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GMOs, Food Safety and the Environment: What Role for Trade Policy and the WTO?

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ABSTRACT

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Current debates about genetically modified organisms (GMOs) in agriculture reveal substantial differences in perception of the associated risks and benefits. Genetically modified crop varieties promise benefits to both farmers and consumers, and can lower damage to the natural environment, for example by reducing pesticide use. But some other environmental issues, together with food safety and ethical concerns with the production and use of GMOs, are being raised as potential negative aspects of GMOs. Hence the recent Biosafety Protocol with its endorsement of the use of the precautionary principle. However, if that Protocol were to encourage discriminatory trade barriers or import bans, or even just long delays in approving the use of imported GM seeds, it may be at odds with countries' obligations under the World Trade Organization. The first part of this paper provides a brief overview of the trade policy issues at stake here. The distributional consequences of adopting GMO technology in agriculture within and between countries, and of proposed trade-related policy responses, cannot be determined a priori. Hence the need for empirical modelling of the economic effects of GMO adoption. The second part of the paper illustrates how such policy or consumer responses can alter significantly the potential size of the global GMO dividend and its distribution. This is done using a well-received empirical model of the global economy (GTAP) to quantify the effects on production, prices, trade patterns and national economic welfare of certain countries' farmers adopting GM maize and soybean crops without and with trade policy or consumer responses in Western Europe (where opposition to GMOs is most vocal).

Keywords: biotechnology, globalization, trade in agriculture, GTAP modelling

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1. Introduction

The use of modern biotechnology to create genetically modified organisms (GMOs) through agricultural research has generated exuberance by those looking forward to a new 'green revolution'. But GMOs have also attracted strong criticism. The opposition is coming from groups concerned about the safety of consuming genetically modified foods, the environmental impact of growing genetically engineered plants, and the ethics related to using that technology *per se*. Scepticism toward genetic engineering has been particularly rife in Western Europe, which has stunted that region's contribution to the development and use of genetically engineered crop seeds. In contrast, farmers in North American and several large developing countries (notably Argentina and China) have actively developed and adopted GM crops, and citizens there have generally (perhaps unwittingly) accepted that development.

In Western Europe where food supplies are abundant and incomes are high, people can afford to be critical about the introduction of new agricultural biotechnologies and production processes about which they are unsure. In developing economies, by contrast, the benefit/cost ratio is very different. Many food-insecure people in developing countries live in rural areas, earn a significant share of their income from agriculture, and meet a substantial share of their food needs from their own production. For them, increasing agricultural productivity and thereby real income is a high priority. And for the urban poor in those countries, anything that lowers the effective price of basic foods and/or boosts the nutritional value of those foods is highly desirable. Given the large value shares of agriculture and textiles in production and food in consumption in developing economies, GMO technologies for such crops as rice and cotton have the potential to generate significant economy-wide benefits that may well dwarf any costs as perceived in those countries in terms of environmental and food safety risks. The same is true for GM maize and soybean from which, along with Bt cotton, rich-country adopters (most notably the United States) appear to be already benefiting, judging by the rapid rate of adoption.

Environmental, food safety and ethical concerns with the production and use of GM crops have been voiced so effectively as to lead to the recent negotiation of a Biosafety Protocol (UNEP 2000) with its endorsement of the use of the precautionary principle. However, if that Protocol were to encourage discriminatory trade barriers or import bans, or even just long delays in approving the use of imported GM seeds, it may be at odds with countries' obligations under the World Trade Organization. The first part of this paper provides a brief overview of the trade policy issues at stake here. It concludes that these issues have the potential to lead to complex and wasteful trade disputes. The extent to which that potential is realized depends on the economic stakes involved. They can only be determined by quantitative economic modelling, using – pending more reliable knowledge --

assumptions about the sizes of any shifts in the crop supply (or demand) curves. The second part of the paper illustrates one way in which this can be done. We use a well-received empirical model of the global economy (GTAP) to quantify the effects on production, prices, trade patterns and national economic welfare of certain countries' farmers adopting GM maize and soybean crops without and then with trade policy or consumer responses in Western Europe (where opposition to GMOs is most vocal). The results suggest such policy or consumer responses can alter significantly the potential size of the global GMO dividend and its distribution.

2. GMOs, agricultural trade policies, and the WTO

National policy reactions to GMOs

While traditional biotechnology improves the quality and yields of plants and animals through, for example, selective breeding, genetic engineering[1] is a new biotechnology that enables direct manipulation of genetic material (inserting, removing or altering genes). In this way the new technology accelerates 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, 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 very rapidly since the introduction of the first genetically modified plants in the 1980s. Transgenic crops currently occupy about 4% of the world's total agricultural area (compared with less than 0.5% as recently as 1996). Cultivation so far has been most widespread in the production of GM soybeans and maize, accounting for 54% and 28% of total transgenic crop production in 1999, respectively, with the United States accounting for almost three-quarters of the total GM crop area. Other major GM crop producers are Argentina, Canada, China, Mexico and South Africa, but India and several Eastern European countries also have a number of transgenic crops in the pipeline for commercialisation (James 1997, 1998, 1999; European Commission 2000).

Meanwhile, the resistance to GMO production and use in numerous countries, especially by well-organised activists in Western Europe, triggered the imposition in October 1998 of a *de facto* moratorium on the authorization of new releases of GMOs.[2] This could be a prelude to a future EU ban on the cultivation of GM crops and on imports of food containing GMOs (following the EU ban on imports of beef produced with the help of growth hormones). Before the imposition of the moratorium, releases of GMOs were reviewed on a case-by-case basis and had to be approved at

[1] 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 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 synonymously.
[2] Even stricter standards are mooted in the revised Directive 90/220, according to the August 2000 issue of *Agra Focus*.

every step from laboratory testing through field testing to final marketing. By contrast, the permit procedure is far simpler and faster in the United States.

There are also marked differences in national labelling requirements. The US Food and Drug Administration does not require labelling of GM foods *per se*, but only if the transgenic food is substantially different from its conventional counterpart. The EU, by contrast, requires labelling of all foodstuffs, additives and flavours containing 1% or more genetically modified material (Regulations 1139/98 and 49/2000). Individual countries within the EU have added further requirements (OECD 2000). In Denmark, for example, suppliers must label their products not only if GMO presence can be verifiable but also if there is a possibility that it could contain GMOs. Numerous non-European countries, including some developing countries, also have enacted GMO consumer legislation. Australia and New Zealand are to introduce mandatory labelling for all foods containing GMOs (ie, a zero threshold), following a poll showing more than 90% approved such a move. Brazil has introduced restrictive conditions on imports of GM products this year. And Sri Lanka has taken the extreme step of banning the imports of GMOs, pending further clarification as to their environmental and food safety impacts.

