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What's behind GM food trade disputes?

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Abstract: Over the past decade, the United States (US) and the European Union (EU) have implemented widely divergent regulatory systems to govern the production and consumption of genetically modified (GM) agricultural crops. In the US, many GM varieties have been commercially produced and marketed, while in the EU few varieties have been approved: a *de facto* moratorium limited EU production, import and domestic sale of most GM crops from late 1998 to April 2004, and since then strict labelling regulations and a slow approval process are having a similar effect. The EU policies have substantially altered trade flows and led in September 2003 to the WTO establishing a WTO Dispute Settlement panel to test the legality of European policy towards imports of GM foods. This paper seeks to better understand the economic forces behind the different regulatory approaches of the US and the EU. It uses a model of the global economy (GTAP) to examine empirically how GM biotechnology adoption would affect the economic welfare of both adopting and non-adopting countries in the absence of alternative policy responses to this technology, and in their presence. These results go beyond earlier empirical studies to indicate effects on real incomes of farm households, and suggest the EU moratorium on GM imports helps EU farmers even though it requires them to forego the productivity boost they could receive from the new GM biotechnology.

New agricultural biotechnologies are being developed every day, including those that involve genetically modified organisms (GMOs). Relative to conventional crop varieties, GM crops promise substantial benefits for farmers (greater productivity, less occupational health and environmental damage from pesticides),

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and ultimately also for consumers (lower food prices, enhanced product attributes). Also, because genetic engineering involves more-controlled manipulation of genetic material, this technology can shave years off R&D programs compared with conventional plant breeding, potentially offering the world another 'green revolution'.

So far the adoption of GM technology has been widespread only in the production of maize, soybean, and canola, as well as in cotton. As of 2004, GM varieties accounted for 29 % of the area planted to those crops globally (and 5 % of all arable land), having been close to zero prior to 1996 (James, 2004). However, almost all GM food is grown in just three countries: Argentina, Canada, and the United States, where, because of production cost savings (>5 %) and few regulatory impediments, the GM shares of those crops average more than 60 % (James, 2004). In the European Union, by contrast, a *de facto* moratorium introduced in 1998 has ensured virtually no GM crop varieties have been approved for production or sale in its member countries, ostensibly in response to strong opposition by some consumer and other community groups concerned about their potentially adverse impacts on food safety (e.g., 'Will they cause cancer?') and the environment (e.g., 'Will they lead to pesticide-resistant superweeds?').

These facts raise several important questions. Leaving aside GM cotton (which has had immediate occupational health and environmental benefits in addition to cost savings for farmers, and raises no food safety concerns), why were these crops the first ones to be targeted by biotech firms? Why have those three American countries but virtually no others adopted this new technology so far? What are the implications for global food markets and economic welfare, including for the poor in developing countries? And what impacts will they have on the rules-based global trading system?

The answer to the first question may be that technologically those three crops were easiest to genetically modify and capture payment for the intellectual property involved, but a more likely or at least supplementary reason has to do with where those crops are grown and sold. The US alone accounts for 30–40 % of global production and consumption of maize and soybean, and in the past five years the US, Canada, and Argentina have enjoyed a combined share of global exports of 80 % for maize, 64 % for soybean (91 % if Brazil is included),[1] and 42 % for canola. By contrast, those countries account for less than one-sixth of global wheat production and less than one-twentieth of global rice production (Anderson and Jackson, 2005a: Tables 3 and 4.) That concentration meant regulatory approval for soybean and maize in just three countries could potentially offer biotech firms access to the lion's share of those products' markets, as well as

1 Between 10 % and 30 % of Brazil's soybean crop is estimated to be illegal GM varieties (USDA, 2003). At end-September 2003 the Brazilian President announced temporarily legalizing GM soybean production and in 2004 that reform was made permanent.

demonstrate to poorer countries that rich countries are willing to produce and consume GM food.

Given that first play in this game, the next two questions are: why have other countries not yet followed the American adoption of GM food, and how is that abstinence impacting on global welfare and in particular on the world's poor? A conventional (but contestable) answer to the first is that Europeans and others care more about the natural environment than do people in North or South America. An additional part of the conventional wisdom is that Europeans have less trust in their food safety regulators than do Americans. While not denying either of those possibilities, we seek further possible explanations by asking how the adoption of GM technology by the first three adopting countries is impacting on the economic interests of first the European Union – particularly EU farmers – and then, given the EU's moratorium stance, on other countries.

