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Global Market Effects of Alternative European Responses to GMOs

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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 allegedly provide farmers with various agronomic benefits, but serious environmental, health and ethical concerns also are being raised. A majority of people in numerous countries want at least to have labels on products that may contain GMOs, while the most extreme opponents (particularly in Western Europe) want to see GM products totally excluded from production and consumption in their country. This paper first discusses the ways in which the emergence of GMOs is generating policy reactions, which could lead to trade disputes between Western Europe and the United States. It then uses an empirical model of the global economy to quantify the effects on production, prices, trade patterns and national economic welfare of certain (non-European) countries adopting GM crops. Those results are compared with what they would be if Western Europe banned imports of those products from countries adopting GM technology. An alternative market-based approach also is considered, whereby a shift in consumer preferences in Europe is investigated.

Key words: GMOs, trade policy, import ban, consumer preferences, labelling

JEL codes: C68, D58, F13, O3, Q17, Q18

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1. Introduction

Current debates about the new agricultural biotechnologies that are generating genetically modified organisms (GMOs) reveal substantially different perceptions of the associated risks and benefits – not only among consumers, ethicists and policymakers but also among scientists. Growing genetically modified crop varieties provides farmers with certain agronomic benefits such as resistance to insect pests and herbicides used to control weeds. However, serious concerns are being voiced about the longer-term environmental impact of cultivating GM crops and the safety of foods containing genetically modified organisms. Scepticism toward genetic engineering has been particularly outspoken in Western Europe, and the development and use of genetically engineered products there has been stunted as a result. In contrast, farmers in North America and several large developing countries such as Argentina and China have adopted genetically modified crops as they have become available, and citizens there have generally accepted that on-going development.

The different responses to the introduction of GMOs in agrifood production around the world are reflected in very different national regulatory approaches. France and other European countries, for example, are inclined to adopt a highly precautionary approach given the scientific uncertainties associated with GM use. To this end, the European Union has imposed a *de facto* moratorium on the authorization of new releases of GMOs as of June 1999. Some may argue that the policies of the European Union are an overreaction to unwarranted perceptions of risk; others will confer that the current degree of uncertainty and the limited practical experience with this new technology does indeed call for a precautionary approach. In any case, the approach in Europe stands in sharp contrast to that of the United States, currently the largest GM crop producer in the world. US authorities do not distinguish between crops developed through conventional breeding techniques and those that have been genetically engineered. Hence both varieties are considered 'like' products and accordingly are subject to the same safety regulations. Given these large differences between the EU and US, future trade disputes concerning GM products are a distinct possibility. Countries that are generally positive about GM use, such as the United States, accuse the Europeans of using this issue as an excuse for replacing price-support policies, which are being phased down following the Uruguay Round agreements, with technical barriers to trade (Sykes 1999).
This paper starts by providing a brief overview of the current status of transgenic crops in agricultural production. An empirical model of the global economy (the GTAP model) is then used to analyse the possible effects on world production and trade patterns and on national economic welfare of selected (non-European) countries adopting genetically modified (GM) crops, first without and then with particular European policy and consumer responses. Such responses are shown to have non-trivial economic implications for both developed and developing country agricultural-exporters.

Specifically, the effects of an assumed degree of productivity growth in the corn (maize) and soybean sectors in selected countries are explored, and those results are then compared with what they would be if Western Europe chose to ban consumption and hence imports of those products from countries adopting GM technology. The effects of an alternative response, a market-based shift in consumer preferences, are then compared with this regulatory approach. The final section of the paper discusses the areas in which future research on the economics of GMOs and related national and international policy and consumer responses might focus.

2. GMOs in agriculture

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 rapidly since the introduction of the first genetically modified plants in the 1980s. In 1999 genetically modified crops occupied 40 million hectares of land – making up 3.4% of the world's total agricultural area[2] and representing a considerable expansion from less than 3 million hectares in 1996. Cultivation of transgenic crops has so far been most widespread in the production of soybeans and maize, accounting for 54% and 28% of total transgenic crop production in 1999, respectively (James 1997, 1999). 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 the total 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).