Needless to say, identity preservation systems to enable reliable labelling of food can be costly, and more so the more stages of processing or intermediate input use a crop product goes through before final consumption. A recent European survey suggests full traceability could add 6-17% to the farmgate cost of different crops.[3] Who bears those costs, and are the benefits sufficient to warrant them? Products containing GMOs that are not verifiably different from their GM-free counterparts are not going to attract a price premium, so their producers would not volunteer to label them as containing GMOs, given (a) the cost of identity preservation throughout the food chain and (b) the negative publicity about GMOs which is likely to lower the price of goods so labelled. Coercion would therefore be required. And for benefits that are difficult to perceive, since the label has virtually no information content because there are no known risks of consuming GMOs -- in contrast to, for example, the positive health warning on cigarette packets.

A non-regulatory alternative to positive labelling regulations is to encourage the voluntary use of negative labels such as ‘this product contains no GMOs’ (Runge and Jackson 1999). With perhaps the majority of processed foods now containing some GMOs, this market alternative would require labels on a much smaller and presumably declining proportion of products. And that subset, like organic food, could attract a price premium sufficient to cover the cost of identity preservation and labelling. That still requires the separation of GM-free products from GM-inclusive ones, however. Furthermore, it begs the question as to what is the threshold below which ‘this product contains no GMOs’ should apply. For the label to be meaningful abroad for exported GM-free products, multilateral agreement on that threshold would be needed.

[3] European Commission (2000). That cost estimate may be excessive, at least after the initial set-up costs of segmentation are sunk. After all, one of the consequences of the information revolution and globalization is that product differentiation and quality upgrading are increasing rapidly in all product areas including foods and drinks. Spring water, for example, now sells in many locations for more than soft drinks and even beer and non-premium wine. Many consumers are willing to pay extra for superior quality, allowing economies of scale to lower the premium required.

The Cartagena Protocol on Biosafety

Given the different attitudes and national approaches to regulation of genetically modified products, future trade disputes are a distinct possibility. With the objective of ensuring safe transboundary movement of living modified organisms resulting from modern biotechnology, the Cartagena Protocol on Biosafety (finalized in Montreal on 29 January 2000) may have added to that likelihood. The Biosafety Protocol, if ratified by the parliaments of 50 signatories, not only reconfirms the rights of signatory countries to set their own domestic regulations but also ostensibly allows each country to decide whether and under what conditions it will accept imports of GM products for release into the environment (for example, as planted seeds). This condoning of import restrictions appears also to apply to GMOs intended as food, feed or for processing.[4] This was sought not only by rich countries; some in developing countries also support it, fearing that their regions might be used as testing grounds for GM food production. Importantly, the Protocol stipulates that lack of scientific evidence regarding potential adverse effects of GMOs on biodiversity, taking into account also the risks to human health, need not prevent a signatory from taking action to restrict the import of such organisms in order to reduce perceived risks (UNEP 2000). In essence, this reflects an acceptance of the guiding influence of the precautionary principle, that is, “better safe than sorry”. [5] The Protocol requires that GMOs intended for intentional introduction into the environment or for contained use must be clearly identified as living modified organisms; but modified organisms intended for direct use as food or feed, or for further processing, just require a label stating that the product “may contain” such organisms. No labelling requirements for processed foods such as cooking oil or meal were established. Hence the Protocol does not address growing demands by hard critics of biotech who call for labelling of products if genetic engineering techniques have been used at any stage in their production process regardless of whether or not this can be verified in the final product through testing – but it goes well beyond the minimalist stance that the some GM-exporting countries might have preferred.

WTO agreements and GMOs

An important aspect of the Biosafety Protocol that is unclear and hence open to various interpretations concerns its relationship with the WTO agreements. The text states that the “Protocol shall not be interpreted as implying a change in the rights and obligations of a Party under any existing international agreements”, but at the same time the Protocol claims that this statement is “not intended to subordinate [the] Protocol to other international agreements” (UNEP 2000 p.1). Certainly the Protocol’s objective of protecting and ensuring sustainable use of biological diversity whilst also taking into account risks to human health is not inconsistent with WTO agreements. The WTO acknowledges the need of member states to apply and enforce trade-restricting measures in order to protect human, animal or plant health and life as well as public morals. That right for a country to set its own environmental and food safety regulations at the national level is provided for

[4] Details concerning the latter products are still to be decided, however, pending the findings of the FAO/WHO Codex Alimentarius Commission’s Ad Hoc Intergovernmental Task Force on Foods Derived from Biotechnology. The Task Force is due to report within four years of its creation in June 1999.

[5] The precautionary principle implies that considerations of human health and the environment rank higher than possible economic benefits in circumstances where there is uncertainty about the outcome. This principle is already used in certain international agreements concerning chemicals. See O’Riordan, Cameraon and Jordan (2000) for current perspectives on this issue in various OECD countries.

in Article XX of the GATT. But the key goal of the WTO is to achieve effective use of the world's resources by reducing barriers to international trade. For that reason WTO members also have agreed to not use unduly trade-restrictive measures to achieve environmental or food safety goals. More than that, such measures must be consistent with the key principles of the WTO: non-discrimination among member states, 'national treatment' of imports once having entered the domestic market, and transparent customs procedures. Whether the current WTO agreements prove to be in conflict with the rights to restrict trade in living modified organisms apparently provided for in the Biosafety Protocol only time – and possibly legal proceedings via the WTO's Dispute Settlement Body -- can tell.

Members of the WTO also have trade obligations under other WTO agreements that restrict the extent to which trade measures can be used against GMOs. More specifically related to food safety and animal and plant health are the Agreement on Sanitary and Phytosanitary Measures (SPS) and the Agreement on Technical Barriers to Trade (TBT). These agreements allow member states to impose certain restrictions on trade if the purpose of the measure is to protect human, animal or plant life and health. The TBT agreement also covers technical measures aimed at protecting the environment and other objectives. At the same time the agreements aim at ensuring that applied measures and technical regulations are no more trade-restrictive than necessary to fulfil the stated objectives (WTO 1995 and 1998a,b).