Again some facts are illuminating. The trade impact of the EU's 1998 moratorium was immediate and dramatic. The US share of EU maize imports fell from around two-thirds in the mid-1990s to virtually zero, as has Canada's share of EU canola imports (from just over one-half in the mid-1990s). The GM-adopting countries lost market share to GM-free suppliers, particularly Brazil for maize and soybean and Australia and Central Europe in the case of canola (Table 1). This strengthened fears that EU members or other food-importing countries would discount or deny market access to products of food-exporting countries if any GM crops are grown in or even imported into those exporting countries. An example is China (representing almost one-fifth of the world's food economy), whose initial reluctance to approve GM food production ostensibly was because it was denied access to the EU market in 1999 for soy sauce that may have been produced using GM soybeans from the US. This fear of losing EU market access was also the ostensible reason Zambia and Zimbabwe did not want to accept US humanitarian food aid in the form of GM maize in 2002–2003.

Uncertainty for food exporters increased further when the multilateral Biosafety Protocol came into effect on 11 September 2003. Already that Protocol has been called on by the European Union to justify its moratorium on the approval of GM imports.

In response to frustration over the way the EU precautionary measures have been applied (e.g., some EU member states maintain national marketing and import bans even on GM varieties that have been approved by the European Commission), the United States, Canada, and Argentina sought the establishment of a WTO Dispute Settlement Panel on 29 August 2003 to rule on the WTO consistency of the measures. (At the time of writing, March 2005, the case was still ongoing.) Subsequent GMO dispute cases are likely to focus on the scientific justification for not approving for sale the products of GM varieties grown abroad.[2]

2 Indeed such a case might have arisen following China's 2001 restriction on GM imports, had China not eased the application of that policy to soybeans the following year in response to strong US objections.

Table 1. Sources of the European Union's non-EU imports of maize, soybean and canola, by volume, 1995 to 2001 (%)

	1995–97	1999–2001	*Supplier's share of world (excl. intra-EU) exports, 1999–2001*
Maize			
United States	64	2	*65*
Argentina	18	72	*13*
Brazil	0	11	*3*
Hungary	17	9	*2*
Rest of world	1	6	*17*
TOTAL	100	100	*100*
Soybean			
United States	60	42	*54*
Argentina	9	4	*9*
Brazil	24	47	*27*
Rest of world	4	5	*10*
TOTAL	100	100	*100*
Soybean meal			
United States	6	2	*19*
Argentina	36	50	*40*
Brazil	56	46	*29*
Rest of world	2	1	*12*
TOTAL	100	100	*100*
Canola (rapeseed)			
Canada	54	0	*59*
Australia	0	22	*24*
Central Europe	39	70	*12*
Rest of world	7	8	*5*
TOTAL	100	100	*100*

Source: www.affa.gov.au/gmmarkets based on EU official trade data.

Since such non-tariff barriers to trade would undermine previously negotiated reductions in tariff protection, they are a direct challenge to the WTO's multilateral agricultural trade liberalization process. This suggests a great deal is at stake, and even some of the directions of the impacts on people's welfare in various countries, let alone their magnitude, cannot be determined without empirical analysis. For example, developing country farmers could lose if they are not given access to this new biotechnology, but would their export sales to the EU be boosted sufficiently by the reduced competition from GM-adopting countries to warrant choosing to remain GM-free for the moment?

Economic analysts have responded to these uncertainties by using simulation models of the global economy to provide empirical estimates of the effects of GM adoption by some countries and policy and consumer reactions in other countries (e.g., Nielsen and Anderson, 2001; Nielsen, Robinson, and Theirfelder, 2003; van Meijl and van Tongeren, 2004). This paper seeks to go beyond those initial studies by addressing firstly the political economy question of *why* countries are choosing such different (and apparently sub-optimal) GM policies, and secondly the question of how policy choices to date have impacted not just on national economies in aggregate but also on the poorest groups within developing countries, namely farmers and unskilled non-farm labourers.

Section 1 outlines a number of alternative or additional possible explanations for key GM policy choices to date. Some of those hypotheses can be subjected to empirical scrutiny using a simulation model of the global economy, which at the same time can provide empirical estimates of the distributional effects between and within countries of GM production, consumption, and import policies. We make use of Version 5.4 of the GTAP data and model of the global economy, modified as described in Section 2, to generate the results presented in Section 3 on the estimated economic effects of recent and alternative GM technology and policy choices. Section 4 then returns to the political economy question on potential drivers of the policy choices countries have made. The final two sections draw out implications of the findings for poverty alleviation in developing countries and for the global trading system.