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[3]. To date genetic engineering in agriculture has mainly been used to modify crops so that they have improved agronomic traits such as tolerance of specific chemical herbicides and resistance to pests and diseases. 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. Nevertheless, crops with improved agronomic

[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] Calculations are based on the FAOSTAT statistical database accessible at www.fao.org.
[3] Private seed companies holding patents on their transgenic seeds are able to extract monopoly rents through price premiums or technology fees. In the 1990s they appeared set to exercise that right, although by the end of the decade some were saying that they would let farmers sow in subsequent years their own retained seed.

characteristics can provide protection against many of the biotic stresses caused by weeds, pests and diseases currently being experienced in developing countries. The development of more complex traits such as drought resistance is underway and also highly relevant for tropical crops that are often growing under harsh natural and weather conditions and on poor-quality soils. Furthermore, the development of foods with enhanced nutritional value – such as the recent development of 'Golden Rice' that is enhanced with Vitamin A and iron[4] – may be a low-cost way of dealing with widespread malnutrition problems. Thus modern biotechnology may well be able to ease food supply constraints and food insecurity problems in the developing world significantly, just as the dwarf cereal varieties did in the 1960s and 1970s. But the extent to which that potential is realised will depend in non-trivial ways on GMO preferences and policy developments in rich countries.

3. National GMO regulations and the WTO

Current national GMO regulations differ substantially in scope and stage of implementation, varying from very restrictive regulations in certain industrial countries to non-existent in many developing countries. The resistance of consumer and environmental groups in the European Union (EU) to genetically modified foods and to the use of GMOs in agricultural production has triggered the imposition of a *de facto* moratorium on the authorization of new releases of GMOs as of June 1999. This could be interpreted as a prelude to a future EU ban on the cultivation of genetically modified crops and on imports of foods containing GMOs. Before the imposition of the current moratorium, *all* deliberate releases of GMOs in the European Union were reviewed on a case-by-case basis and had to be approved at all steps from laboratory testing, to field testing and final marketing. By contrast, the permit procedure in the United States is more flexible. Permits for field-testing and release into the environment of transgenic crops must be obtained from the Animal and Plant Health Inspection Service (APHIS) of the USDA. But for transgenic crops with which APHIS has experience, a notification system enables a more rapid permitting procedure (Nelson et al. 1999).

Furthermore, the United States Food and Drug Administration (FDA) does not distinguish between foods produced from genetically modified crops and foods produced from crops developed by other technologies. Hence genetically engineered foods and food ingredients are 'just' required to meet the same safety standards as other food products (Food and Drug Administration 1995). This also means that GMO-inclusive foods need not be labelled to indicate they contain GMOs. The EU, by contrast, requires GMO labelling of all foodstuffs, additives and flavours containing 1% or more genetically engineered material (Regulations 1139/98 and 49/2000). This 1% tolerance level takes into account the fact that a certain degree of co-mingling is unavoidable with common handling and transportation systems in the agri-food process. GMO labelling in the EU is based on scientific evidence proving the presence of genetically engineered DNA or protein. This provides a loophole, however, because processed foods whose ingredients have been genetically modified, but where the food production process has eliminated the external DNA or protein, will not need to be labelled. In response hereto, retail companies in individual countries within the EU, such as Denmark, are taking their labelling requirements one step further by requiring suppliers to label their products not only if GMO presence can be verified scientifically, but also if there is a possibility that the

[4] See, for example, Nielsen and Anderson (2000b).

product *may* contain GMOs. Regulatory changes are also taking place in other countries. South Korea, Japan, Australia, Mexico, China and New Zealand, for example, have recently decided to enact labelling requirement laws for transgenic products. Operational field-testing regulations have been implemented in, for example, Argentina, Brazil, Mexico, Chile, Costa Rica, Cuba, India, the Philippines and Thailand (James 1998). Sri Lanka has taken a more drastic step by simply banning the imports of GMOs. pending further clarification as to their environmental and food safety impacts.