Both the SPS and TBT agreements encourage the use of international standards, guidelines and recommendations where they exist, such as in the realms of the Codex Alimentarius (the FAO's international food standards body). Currently there are no international standards for genetically modified products,[6] although the Biosafety Protocol explicitly notes that signatories "shall consider the need for and modalities of developing standards with regard to the identification, handling, packaging and transport practices, in consultation with other relevant international bodies." (UNEP 2000 p. 10, Article 18.3.) International harmonization of regulatory approval procedures for genetically modified products is currently under discussion in several forums including the FAO and OECD. The establishment of international standards for the production, regulation and labelling of these products may be helpful as a way of reducing future trade disputes among developed countries – but could impose onerous compliance costs on poorer GM-exporting countries.

Under the SPS agreement a country may apply higher than international standards *only* if these can be justified by appropriate scientific risk assessments. In other words, while the SPS agreement explicitly allows member states to set their own standards for food safety and animal and plant health, it requires that measures be based on scientific risk assessments in a consistent way across commodities. The TBT agreement is more flexible because member states can decide that international standards are inappropriate for a number of other reasons, such as national security interests (GATT Article XXI). Hence determining which WTO agreement a given trade measure is covered by is of key importance. The SPS agreement covers food safety measures and animal and plant health standards regardless of whether or not these are technical requirements. The TBT agreement, on the other hand, covers all technical regulations, voluntary standards and compliance procedures, except when these are sanitary and phytosanitary measures as defined in the SPS agreement (WTO 1998a).

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[6] However, the Codex Committee on Food Labelling is currently considering the adoption of an international standard on GMO labelling.

The SPS agreement's scientific requirement is important because it is more objective than the TBT agreement's criteria for determining what is a justifiable trade restriction and what is hidden protectionism. On the other hand, the SPS agreement may be inadequate for legally justifying restrictions introduced on the basis of some vocal groups' opposition to GM foods. Official disputes about trade in genetically modified products have not yet materialized, but experience from earlier WTO dispute settlement cases that are comparable to the GMO debate give an indication as to how the existing rules may be applied. The SPS agreement was used in the beef hormone dispute between the US and the EU, for example (WTO 1998c). In short, the EU import ban on meat and meat products from hormone-fed livestock was found to be in conflict with the EU's WTO obligations, the main argument being that the EU could not present documented scientific risk assessment of the alleged health risk to justify the ban.

Scientific evidence is not always sufficient for governments to make policy decisions, or it may simply be unavailable. In such cases, Article 5.7 of the SPS agreement allows WTO member states to take precautionary measures based on available pertinent information. At the same time, members are obliged to seek additional information so that a more objective evaluation of the risks related to the relevant product or process can be made within a reasonable period of time. The precautionary principle is an understandable approach to uncertainties about genetically modified products, but there is a risk that when used in connection with internationally traded products, it can be captured by import-competing groups seeking protection against any new technology-driven competition from abroad. It may thus be extremely difficult to assess whether a measure is there for precautionary reasons or simply as a form of hidden protectionism. For this reason, attention will focus on how the provisions of the Biosafety Protocol – the most explicit acceptance of the use of the precautionary principle in an international trade agreement relating to food products to date – are interpreted given current WTO commitments.

The existing trade agreements deal with regulations and standards concerning not just products but also production processes and methods *if but only if they affect the characteristics or safety of the product itself*: standards for production processes that do *not* affect the final product are not covered by the existing agreements. In relation to genetically engineered products, if the process itself were to alter the final product in such a way that there are adverse environmental or health effects associated with consumption, use or disposal of the product, restricting trade in this product need not violate existing WTO rules, ceteris paribus. However, if genetic engineering only concerns the production process and not the final characteristics of a transgenic product, domestic regulations that restrict the use of this method of production cannot be used to restrict imports of products produced by this method simply because the importing country finds it unacceptable by its own environmental, ethical or other norms.[7]

This discussion leads back to the role of scientific evidence. Some would argue that genetically modified products are different from conventional products *regardless* of whether or not this can be verified scientifically in the final product. One of the priorities of the European Commission in the next WTO round of multilateral trade negotiations is to obtain a clarification of the role of non-product-related processes and production methods within the WTO (European Commission 1999). If

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[7] This product/process distinction came to a head at the WTO in the famous tuna-dolphin case in the early 1990s. The general issue continues to be hotly debated. See, for example, the recent paper by Howse and Regan (2000).

trade restrictions based on production methods are allowed, this could lead to the inclusion of a long list of non-tariff barriers, and not only in relation to biotechnology products.

Labelling of foods in relation to international trade is normally covered by the TBT agreement unless the label relates directly to food safety, in which case it is covered by the SPS agreement. Only labelling programs that concern production processes affecting the final product would be covered by the existing TBT agreement. Determining whether or not a genetic modification affects the final product will probably have to be done on a case-by-case basis. Where labelling programs are not encompassed by the TBT agreement, which potentially may be the case for many transgenic products, the other agreements of the WTO will be applicable without exceptions (Tietje 1997). GATT Article III concerning non-discrimination, for example, stipulates that member states may not discriminate between otherwise like goods on the basis of their country of origin. A key issue using this Article will be the interpretation of the concept of 'like goods' and whether the presence of genetically modified material is 'sufficient' to differentiate products. Article III seeks to avoid measures that are based on a false differentiation of products.

In short, the emergence of GMOs in agricultural and food production introduces several new and contentious issues to be dealt with by the WTO membership and ultimately its Dispute Settlement Body (DSB). The DSB has not yet been able to resolve the dispute over the EU's ban on imports of beef produced with growth hormones (WTO 1998c), so it is difficult to see how it will be able to do any better with the far more complex issue of GM products should the EU choose to ban their importation too – particularly now that there is a Biosafety Protocol on the table condoning the use of the precautionary principle and suggesting scientific evidence need not prevent importing countries from restricting GM trade.

To get a sense of the risk of trade disputes erupting over GMOs, it is necessary to assess the economic stakes involved. That is, how large are the potential gains from GMO crop technologies, to what extent will various countries benefit (or lose) from their adoption, and how would trade policy responses or adverse consumer reactions affect those projected outcomes? It is to these questions that we now turn.

