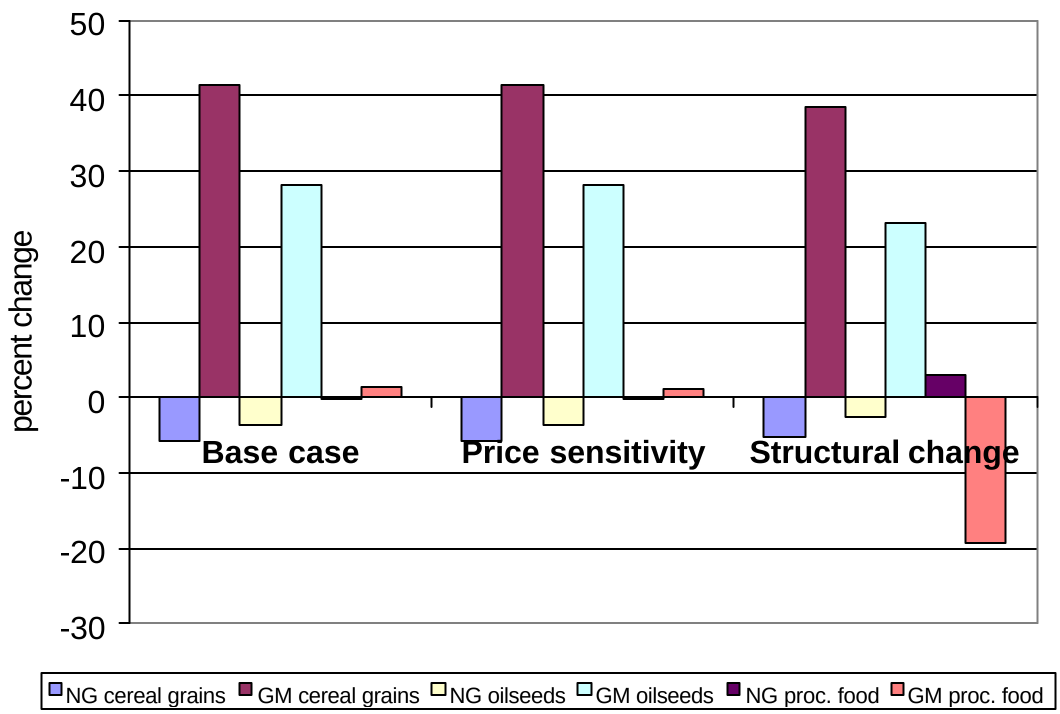

FIGURE 11. **Changes in total absorption**

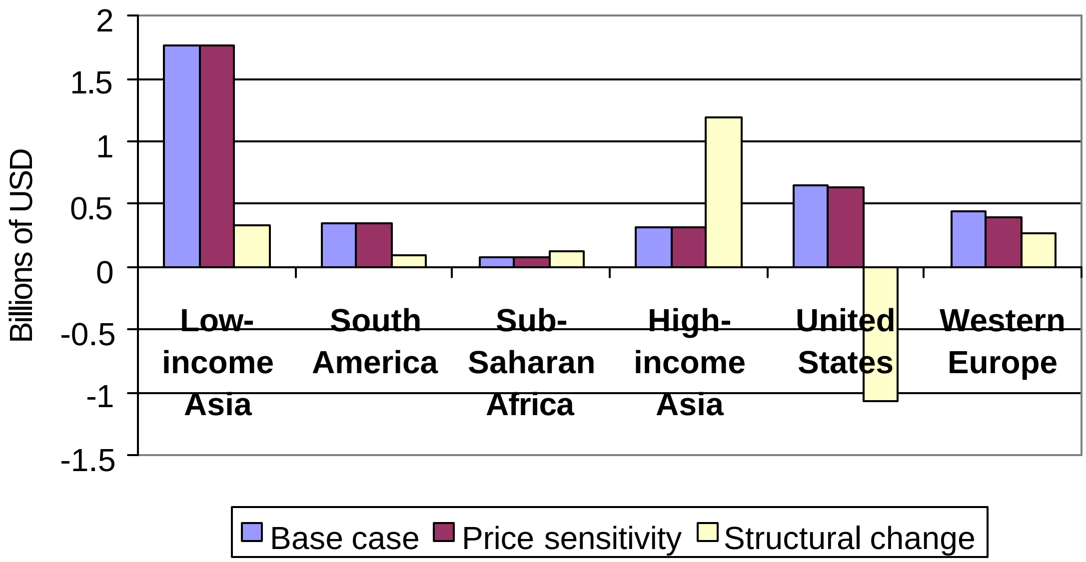

TABLE 1. **Trade dependence: agricultural and food products, 1995**

	Cairns group	High-income Asia	Low-income Asia	United States	Rest of South America	Western Europe	Sub-Saharan Africa	Rest of World
Value of exports in % of total production value								
Cereal grains	9.7	0.2	0.7	16.0	0.7	3.7	4.3	0.7
Oilseeds	15.7	4.1	2.7	28.7	32.4	1.8	5.8	11.2
Wheat	28.5	0.0	0.3	39.2	6.6	6.8	0.1	1.5
Other crops	15.4	0.7	3.5	18.9	29.2	4.7	20.0	6.6
Livestock	7.3	0.2	1.5	2.4	2.9	1.2	2.4	1.7
Veg.oils fats	32.8	4.8	3.2	7.2	4.0	4.3	10.3	6.7
Meat&dairy	10.2	0.4	12.6	4.9	1.5	3.1	11.3	1.7
Oth pr. foods	12.6	0.7	10.3	5.2	10.9	6.2	15.7	4.1
Value of imports in % of total absorption value								
Cereal grains	7.2	18.3	5.5	0.9	14.8	5.0	7.2	10.3
Oilseeds	6.5	71.1	0.9	2.4	55.2	38.2	0.4	10.6
Wheat	11.9	17.1	10.4	3.4	51.4	3.7	15.5	17.7
Other crops	5.5	6.5	2.3	17.8	5.7	18.3	1.4	8.0
Livestock	0.9	5.4	1.5	2.1	1.6	2.3	0.4	2.4
Veg.oils fats	3.1	19.0	17.2	5.0	15.3	4.1	14.5	23.1
Meat&dairy	2.0	9.9	6.4	1.8	8.9	1.5	35.1	10.4
Oth pr.foods	4.6	4.2	3.5	4.6	5.9	3.6	15.8	10.3

Source: Multi-region GMO model database derived from GTAP version 4 data.