Given the difference in national approaches to regulation of genetically modified products, future trade disputes are a distinct possibility. An attempt to bridge the gap between the essentially very different principles underlying these regulatory systems is manifested in the agreement of the Cartagena Protocol on Biosafety, which was finalized in Montreal on 29 January 2000. With the objective of ensuring safe transboundary movement of living modified organisms resulting from modern biotechnology, and if ratified by the parliaments of 50 signatories, the Biosafety Protocol will allow governments to decide whether or not to accept GMO imports and under what conditions. The Protocol reconfirms the rights of governments to set their own domestic regulations. Most importantly, the Protocol stipulates that lack of scientific evidence regarding potential adverse effects of GMOs on biodiversity, taking also into account risks to human health, shall not prevent a signatory from taking action to restrict the import of such organisms in order to avoid or minimize risks (UNEP 2000). In essence, this reflects an acceptance of the guiding influence of the precautionary principle[5], i.e. "better safe than sorry". In terms of documentation, the Protocol requires that GMOs destined for intentional introduction into the environment or for contained use, are clearly identified as such. But for modified organisms intended for direct use as food or feed, or for further processing, the requirement is only a label stating that they "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. The finalization of the Biosafety Protocol is nevertheless an important step toward establishing international guidelines for ensuring that trade in agricultural and food products is safe for human and animal consumption as well as for the environment.

However, there is an important aspect of the Protocol, which seems open to interpretation and hence potential dispute. This is the unclear relationship between the Protocol and the WTO agreements. The Protocol has the objective of protecting and ensuring sustainable use of biological diversity whilst also taking into account risks to human health. Agreements within the World Trade Organization also acknowledge the rights of a country to protect its environment, ensure food safety and to inform consumers. But WTO members are also obliged to adhere to agreements that restrict the way trade-related measures are used to achieve these goals. Hence some of the current WTO agreements may prove to be in conflict with the rights to restrict trade in living modified organisms provided for in the Biosafety Protocol.

Most notably, while the WTO's Agreement on Sanitary and Phytosanitary measures (SPS)

[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 some international agreements concerning chemicals.

explicitly allows member states to set their own standards for food safety and animal and plant health, it also requires that measures be based on scientific risk assessments (WTO 1998a,b). In principle this provides for a more objective approach to determining what is a justified trade restriction and what is hidden protectionism. This requirements now stands in sharp contrast to the Biosafety Protocol in which it is explicitly stated that lack of scientific evidence need not prevent importing countries from taking action. The latter suggests that the Protocol allows a country to ban the use and importation of genetically modified organisms until they are scientifically proven safe. While this precautionary approach is understandable given the scientific uncertainties, there is a risk that when used in an international trade context, it could develop into protectionism against any new technology in e.g. agriculture. It would be extremely difficult to assess whether a measure is there for precautionary reasons or simply as a form of hidden protectionism.[6]

4. Estimating economic effects of GMO adoption and of policy and consumer reactions

The above institutional considerations and apparent differences in preferences and views on consumers' right to know are unlikely to disappear in the foreseeable future. The extent to which that could lead to trade disputes depends heavily on the directions and magnitudes of the production, trade and welfare consequences of different responses for different countries. Theory alone is incapable of determining even the likely direction, let alone the magnitude, of some of the effects of various policy or consumer responses to GMO adoption. Hence an empirical modelling approach is called for, to estimate the size of various assumed productivity and preference changes. What follows is an early attempt at doing that for maize and soybean.

Specifically, this section examines empirically the production, trade and welfare effects of GM crop adoption by selected regions, first without and then with specific policy and consumer responses in Western Europe. This is done using an applied analytical framework involving a global economy-wide model and database known as GTAP (Global Trade Analysis Project).[7] Being a general equilibrium model, GTAP 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 this application reflects the global economic structures and trade flows of 1995 (GTAP database Version 4 – see McDougall et al. 1998) 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. That includes not only maize and soybean for the present analysis but also rice and cotton, which are analysed in Nielsen and Anderson (2000b).