3. An empirical illustration

Theory alone is incapable of determining even the likely direction, let alone the magnitude, of some of the effects of subsets of farmers adopting GM-inclusive seeds. Hence an empirical modelling approach is called for. To illustrate their usefulness in informing GMO debates, this section summarizes one recent quantitative effort by the authors. It makes use of a well-received empirical model of the global economy (the GTAP model) to examine what the effects of some (non-European) countries adopting the new GMO technology might be (Nielsen and Anderson 2000b). Specifically, the effects of an assumed degree of GM-induced productivity growth in selected countries are explored for maize and soybean.[8] Those results are compared with what they would be

[8] These two crops are perhaps the most controversial because they are grown extensively in rich countries and are consumed by people there both directly and via animal products. Much less controversial are cotton (because it is not a food) and rice (because it is mostly consumed in developing countries). For a parallel quantitative assessment of the latter two products, see Nielsen and Anderson (2000c).

if (a) Western Europe chose to ban consumption and hence imports of those products from countries adopting GM technology or (b) some Western European consumers responded by boycotting imported GM foods.

Being a general equilibrium model, GTAP (Global Trade Analysis Project) describes both the vertical and horizontal linkages between all product markets both within the model's individual countries and regions as well as between countries and regions via their bilateral trade flows. The database used for these applications reflects the global economic structures and trade flows of 1995, and has been aggregated to 16 regions to highlight the main participants in the GMO debate and other key interest groups, and 17 sectors with focus placed on the primary agricultural sectors affected by the GMO debate and their related processing industries.[9]

The scenarios analysed here assume that GM-driven productivity growth occurs only in the following GTAP sectors and for a subset of countries: coarse grain other than wheat and rice (primarily maize in the countries considered) and oilseeds (primarily soybean in the countries considered). Detailed empirical information about the impact of GMO technology in terms of reduced chemical use, higher yields and other agronomic improvements is at this stage quite limited (see e.g. OECD (1999) and Nelson et al. (1999)). Available empirical evidence (e.g. USDA 1999 and James 1997, 1998) does, however, suggest that cultivating GM crops has general cost-reducing effects.[10] The following scenarios therefore are based on a simplifying assumption that the effect of adopting GM crops can be captured by a Hicks-neutral technology shift, i.e. a uniform reduction in all primary factors and intermediate inputs to obtain the same level of production. For present purposes the GM-adopting sectors are assumed to experience a one-off increase in total factor productivity of 5%, thus lowering the supply price of the GM crop to that extent.[11] Assuming sufficiently elastic demand conditions, the cost-reducing technology will lead to increased production and higher returns to the factors of production employed in the GM-adopting sector. Labour, capital and land consequently will be drawn into the affected sector. As suppliers of inputs and buyers of agricultural products, other sectors will also be affected by the use of genetic engineering in GM-potential sectors through vertical linkages. Input suppliers will initially experience lower demand because the production process in the GM sector has become more efficient. To the extent that the production of GM crops increases, however, the demand for inputs

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9 The GTAP (Global Trade Analysis Project) model is a multi-regional, static, applied general equilibrium model based on neo-classical microeconomic theory with international trade described by an Armington (1969) specification (which means that products are differentiated by country of origin). See Hertel (1997) for comprehensive model documentation and McDougall et al. (1998) for the latest GTAP database.

10 Nelson et al. (1999), for example, suggest that glyphosate-resistant soybeans may generate a total production cost reduction of 5%, and their scenarios have *Bt* corn increasing yields by between 1.8% and 8.1%.

11 Due to the absence of sufficiently detailed empirical data on the agronomic and hence economic impact of cultivating GM crops, the 5% productivity shock applied here represents an average shock (over all specified commodities and regions). Changing this shock (e.g. doubling it to 10%) generates near-linear changes (i.e. roughly a doubling) in the effects on prices and quantities. This lowering of the supply price of GM crops is net of the technology fee paid to the seed supplier (which is assumed to be a payment for past sunk costs of research) and of any mandatory ‘may contain GMOs’ labeling and identity preservation costs. The latter are ignored in the CGE analysis to follow, but further research might explicitly include them and, to fine-tune the welfare calculations, even keep track of which country is the home of the (typically multinational) firm receiving the technology fee. The mergers and acquisitions among life science firms in recent years, induced in part by reforms to intellectual property rights (Maskus 2000; Santaniello et al. 2000), has concentrated ownership of biotechnology patents in the hands of a small number of US and EU conglomerates (Falcon 2000).

by producers of those crops may actually rise despite the input-reducing technology. Demanders of primary agricultural products such as grains and soybean meal for livestock feed will benefit from lower input prices, which in turn will affect the market competitiveness of livestock products.

The widespread adoption of GM varieties in certain regions will affect international trade flows depending on how traded the crop in question is and whether or not this trade is restricted specifically because of the GMOs involved. To the extent that trade is not further restricted and not currently subject to binding quantitative restrictions, world market prices for these products will have a tendency to decline and thus benefit regions that are net importers of these products. For exporters, the lower price may or may not boost their trade volume, depending on price elasticities in foreign markets. Welfare in the exporting countries would go down for non-adopters but could also go down for some adopters if the adverse terms of trade change were to be sufficiently strong. Hence the need for empirical analysis.

In order to appreciate the relative importance of these primary agricultural sectors and their related processing sectors to the economies of different regions, note that coarse grains (particularly maize) and oilseeds (particularly soybean) are of equal or greater importance to North American and Western European agriculture as they are to the farm sectors of most developing country regions. Also important to understand are the various regions' net trading situations in raw and processed forms, and the export dependence of these products. (Details are provided in Anderson, Nielsen and Robinson (2000, Tables 2-4).)

Scenario 1: Selected regions adopt GM maize and soybean

Three maize/soybean scenarios are considered. The first of them (scenario 1) is a base case with no policy or consumer reactions to GMOs. GM-driven productivity growth of 5% is applied to North America, Mexico, the Southern Cone region of Latin America, India, China, Rest of East Asia (excluding Japan and the East Asian NICs), and South Africa. The countries of Western Europe, Japan, Other Sub-Saharan Africa and elsewhere are assumed to refrain from using or be unable at this stage to adopt GM crops in their production systems. The other two scenarios impose on this base case a policy or consumer response in Western Europe. In scenario 2, Western Europe not only refrains from using GM crops in its own domestic production systems, but the region is also assumed to reject imports of maize and soybean products from GM-adopting regions. Scenario 3 considers the case in which consumers express their preferences through market mechanisms rather than through government regulation.

Table 1 reports the results for scenario 1. A 5% reduction in overall production costs in these sectors leads to increases in coarse grain production of between 0.4% and 2.1%, and increases in oilseed production of between 1.1% and 4.6%, in the GM-adopting regions. The production responses are generally larger for oilseeds as compared with coarse grain. This is because a larger share of oilseed production as compared with coarse grain production is destined for export markets in all the reported regions, and hence oilseed production is not limited to the same extent by domestic demand, which is less price-elastic. Increased oilseed production leads to lower market prices and hence cheaper costs of production in the vegetable oils and fats sectors, expanding output there. This expansion is particularly marked in the Southern Cone region of South America where no less than one-fourth of this production is sold on foreign markets. In North America maize and soybean meal are used as livestock feed, and hence the lower feed prices lead to an expansion of the livestock and meat processing sectors there.