TABLE 2. **Composition of world trade, 1995**

	Cairns group	High-income Asia	Low-income Asia	United States	Rest of South America	Western Europe	Sub-Saharan Africa	Rest of World	Total
Value of exports in % of value of world trade									
Cereal grains	11.29	0.10	1.06	75.88	0.55	9.29	0.71	1.13	100
Oilseeds	26.48	0.48	6.89	49.83	4.18	2.43	2.52	7.20	100
Wheat	31.88	0.01	0.64	48.20	0.86	15.68	0.03	2.69	100
Other crops	28.05	1.83	8.78	16.29	15.01	7.47	12.44	10.13	100
Livestock	40.41	1.27	8.95	17.73	4.06	15.57	1.59	10.41	100
Veg.oils fats	55.86	2.16	3.50	11.37	1.30	18.22	1.67	5.91	100
Meat&dairy	34.65	1.05	4.68	24.33	1.01	29.84	0.45	3.98	100
Oth pr. foods	27.44	3.70	8.90	16.39	6.54	27.83	2.30	6.89	100
Value of imports in % of world trade									
Cereal grains	8.50	40.82	8.97	3.42	11.42	8.14	1.27	17.46	100
Oilseeds	9.65	29.88	2.20	2.85	9.54	38.99	0.19	6.71	100
Wheat	8.45	13.99	21.40	2.00	9.49	5.10	4.74	34.82	100
Other crops	9.48	17.94	5.88	15.43	2.20	35.47	0.75	12.86	100
Livestock	4.79	28.59	9.62	14.66	2.12	25.43	0.26	14.53	100
Veg.oils fats	4.10	10.50	25.26	7.81	5.69	17.04	2.71	26.90	100
Meat&dairy	6.74	32.60	2.36	8.75	6.51	14.10	2.40	26.53	100
Oth pr.foods	10.63	26.08	3.30	15.31	3.65	17.60	2.73	20.69	100

Source: Multi-region GMO model database derived from GTAP version 4 data.