Currently it is primarily maize and soybean that are benefiting most from GM-technology. Hence the scenarios analysed here assume that GM-driven productivity growth occurs only in

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[6] See Nielsen and Anderson (2000a) for a more extensive discussion of the Biosafety Protocol and the current WTO agreements.

[7] ***The GTAP (Global Trade Analysis Project) model is a multi-regional, static, applied general equilibrium model based on neo-classical microeconomic theory. See Hertel (1997) for comprehensive documentation.***

the following GTAP sectors: cereal grains (excluding wheat and rice) and oilseeds. 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. The scenarios analysed here are therefore 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 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[8]. 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 by producers of those crops may actually rise despite the input-reducing technology. Demanders of primary agricultural products such as grains for livestock feed will benefit from lower 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 tariff quotas, 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.

Three scenarios are considered below: The first scenario is a base case with no policy or consumer reactions to GMOs, while the second and third scenarios impose on this base case a specific policy or consumer response. The base scenario examines the implications of widespread adoption of GM maize and soybeans in a number of current and potential biotech front-runner countries: North America, Mexico, the Southern Cone region of Latin America, India, China, East Asia's other lower-income countries, and South Africa. The countries of Western Europe and elsewhere are assumed to refrain completely from the use of GM crops in their production systems. For the EU this may be interpreted as an extension of the *de facto* moratorium that has been in place there since June 1999, awaiting the proposal of tighter laws on GMOs. Most notably among the developing countries, Sub-Saharan Africa is assumed to be unable to take advantage of the new technology. As mentioned above the technology change is assumed to imply a 5% productivity growth in the adopting sectors. Moreover, consumers are assumed not to be concerned about the introduction of GM crops in the agri-

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[8] 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 both 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.

food system, and hence genetically modified and conventional crops are produced side-by-side and traded in one co-mingled market. There are no restrictions on trade with genetically modified products.

In the second 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 cereal grains from GM-adopting regions. It is assumed that the labelling requirements of the Biosafety Protocol enable Western European importers to identify such shipments and that basically all oilseed and cereal grain exports from GM-adopting regions will be labelled "may contain GMOs". Hence the distinction between GM and GM-free products is simplified to one that relates directly to the country of origin[9]. Furthermore, given the formulation of the labelling requirement in the Biosafety Protocol ("may include GMOs") it may not be very costly for producers to place such a label on products sold to sensitive markets and hence such labelling costs are ignored. This import ban scenario reflects the most extreme application of the precautionary principle within the framework of the Biosafety Protocol.

In the event that this is found to be in conflict with WTO rules, a Western European import ban may be ruled out. The final scenario therefore considers the case in which consumers express their preferences through market mechanisms rather than through government regulation. The scenario analyses the impact of a partial shift in Western European preferences away from imported cereal grains and oilseeds and in favour of domestically produced crops[10]. This is implemented as an exogenous 25% reduction in final consumer and intermediate demand[11] for all imported oilseeds and cereal grains, i.e. not only those which can be identified as coming from GM adopting regions. This can be interpreted as an illustration of the incomplete information 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. In response, this demand is shifted in favour of domestically produced goods. Western European producers and suppliers are assumed to be able to signal - at no (significant) 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.

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[9] By distinguishing between GMO-inclusive and GMO-free products by country of origin, one concern may be that GM-adopting regions channel their exports to the country or region imposing the import ban (here Western Europe) through third countries that are indifferent as to the content of GMOs and that do not adopt GM technology in their own production systems. The possibility of such transshipments is abstracted from in this analysis.

[10] 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).

[11] 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.

Scenario 1: Selected non-European regions adopt GM cereal grains and oilseeds

Table 1 reports the results of the first experiment for selected regions, with Western Europe and Sub-Saharan Africa as non-adopters and the other reported regions (North America, Southern Cone, China and India) as adopters of GM cereal grains and oilseeds. A 5% reduction in overall production costs in these sectors leads to increases in cereal grains 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 cereal grains. This is because a larger share of oilseed production as compared with cereal grains 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, thereby allowing for a larger production response to the reduced costs of production in this sector. In North America cereal grains are also used as livestock feed, and hence the lower feed prices lead to an expansion of the livestock and meat processing sectors.