Due to the very large world market shares of oilseeds from North and South America and coarse grain from North America, the increased supply from these regions causes world prices for coarse grain and oilseeds to decline by 4.0% and 4.5%, respectively. As a consequence of the more intense competition from abroad, production of coarse grain and oilseeds declines in the non-adopting regions. This is particularly so in Western Europe, a major net importer of oilseeds, of which about half comes from North America. Coarse grain imports into Western Europe increase only slightly (0.1%), but the increased competition and lower price are enough to entail a 4.5% decline in Western European production. In the developing countries too, production of coarse grain and oilseeds is reduced slightly. The changes in India, however, are relatively small compared with e.g. China and the Southern Cone region. This is explained by the domestic market orientation of these sales. That means India's relatively small production increase causes rather substantial declines in domestic prices for these products, which in turn benefits the other agricultural sectors. For example, 67% of intermediate demand for coarse grain and 37% of intermediate demand for oilseeds in India stems from the livestock sector, according to the GTAP database.

Global economic welfare (as traditionally measured in terms of equivalent variations of income, ignoring any externalities) is boosted in this first scenario by US$9.9 billion per year, two-thirds of which is enjoyed by the adopting regions (Table 1b). It is noteworthy that all regions (both adopting and non-adopting) gain in terms of economic welfare, except Sub-Saharan Africa which loses slightly because a small change in the terms of trade. Most of this gain stems directly from the technology boost. The net-exporting GM-adopters experience worsened terms of trade due to increased competition on world markets, but this adverse welfare effect is outweighed by the positive effect of the technological boost. Western Europe gains from the productivity increase in the other regions only in part because of cheaper imports; mostly it gains because increased competition from abroad shifts domestic resources out of relatively highly assisted segments of EU agriculture. The group of other high-income countries, among which are East Asian nations that are relatively large net importers of the GM-potential crops, benefits equally from lower import prices and a more efficient use of resources in domestic farm production.

Scenario 2: Selected regions adopt GM maize and soybean plus Western Europe bans imports of those products from GM-adopting regions

In this scenario, Western Europe not only refrains from using GM crops in its own domestic production systems, but the region is also assumed to reject imports of genetically modified oilseeds and coarse grain from GM-adopting regions. This assumes that the labelling enables Western European importers to identify such shipments and that all oilseed and coarse grain exports from GM-adopting regions will be labelled "may contain GMOs". Under those conditions the distinction between GM-inclusive and GM-free products is simplified to one that relates directly to the country of origin, and labelling costs are ignored. This import ban scenario reflects the most extreme application of the precautionary principle within the framework of the Biosafety Protocol.

A Western European ban on the imports of genetically modified coarse grain and oilseeds changes the situation in scenario 1 rather dramatically, especially for the oilseed sector in North America which has been highly dependent on the EU market. The result of the European ban is not only a decline in total North American oilseed exports by almost 30%, but also a production decline of 10%, pulling resources such as land out of this sector (Table 2). For coarse grain, by contrast, only 18% of North American production is exported and just 8% of those exports are destined for Western Europe. Therefore the ban does not affect North American production and exports of maize to the same extent as for soybean, although the downward pressure on the international price of maize nonetheless dampens significantly the production-enhancing effect of the technological boost. Similar effects are evident in the other GM adopting regions, except again for India.

For Sub-Saharan Africa, which by assumption is unable to adopt the new GM technology, access to the Western European markets when other competitors are excluded expands. Oilseed exports from this region rise dramatically, by enough to increase domestic production by 4%. Western Europe increases its own production of oilseeds, however, so the aggregate increase in oilseed imports amounts to less than 1%. Its production of coarse grain also increases, but not by as much because of an initial high degree of self-sufficiency. Europe's shift from imported oilseeds and coarse grain to domestically produced products has implications further downstream. Given an imperfect degree of substitution in production between domestic and imported intermediate inputs, the higher prices of domestically produced maize and soybean mean that livestock feed is slightly more expensive. (Half of intermediate demand for coarse grain in Western Europe stems from the livestock sector.) Inputs to other food processing industries, particularly the vegetable oils and fats sector, also are more expensive. As a consequence, production in these downstream sectors decline and competing imports increase.

Aggregate welfare implications of this scenario are substantially different from those of scenario 1. Western Europe now experiences a decline in aggregate economic welfare of US$4.3 billion per year instead of a boost of $2 billion (compare Tables 4b and 3b). Taking a closer look at the decomposition of the welfare changes reveals that adverse allocative efficiency effects explain the decline. Most significantly, EU resources are forced into producing oilseeds, of which a substantial amount was previously imported. Consumer welfare in Western Europe is reduced in this scenario because, given that those consumers are assumed to be indifferent between GM-inclusive and GM-free products, the import ban restricts them from benefiting from lower international prices. Bear in mind, though, that in this as in the previous scenarios it is assumed citizens are indifferent to GMOs. To the extent that some Western Europeans in fact value a ban on GM products in their domestic markets, that would more or less than offset the above loss in economic welfare.

The key exporters of the GM products, North America, Southern Cone and China, all show a smaller gain in welfare in this as compared with the scenario in which there is no European policy response. Net importers of maize and soybean (e.g. 'Other high-income' which is mostly East Asia), by contrast, are slightly better off in this than in scenario 1. Meanwhile, the countries in Sub-Saharan Africa are affected in a slight positive instead of slight negative way, gaining from better terms of trade. In particular, a higher price is obtained for their oilseed exports to Western European markets in this as compared with scenario 1.

Two-thirds of the global gain from the new GM technology as measured in scenario 1 would be eroded by an import ban imposed by Western Europe: it falls from $9.9 billion per year to just $3.4 billion, with almost the entire erosion in economic welfare borne in Western Europe (assuming as before that consumers are indifferent between GM-free and GM-inclusive foods). The rest is borne by the net-exporting adopters (mainly North America and the Southern Cone region). Since the non-adopting regions generally purchase most of their imported coarse grain and oilseeds from the North American region, they benefit even more than in scenario 1 from lower import prices: their welfare is estimated to be greater by almost one-fifth in the case of a Western European import ban as compared with no European reaction.