TABLE 3. **Pattern of exports from Low-income Asia, 1995**

	Cairns	High-income Asia	Low-income Asia	USA	South America	Western Europe	Sub-Saharan Africa	Rest of World	Total
Cereal grains	19.5	33.1	0.0	0.0	0.0	7.6	1.7	38.1	100
Oilseeds	31.5	34.5	0.0	1.8	0.0	17.8	0.4	13.9	100
Wheat	13.3	2.7	0.0	0.0	0.0	1.3	24.0	58.7	100
Other crops	11.2	28.4	0.0	10.7	1.2	21.5	1.4	25.7	100
Livestock	4.8	53.2	0.0	6.9	0.1	30.7	0.0	4.2	100
Veg.oils fats	17.1	44.3	0.0	6.6	0.0	22.1	0.0	9.9	100
Meat&dairy	5.9	56.0	0.0	0.4	0.1	9.0	0.5	28.0	100
Oth pr. foods	13.8	46.9	0.0	7.6	0.3	11.6	3.6	16.0	100

TABLE 4. **Pattern of exports from South America, 1995**

	Cairns	High-income Asia	Low-income Asia	USA	South America	Western Europe	Sub-Saharan Africa	Rest of World	Total
Cereal grains	91.8	1.6	0.0	1.6	0.0	4.9	0.0	0.0	100
Oilseeds	49.6	10.6	0.0	13.1	0.0	25.2	0.5	1.0	100
Wheat	4.0	0.0	0.0	0.0	0.0	46.5	0.0	49.5	100
Other crops	7.3	5.7	2.9	44.3	0.0	33.4	0.1	6.4	100
Livestock	4.7	1.4	0.0	89.6	0.0	4.2	0.0	0.2	100
Veg.oils fats	43.1	1.1	0.6	26.0	0.0	24.3	0.0	5.0	100
Meat&dairy	17.1	19.1	0.3	37.4	0.0	23.3	0.3	2.5	100
Oth pr. foods	11.9	9.6	7.6	39.6	0.0	25.9	0.1	5.4	100

TABLE 5. **Pattern of exports from Sub-Saharan Africa, 1995**

	Cairns	High-income Asia	Low-income Asia	USA	South America	Western Europe	Sub-Saharan Africa	Rest of World	Total
Cereal grains	39.0	14.3	2.6	0.0	1.3	27.3	0.0	15.6	100
Oilseeds	8.2	29.1	0.0	4.5	0.0	31.1	0.0	27.0	100
Wheat	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
Other crops	7.7	4.0	5.9	5.5	0.2	68.0	0.0	8.7	100
Livestock	3.8	9.9	6.5	2.3	0.0	25.6	0.0	51.9	100
Veg.oils fats	3.4	0.4	0.0	0.4	0.0	92.7	0.0	3.0	100
Meat&dairy	8.9	0.6	0.6	0.6	0.0	76.4	0.0	12.7	100
Oth pr. foods	4.9	13.6	0.4	3.6	0.0	74.0	0.0	3.4	100

TABLE 6. **Selected trade results of base experiment, percentage changes**

	Low-income Asia	South America	Sub-Saharan Africa	High-income Asia	United States	Western Europe
Exports						
NG cereal grains	-8.0	-7.2	-4.1	-3.4	-2.4	-3.0
GM cereal grains	22.6	15.4	23.0	17.4	9.0	16.5
NG oilseeds	-9.1	-5.4	-3.0	-3.0	-2.1	-2.9
GM oilseeds	16.7	12.8	20.7	13.5	8.6	17.6
NG livestock	-0.4	-0.8	-0.3	-0.4	-0.4	-0.2
GM livestock	0.9	1.0	2.0	0.7	2.1	1.1
NG meat & dairy	-0.4	-0.5	-0.1	-0.3	-0.5	-0.2
GM meat & dairy	0.8	1.0	1.2	0.8	1.6	1.0
NG veg. oils & fats	-2.2	-1.4	-0.6	-1.9	-1.3	-1.0
GM veg. oils & fats	3.7	2.1	3.6	6.4	3.4	3.9
NG other proc. food	-0.4	-0.3	-0.1	-0.2	-0.3	-0.2
GM other proc. food	0.9	0.8	1.1	0.8	0.7	0.8
Imports						
NG cereal grains	-12.3	-8.7	-4.8	-0.2	-1.8	-0.3
GM cereal grains	19.7	14.4	32.8	1.7	2.7	0.8
NG oilseeds	-14.8	-8.4	-5.5	-3.0	-4.3	-1.7
GM oilseeds	16.4	9.0	27.4	10.7	5.1	9.2
NG livestock	-0.5	-0.6	-0.4	-0.2	-0.9	-0.1
GM livestock	0.9	1.6	2.6	1.2	0.8	1.1
NG meat & dairy	-0.4	-0.5	-0.2	-0.3	-0.9	-0.1
GM meat & dairy	0.5	1.2	1.1	1.0	1.3	0.9
NG veg. oils & fats	-2.6	-1.4	-0.8	-1.7	-1.3	-0.9
GM veg. oils & fats	3.6	2.4	4.7	4.7	1.9	3.9
NG other proc. food	-0.5	-0.3	-0.2	-0.2	-0.3	-0.1
GM other proc. food	0.7	0.7	1.1	0.8	0.6	0.8