Due to the very large world market shares of oilseeds from North and South America and cereal grains from North America, the increased supply from these regions causes world prices for cereal grains and oilseeds to decline by 4.0% and 4.5%, respectively. As a consequence of the more intense competition from abroad, production of cereal grains and oilseeds declines in the non-adopting regions. This is particularly so in Western Europe, a major net importer of oilseeds, of which 47% initially comes from North America. Cereal 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 cereal grains 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. As a consequence, the relatively small production increase causes rather substantial declines in market prices for these products, which in turn benefits the other agricultural sectors through vertical linkages. For example, 67% of intermediate demand for cereal grains and 37% of intermediate demand for oilseeds in India stems from the livestock sector.

Global welfare (as traditionally measured in terms of equivalent variations of income) is boosted in this first scenario by US$9.9 billion per year, two-thirds of which is enjoyed by the adopting regions (Table 1(b)). It is noteworthy that all regions (both adopting and non-adopting) gain in terms of economic welfare except Sub-Saharan Africa. 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 the 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 production.

Scenario 2: Western Europe bans the imports of GM cereal grains and oilseeds

A Western European ban on the imports of genetically modified cereal grains and oilseeds would change the situation rather dramatically, especially for the oilseed sector in North America, which is initially 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 cereal grains, 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 cereal grains to the same extent as for oilseeds, although the downward pressure on the international price of maize nonetheless dampens the production-enhancing effect of the technological boost significantly. Similar effects are evident in the other GM adopting regions, except for India – once again because its production of these particular crops is largely unaffected by world market developments.

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 cereal grains also increases, but not as much because of an initial high degree of self-sufficiency. The shift from imported oilseeds and cereal grains 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 on domestically produced grains and oilseeds mean that livestock feed is slightly more expensive (half of intermediate demand for cereal grains in Western Europe stems from the livestock sector). Inputs to the 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 as compared with scenario 1 are substantially different. Western Europe now experiences a decline in aggregate welfare of US$4.3 billion per year instead of a boost of $2 billion (compare Tables 2(b) and 1(b)). Taking a closer look at the decomposition of the welfare changes reveals that adverse allocative efficiency effects explain the decline. Most significantly, 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 and GM-free crops, the import ban restricts them from benefiting from lower international prices.[12]

The key exporters of the GM products, North America, Southern Cone and China, allshow a

[12] Of course in so far as Western Europeans value a ban on GM products in their domestic markets, that would offset the welfare loss reported above.

smaller gain in welfare in this as compared with the scenario in which there is no EU response. Net importers of corn and soybean (e.g. 'Other high-income' which is mostly East Asia), by contrast, are slightly better off in this than the first scenario. 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 the first scenario.

Two-thirds of the global gains from the new GM technology as measured in scenario 1 are eroded by the import ban imposed by Western Europe: they fall from $9.9 billion per year to just $3.4 billion (assuming as before that consumers are indifferent between GM-free and GM-inclusive foods). Almost the entire erosion in economic welfare is borne in Western Europe, with the rest 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 cereal grains and oilseeds from the North American region, they benefit even more 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: Partial shift in Western European preferences against GM cereal grains and oilseeds

The final scenario assumes the import ban is removed but that some Western European consumers have a strong bias against genetically modified crops. Given the essentially incomplete information embodied in the "may contain GMOs" label, recall that preferences in this scenario are assumed to shift away from imported cereal grains and oilseeds in general, not only from declared GMO-producing regions. 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, and production responses in cereal grains 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 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 shares 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[13]. Furthermore, the estimated decline in economic welfare that

[13] Note that the measure of welfare used here is based on efficiency-price considerations. It does not explicitly capture the assumed fact that some consumers and firms in non-adopting Western Europe now prefer

Western Europe would experience if it banned cereal grain and oilseed imports is changed to a slight gain in this scenario (although recall that scenario 2 assumes consumers are indifferent to whether a food contains GMOs). 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, and production in all other (more heavily distorted) agri-food sectors Western Europe declines.