Scenario 3: Selected regions adopt GM maize and soybean plus some Western Europeans' preferences shift against GM maize and soybean

As an alternative to a policy response, this scenario analyses the impact of a partial shift in Western European preferences away from imported coarse grain and oilseeds and in favour of domestically produced crops.[12] The scenario is implemented as an exogenous 25% reduction in final consumer and intermediate demand for *all* imported oilseeds and coarse grain (that is, not only those which can be identified as coming from GM-adopting regions).[13] This can be interpreted as an illustration of incomplete information being provided about imported products (still assuming that GM crops are not cultivated in Western Europe), if a label only states that the product "may contain GMOs". Such a label does not resolve the information problem facing the most critical Western European consumers who want to be able to distinguish between GMO-inclusive and GMO-free products. Thus some European consumers and firms are assumed to choose to completely avoid products that are produced outside Western Europe. That import demand is shifted in favour of domestically produced goods. Western European producers and suppliers are assumed to be able to signal - at no additional cost – that their products are GM-free by e.g. labelling their products by country of origin. This is possible because it is assumed that no producers in Western Europe adopt GM crops (perhaps due to government regulation), and hence such a label would be perceived as a sufficient guarantee of the absence of GMOs.

As the results in Table 3 reveal, having consumers express their preferences through market mechanisms rather than through a government-implemented import ban has a much less damaging effect on production in the GM-adopting countries. In particular, instead of declines in oilseed production as in scenario 2 there are slight increases in this scenario, and production responses in coarse grain are slightly larger. Once again the changes are less marked for India and in part also for China, which are less affected by international market changes for these products. As expected, domestic oilseed production in Western Europe must increase somewhat to accommodate the shift in preferences, but not nearly to the same extent as in the previous scenario. Furthermore, there are in fact minor price reductions for agri-food products in Western Europe in part because (by assumption) the shift in preferences is only partial, and so some consumers and firms do benefit from lower import prices. In other words, in contrast to the previous scenario, a certain link between

[12] See the technical appendix of Nielsen and Anderson (2000a), which describes how the exogenous preference shift is introduced into the GTAP model, a method adopted from Nielsen (1999).
[13] The size of this preference shift is arbitrary, and is simply used to illustrate the possible direction of effects of this type of preference shift as compared with the import ban scenario.

EU prices and world prices is retained here because we are dealing with only a partial reduction in import demand. The output growth in Sub-Saharan Africa in scenario 2, by taking the opportunity of serving European consumers and firms while other suppliers were excluded, is replaced in this scenario by declines: Sub-Saharan Africa loses export share to the GM-adopting regions.

The numerical welfare results in this scenario are comparable with those of scenario 1 (the scenario without the import ban or the partial preference shift) for all regions except, of course, Western Europe. Furthermore, the estimated decline in economic welfare that Western Europe would experience if it banned maize and soybean imports is changed to a slight gain in this scenario. The dramatic worsening of resource allocative efficiency in the previous scenario is changed to a slight improvement in this one. This is because production in the lightly assisted oilseeds sector increases at the expense of production in all other (more heavily distorted) agri-food sectors in Western Europe.

The welfare gains for North America are more similar in this scenario than in the previous one to those of scenario 1. But even in scenario 2 its gains are large, suggesting considerable flexibility in both domestic and foreign markets to respond to policy and consumer preference changes, plus the dominance of the benefits of the new technology for adopting countries. Given that the preference shift in scenario 3 is based on the assumption that non-adopters outside Western Europe cannot guarantee that their exports to this region are GMO-free, Sub-Saharan Africa cannot benefit from the same kind of ‘preferential’ access the region obtained in the previous scenario, where coarse grain and oilseeds from just identifiable GMO-adopting regions were banned completely. Hence Sub-Saharan Africa slips back to a slight loss in this scenario due to a net worsening of its terms of trade and the absence of productivity gains from genetic engineering techniques. Globally, welfare in this case is only a little below that when there is no preference shift: a gain of $8.5 billion per year compared with $9.9 billion in scenario 1, with Western Europe clearly bearing the bulk of this difference.

4. Conclusions

Lessons

What have we learned? First, the potential economic welfare gains from adopting GMO technology in even just a subset of producing countries for these crops is non-trivial. In the case considered in the first scenario it amounts to around $10 billion per year for coarse grain and oilseeds (gross of the cost of the R&D that generated GM technology). Moreover, developing countries would receive a sizeable share of those gains, and more so the more of them that are capable of introducing the new GM technology. These gains, especially for developing countries, are sufficiently large that policy makers should not ignore them when considering policy responses to appease opponents of GMOs.

Second, the illustrative scenarios show that the most extreme use of trade provisions, such as an import ban on GM crops by Western Europe, would be very costly in terms of economic welfare for the region itself – a cost which governments in the region should weigh against the perceived benefits to voters of adopting the precautionary principle in that way. Imposing a ban prevents European consumers and intermediate demanders from gaining from lower import prices. It also means domestic production of corn and soybean would be forced to rise at the expense of other farm production, and hence overall resource allocative efficiency in the region would be worsened. In the case modelled the GM-adopting regions still enjoy welfare gains due to the dominating positive effect of the assumed productivity boost embodied in the GM crops, but those gains are reduced by the import ban as compared with the scenario in which GM crops are traded freely. To the extent that some developing and other countries do not adopt GM crops (by choice or otherwise) and they can verify this at the Western European borders, our results suggest it is possible they could gain slightly in gross terms from retaining access to the GMO-free markets when others are excluded. Whether they gain in net terms would depend on the cost of compliance with European regulations (a cost not included in the above analysis).[14]

Third, even if many consumers in Western Europe are concerned about GMOs, the results of the market-based partial preference shift experiment (scenario 3) suggest that letting consumers express that preference through the market reduces the welfare gains from the new technology much less for both Europe and the GM adopters than if (as in scenario 2) a GMO import ban is imposed in Europe. The results also suggest, however, that developing countries that do not gain access to GM technology may be slightly worse off in terms of economic welfare if they cannot guarantee that their exports entering the Western European markets are GMO-free. A complete segregation of GMO-inclusive and GMO-free markets, or a decision not to produce GM crops at all, may be ways in which these developing countries could reap benefits from selling ‘conventional’ products to GM-critical consumers in industrialised countries. Whether that is profitable would depend on the premium those consumers are willing to pay to avoid GMOs and thus the aggregate degree of substitutability between the GM-free and GM-inclusive variant of each product.[15]

And fourth, large though the estimated welfare gains from the adoption of GM technology are, they are dwarfed by the welfare gains that could result from liberalizing global markets for farm products and textiles and clothing (recently estimated at around $180 billion per year *even after* the Uruguay Round is fully implemented in 2005, almost one-third of which would accrue to developing countries – see Anderson et al. (2000)). Should opposition to GMOs lead to the erection of further barriers to farm trade, that would simply add to the welfare cost of restrictive trade policies. Western Europe may consider that cost small (the difference in their welfare as between Scenarios 2 and 3 is only $13 per capita per year), but four caveats need to be kept in mind: that estimate refers to only two of many products that the new biotechnology may impact; the next generation of GM foods may be quality enhanced as well; a ban on imports will dampen investment and so reduce future growth in GDP; and developing countries in particular would enjoy less technological spillovers as a result, and for the poor in those countries especially the welfare foregone would be a far higher percentage of their income than is the case in Europe.