TABLE 7. **Selected trade results of price sensitivity experiment, percentage changes**

	Low-income Asia	South America	Sub-Saharan Africa	High-income Asia	United States	Western Europe
Exports						
NG cereal grains	-7.9	-7.2	-4	-3.3	-2.2	-2.8
GM cereal grains	22.3	15.2	22.2	16.5	8.5	15
NG oilseeds	-8.2	-4.6	-2.3	-1.5	-0.7	-2.4
GM oilseeds	14.7	10.7	18.9	8.7	4.9	13.8
NG livestock	-0.3	-0.8	-0.3	-0.3	-0.3	-0.2
GM livestock	0.6	1	1.8	0.4	1.9	0.8
NG meat & dairy	-0.3	-0.4	-0.1	-0.2	-0.4	-0.1
GM meat & dairy	0.6	0.8	0.8	0.6	1.4	0.7
NG veg. oils & fats	-1.8	-1.4	-0.4	-1.2	-1	-0.7
GM veg. oils & fats	2.3	1.6	2.2	5.4	2.9	3
NG other proc. food	-0.3	-0.3	-0.1	-0.1	-0.2	-0.1
GM other proc. food	0.7	0.7	0.7	0.6	0.5	0.6
Imports						
NG cereal grains	-12.3	-8.7	-4.8	0.1	-1.8	0.1
GM cereal grains	19.7	14.5	32.8	0.3	2.8	-1.7
NG oilseeds	-14.8	-8.5	-5.5	-0.7	-4.7	-0.8
GM oilseeds	17.3	9.5	28.4	5.1	6.6	2.8
NG livestock	-0.5	-0.6	-0.4	-0.1	-0.9	0
GM livestock	1	1.6	2.6	0.9	0.8	0.5
NG meat & dairy	-0.4	-0.5	-0.1	-0.1	-0.8	0
GM meat & dairy	0.5	1.2	0.9	0.6	1.2	0.4
NG veg. oils & fats	-2.4	-1.3	-0.6	-0.4	-1.2	-0.5
GM veg. oils & fats	3.5	2.4	4.3	1.4	1.8	2.1
NG other proc. food	-0.4	-0.3	-0.2	-0.1	-0.3	-0.1
GM other proc. food	0.7	0.7	1	0.4	0.6	0.4

TABLE 8. **Selected trade results of structural shift experiment, percentage changes**

	Low-income Asia	South America	Sub-Saharan Africa	High-income Asia	United States	Western Europe
Exports						
NG cereal grains	-1.7	-5.4	0.8	4	8.1	3.8
GM cereal grains	4.1	7.9	-2	-42.5	-17.4	-30.7
NG oilseeds	1.6	4.3	5.1	12.9	14.5	2.2
GM oilseeds	-9.6	-12.1	-5.9	-45.8	-33.3	-33.7
NG livestock	10.6	1.4	3.4	10.6	10.5	8.1
GM livestock	-43	-5.3	-19.1	-36.6	-36.1	-40.2
NG meat & dairy	11.3	4.1	6.9	17.1	9.1	8.9
GM meat & dairy	-39.5	-23.6	-48.4	-39.3	-32.7	-38.4
NG veg. oils & fats	6.5	1.6	6.4	11.3	3.7	6.5
GM veg. oils & fats	-35.6	-14.8	-50.2	-29.7	-10.6	-29.2
NG other proc. food	7.5	3.6	6.9	11.1	5.4	8
GM other proc. food	-35.3	-19.8	-50.6	-39.6	-30.3	-37.4
Imports						
NG cereal grains	-12.6	-10	-4	18.9	-0.1	9.8
GM cereal grains	21.2	19.4	34.8	-70.7	0.7	-59.1
NG oilseeds	-14.1	-9.9	-4.2	23.5	-6	10.3
GM oilseeds	28.8	17.4	40.3	-56.8	22.7	-60.4
NG livestock	-0.1	-1.9	1.8	19.5	1.4	9.4
GM livestock	5.6	10.5	-1.7	-56	1.4	-58.3
NG meat & dairy	2.2	-0.8	6.2	23.3	1	8.6
GM meat & dairy	2.3	5	-28.7	-68.6	2.8	-62.8
NG veg. oils & fats	0.8	0.4	5.4	24.8	2.6	9.5
GM veg. oils & fats	1.5	2.3	-11.2	-72.4	-1.7	-59.5
NG other proc. food	3.4	0.9	3.9	15.4	2.6	8.5
GM other proc. food	-1	4.2	-10.5	-66.8	0.2	-60.2

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