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 these policy and consumer preference changes, plus the dominance of the benefits of the new technology to adopting countries.Given that the preference shift in this third scenario 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 cereal grains and oilseeds from 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.

5. Conclusions

The empirical analysis performed here shows that the most extreme use of European trade provisions, namely an import ban on GM crops, would be very costly in terms of economic welfare for the Western European region itself – a cost which governments in the region need to weigh against the perceived benefits to voters of adopting the precautionary principle in this way. Imposing a ban hinders European consumers and intermediate demanders in gaining from lower import prices, domestic production of corn and soybean is forced to rise at the expense of other production, and hence overall allocative efficiency in the region is worsened. 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.

In so far as consumers in Western Europe are concerned about GMOs, the results of the market-based partial preference shift experiment suggest that letting consumers express that preference through the market reduces the welfare gains from the new technology much less than if a ban on GMOs 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

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domestically produced cereal grains and oilseeds.

European markets are GMO-free. For these countries, a complete segregation of GMO-inclusive and GMO-free markets may be a way in which they could reap benefits from selling 'conventional' products to GM-critical consumers in industrialised countries[14]. But to do so would require that the relative price premium on these products is sufficient to outweigh the productivity growth foregone plus the potentially significant costs of compliance.

It is clear from the brief discussion of the different national regulatory regimes and their compatibility with existing WTO agreements that GMOs have considerable potential to generate trade frictions in the years ahead. According to the above results, the estimated impacts on GM-adopting exporters may not seem huge. That finding is based, however, on the assumed flexibility of markets in the GTAP model, with most of the global welfare loss from an import ban being borne by the banning region. Lest that give rise to complacency, recall that this study focuses on a small number of countries adopting GM technology for just two products, and with defensive reactions by just one (albeit the largest and most likely) region. The potential of this technology and the associated gains through trade in the decades ahead are many times greater than the above estimates. Hence so too are the stakes in terms of potential trade disputes, should governments respond to GMO developments in ways that upset other WTO members.

[14] See Nielsen, Robinson and Thierfelder (2000) for an analysis of preference changes in Europe when GM and non-GM products are traded in segregated markets.

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Table 1. Scenario 1: Selected non-European regions adopt GM cereal grains & oilseeds
(a) production, price and trade effects, % changes

	North America	Southern Cone	China	India	Western Europe	Sub-Saharan Africa
Production						
Cereal grains	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						
Cereal grains	-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**						
Cereal grains	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**						
Cereal grains	-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

*Includes intra-regional trade.

(b)Selected economic welfare results

	Equivalent Variation (EV) US$ million pa	Decomposition of welfare results, contribution of (US$ million): 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	1,186	554	641	0
Other developing and transition econs.	1,120	171	289	673
WORLD	9,859	2,756	0	7,108

Source: Authors' GTAP model results.

Table 2. Scenario 2: Western Europe bans imports of GM products
(a) production, price and trade effects, % changes

	North America	Southern Cone	China	India	Western Europe	Sub-Saharan Africa
Production						
Cereal grains	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 grains	-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*						
Cereal grains	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*						
Cereal grains	-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

*Includes intra-regional trade.

(b) Selected economic welfare results

	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	1,371	592	782	0
Other developing and transition econs.	1,296	101	531	672
WORLD	3,419	-3,541	0	6,966

Source: Authors' GTAP model results.

Table 3. **Scenario 3: Partial shift of Western European preferences away from GMOs**
(a) production, price and trade effects, % changes

	North America	Southern Cone	China	India	Western Europe	Sub-Saharan Africa
Production						
Cereal grains	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						
Cereal grains	-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*						
Cereal grains	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*						
Cereal grains	-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

*Includes intra-regional trade.

Table 3. **Scenario 3: Partial shift of Western European preferences away from GMOs**

(b) Selected economic welfare results

	Equivalent Variation (EV) US$ million pa	Decomposition of welfare results, contribution of (US$ million): 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	1,233	567	674	0
Other developing and transition econs.	1,120	168	293	673
WORLD	8,503	1,428	0	7,081

Source: Authors' GTAP model results.

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