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[14] For more on the impact of agricultural biotechnology on developing countries, see Persley and Lantin (2000) and, as it affects trade agreements, Zarrilli (2000).

[15] A first attempt to model such segregation of maize and soybean markets globally is reported in Anderson, Nielsen and Robinson (2000).

What role for trade policy and WTO?

We know from trade theory that trade policy measures are almost never first-best ways to achieve domestic objectives, and food safety is no exception (see Corden 1997). Voluntary verifiable labelling of products free of GMOs, together with credible identity preserved production and marketing (IPPM) systems, should be able to satisfy most people's food safety concerns. IPPMs for GM-free products need not be prohibitively expensive, as markets for organic food and for grains with other special quality attributes testify.

The above facts may well not prevent some countries from imposing import restrictions on GM products however, for at least three reasons. First, the Biosafety Protocol might be interpreted by them as absolving them of their WTO obligations not to raise import barriers. Second, if domestic production of GM crops is banned, farmers there would join with GMO protesters in calling for a raising of import barriers so as to keep out lower-cost 'unfair' competition. And third, the on-going lowering of import barriers, following the Uruguay Round Agreement on Agriculture and the information revolution's impact in reducing costs of trading internationally, pressure import-competing farmers to look for other ways of curtailing imports.[16]

Given these political economy forces, is there a way for WTO to accommodate them without having to alter WTO rules? Bagwell and Staiger (1999) address this question in a more-general setting and offer a suggestion. It is that when a country is confronted from greater import competition because of the adoption of a new domestic standard that is tougher than applies abroad, it should be allowed to raise its bound tariff by as much as is necessary to curtail that import surge. One can immediately think of problems with this suggestion, such as how to determine what imports would have been without that new standard, but options of this sort may nonetheless have to be contemplated if the alternative is to add to the EU beef hormone case a series of dispute settlement cases at the WTO that are even-more difficult to resolve.

[16] The emergence of the concept of agriculture's so-called 'multifunctionality', and the call for trade policy and the WTO to deal with environmental and labour standards issues, can be viewed in a similar light (Anderson 1998, 2000).

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Table 1. Scenario 1: Effects of selected regions[a] adopting GM maize and soybean

(a) Effects on production, domestic prices and trade (percentage changes)

	North America	Southern Cone	China	India	Western Europe	Sub-Saharan Africa
Production						
Coarse grain	2.1	1.6	1.0	0.4	-4.5	-2.3
Oilseeds	3.6	4.6	1.8	1.1	-11.2	-1.3
Livestock	0.8	-0.0	0.1	0.4	-0.2	-0.1
Meat & dairy	0.5	0.0	0.1	1.3	-0.1	-0.1
Veg. oils, fats	1.1	4.5	1.4	0.0	-0.9	-1.2
Other foods	0.2	0.1	0.4	1.5	-0.1	0.0
Market prices						
Coarse grain	-5.5	-5.5	-5.6	-6.7	-0.5	-0.4
Oilseeds	-5.5	-5.3	-5.6	-6.5	-1.2	-0.3
Livestock	-1.8	-0.3	-0.4	-1.4	-0.3	-0.3
Meat & dairy	-1.0	-0.2	-0.3	-1.0	-0.2	-0.2
Veg. oils, fats	-2.4	-3.1	-2.6	-1.0	-0.5	-0.2
Other foods	-0.3	-0.2	-0.5	-1.0	-0.1	-0.2
Exports[b]						
Coarse grain	8.5	13.3	16.8	37.3	-11.5	-20
Oilseeds	8.5	10.5	8.2	21.5	-20.5	-26.5
Livestock	8.9	-2.0	-3.3	9.4	-1.1	-1.5
Meat & dairy	4.8	-0.9	-0.9	5.8	-0.5	-0.2
Veg. oils, fats	5.8	14.3	5.6	-3.8	-4.9	-5.3
Other foods	0.2	0.1	1.6	7.6	-0.6	0.1
Imports[b]						
Coarse grain	-1.6	-4.6	-4.2	-20.5	0.1	11.3
Oilseeds	-2.6	-9.2	-1.6	-8.6	2.5	16.5
Livestock	-2.1	1.3	0.9	-5.2	0.2	0.5
Meat & dairy	-1.9	0.2	0.8	-1.7	-0.0	0.1
Veg. oils, fats	-3.7	-3.6	-1.7	3.1	1.3	3.4
Other foods	0	-0.1	-0.6	-3.1	0.1	-0.1

(b) Effects on regional economic welfare

	Equivalent Variation (EV)	Decomposition of welfare results, contribution of (US$ million):		
	US$ million pa	Allocative Efficiency Effects	Terms of Trade effects	Technical Change
North America	2,624	-137	-1,008	3,746
Southern Cone	826	120	-223	923
China	839	113	66	672
India	1,265	182	-9	1,094
Western Europe	2,010	1,755	253	0
Sub-Saharan Africa	-9	-2	-9	0
Other high-income[c]	1,186	554	641	0
Other developing and transition econs.	1,120	171	289	673
WORLD	9,859	2,756	0	7,108

[a] North America, Mexico, Southern Cone, China, Rest of East Asia, India, and South Africa. For space reasons, results for numerous regions are omitted from this table. [b] Includes intra-regional trade.

[c] Japan, newly industrialized Asia, Australia and New Zealand.

Source: Nielsen and Anderson's (2000b) GTAP model results.

Table 2. Scenario 2: Effects of selected regions[a] adopting GM maize and soybean *plus* Western Europe bans imports of those products from GM-adopting regions

(a) Effects on production, domestic prices and trade (percentage changes)

	North America	Southern Cone	China	India	Western Europe	Sub-Saharan Africa
Production						
Cereal grain	0.9	0.0	0.8	0.4	5.3	-2.2
Oilseeds	-10.2	-3.6	-0.8	0.8	66.4	4.4
Livestock	1.2	0.3	0.2	0.4	-0.8	0.0
Meat & dairy	0.8	0.3	0.2	1.4	-0.5	-0.0
Veg.oils,fats	2.4	8.1	1.6	0.1	-3.4	0.0
Other foods	0.3	0.4	0.5	1.6	-0.5	-0.1
Market prices						
Cereal grain	-6.2	-6.0	-5.6	-6.7	0.8	-0.0
Oilseeds	-7.4	-6.8	-6.0	-6.5	5.8	0.4
Livestock	-2.2	-0.7	-0.4	-1.4	0.5	0.1
Meat & dairy	-1.3	-0.4	-0.3	-1.0	0.3	0.1
Veg.oils,fats	-3.3	-4.0	-2.7	-1.0	2.0	0.0
Other foods	-0.4	-0.3	-0.5	-1.0	0.1	0.0
Exports[b]						
Cereal grain	0.3	-2.9	5.0	23.4	15.9	-13.1
Oilseeds	-28.8	-69.2	-18.4	-8.7	167.2	105.0
Livestock	13.7	4.0	-1.4	12.6	-3.8	-1.8
Meat & dairy	7.5	2.1	0.1	7.1	-1.4	0.3
Veg.oils,fats	14.4	26.2	7.0	1.3	-15.0	5.8
Other foods	1.5	1.9	2.0	8.0	-1.4	-0.6
Imports[b]						
Cereal grain	-1.9	-5.3	-2.8	-20	3.3	13.4
Oilseeds	-5.6	-21.9	3.0	-3.7	0.6	22.5
Livestock	-3.2	0.1	0.1	-5.9	0.9	0.5
Meat & dairy	-2.8	-0.5	0.8	-1.8	-0.2	-0.0
Veg.oils,fats	-7.7	-5.5	-1.7	4.0	5.5	2.4
Other foods	-0.6	-0.6	-0.8	-2.8	0.1	0.2

(b) Effects on regional economic welfare

	Equivalent Variation (EV) US$ million pa	Decomposition of welfare results (US$ million pa): Allocative Efficiency Effects	Terms of Trade effects	Technical Change
North America	2,299	27	-1,372	3,641
Southern Cone	663	71	-303	893
China	804	74	70	669
India	1,277	190	-3	1,092
Western Europe	-4,334	-4,601	257	0
Sub-Saharan Africa	42	5	38	0
Other high-income[c]	1,371	592	782	0
Other developing and transition econs.	1,296	101	531	672
WORLD	3,419	-3,541	0	6,966

[a] North America, Mexico, Southern Cone, China, Rest of East Asia, India, and South Africa. For space reasons, results for numerous regions in Table 1 are omitted from this table.
[b] Includes intra-regional trade.
[c] Japan, newly industrialized Asia, Australia and New Zealand.
Source: Nielsen and Anderson's (2000b) GTAP model results.

Table 3. Scenario 3: Effects of selected regions[a] adopting GM maize and soybean *plus* partial shift of Western European preferences away from imports of GM products

(a) Effects on production, domestic prices and trade (percentage changes)

	North America	Southern Cone	China	India	Western Europe	Sub-Saharan Africa
Production						
Coarse grain	1.8	1.3	1.0	0.4	-2.0	-2.6
Oilseeds	1.0	2.8	1.1	1	8.7	-1.6
Livestock	0.9	0.0	0.2	0.4	-0.4	-0.1
Meat & dairy	0.6	0.1	0.1	1.3	-0.2	-0.0
Veg. oils, fats	1.2	5.0	1.4	-0.0	-1.1	-1.2
Other foods	0.2	0.2	0.4	1.5	-0.2	0.1
Market prices						
Coarse grain	-5.7	-5.6	-5.6	-6.7	-0.2	-0.4
Oilseeds	-5.9	-5.6	-5.7	-6.5	0.1	-0.3
Livestock	-1.9	-0.4	-0.4	-1.4	-0.1	-0.3
Meat & dairy	-1.1	-0.2	-0.3	-1.0	-0.1	-0.2
Veg. oils, fats	-2.6	-3.3	-2.6	-1.0	-0.4	-0.2
Other foods	-0.3	-0.2	-0.5	-1.0	-0.1	-0.2
Exports[b]						
Coarse grain	6.6	9.7	13.9	34.1	-29.7	-24.1
Oilseeds	1.4	-4.5	2.1	14.1	-41.5	-32.4
Livestock	9.8	-0.9	-3.0	10.0	-1.8	-1.2
Meat & dairy	5.3	-0.4	-0.8	6.0	-0.7	0.1
Veg. oils, fats	6.7	15.8	5.5	-4.0	-5.8	-4.9
Other foods	0.4	0.4	1.7	7.6	-0.7	0.1
Imports[b]						
Coarse grain	-1.7	-4.8	-3.9	-20.4	-23.6	11.5
Oilseeds	-2.9	-9.6	-0.7	-7.4	-17.7	17.3
Livestock	-2.3	1.1	0.8	-5.3	0.4	0.2
Meat & dairy	-2.1	0.1	0.8	-1.7	-0.1	-0.0
Veg. oils, fats	-4.2	-3.8	-1.5	3.4	1.5	3.4
Other foods	-0.1	-0.2	-0.6	-3	0.1	-0.1

(b) Effects on regional economic welfare

	Equivalent Variation (EV)	Decomposition of welfare results, contribution of (US$ million):		
	US$ million pa	Allocative Efficiency Effects	Terms of Trade effects	Technical Change
North America	2,554	-100	-1,092	3,726
Southern Cone	785	109	-246	917
China	834	106	69	672
India	1,267	184	-9	1,093
Western Europe	715	393	319	0
Sub-Saharan Africa	-5	0	-7	0
Other high-income[c]	1,233	567	674	0
Other developing and transition econs.	1,120	168	293	673
WORLD	8,503	1,428	0	7,081

[a] North America, Mexico, Southern Cone, China, Rest of East Asia, India, and South Africa. For space reasons, results for numerous regions in Table 1 are omitted from this table. [b] Includes intra-regional trade.

[c] Japan, newly industrialized Asia, Australia and New Zealand. Source: Nielsen and Anderson's (2000b) GTAP model results.

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