1. Why such different GM policies?

Given the attributes described above of the new GM food technology, one might expect the optimal initial policy response would be to test for both the environmental effects of producing GM varieties and the safety of consuming them. If concerns remained about cross-pollination with native species, producers could be required to leave buffer zones between GM crops and nature belts; and, if no food safety issues were identified but some consumers still preferred to avoid GM food, the government could establish certification guidelines for voluntary labelling of non-GM varieties, for example.

To date there appears to be little evidence to justify the concerns reflected in the precautionary stance taken by all but three GM-adopting countries. On the consumer/food safety side, the worries have been that GM-derived food may be more toxic or carcinogenic, result in more allergies, or be nutritionally less adequate than GM-free food; and that transgenes might survive digestion and alter the genome of the person or animal consuming them. But a recent UK government report by eminent scientists that reviewed available evidence found no adverse effects anywhere in the world. So like previous similar reports it concluded that, on balance, 'the risks to human health are very low for GM crops currently on the market' (King, 2003: 23). Nor could the King committee find any theoretical reason or empirical evidence to suggest that GM crops would be any more invasive or persistent, or toxic to soil or wildlife outside the farmed environment than conventional crop varieties, or spread their genes to other plants.

Several reasons for the EU's strict policy stance have been suggested. One is simply that the government wishes to appease the anti-GM protesters, but they are noisy on both sides of the Atlantic so that is unlikely to be a major explanation for the policy difference. Another possible explanation is that the government is giving EU biotech firms time to catch up with American competitors so that intellectual property rights are paid to domestic rather than foreign patent holders. That hypothesis is difficult to test immediately, but could be examined if/when the EU and others do begin to approve GM varieties. A third possible explanation is that the farm lobby benefits from the stance taken by the government of each country/region even if the regional economy as a whole loses. That hypothesis is empirically testable in principle, although some practical considerations should be borne in mind. For example, if buffer zoning were to be required to reduce the risk that GM crops cross-pollinate with native grasses, such regulations would be more costly (and hence more discouraging of adoption) in closely settled, densely populated environments such as in Western Europe and Northeast Asia than in broad-acre settings such as North and South America and Australia. Also, if domestic GM production diminished the country's profits from non-GM food sales (for example through tarnishing its generic reputation as a supplier of safe food), farmers may consider the amortised cost of that outweighs the expected benefit from the new technology, bearing in mind any costs associated with co-existence requirements, and taking into account any price difference between GM- and non-GM varieties. Even where there is a net gain to farmers as a group, those within that group wishing to remain non-GM producers may lobby to keep it GM free so as to avoid new identity preservation and contamination-avoidance costs, higher land rents, and perhaps lower product prices because of erosion of generic reputation as a safe food supplier.

For many developing countries not needing to segregate crop varieties for domestic sales, the costs of identity preservation and contamination avoidance in order to export may be prohibitive, giving rise to what Baldwin (2001) described as a two-tier world under technical barriers of trade: if they wanted to continue exporting food to the EU, they had no choice but to ban GM food production while the EU moratorium was in effect. On the other hand, for wealthier countries willing and able to pay the premium required for a segregation/identity preservation system, labelling may be optimal. But, even they will find the EU's labelling regulations, which came into effect from 1 May 2004, draconian. The number of categories of products subject to testing in the EU is enormous, and the threshold levels of tolerance of accidental GMO contamination are very low. Moreover, feedstuffs also are now included in the EU's list and must be labelled, even though GM protein or DNA will not be present in the livestock products of feedlot operators using feed ingredients based on GM crops.

As a first step towards shedding light on this issue, it is helpful to be aware of the world market shares of the key players in grain and oilseed markets. In 1998–2002 the US shares in global production have been 40% for maize and 43% for soybean, and its shares in global exports (including intra-EU trade) are 66 and 51 %, respectively. By contrast the EU produced only 6 % of the world's maize and only 1 % of the soybean. The other big players in these two markets are China, Brazil, and Argentina. China accounts for roughly one-fifth of global production and consumption (and one-tenth of global exports) of maize, and for one-tenth, one-third, and one-fifth of global production, consumption, and imports of soybean, respectively. Brazil and Argentina are smaller players in the maize market (6 and 3 % of global production, respectively, although Argentina accounts for one-eighth of global maize exports), but they are both significant in the soybean market: together they account for 37 % of global production, 29 % of global consumption, and 38 % of exports. Canada together with the EU and China account for three-quarters of global canola production, and Australia another 5 %. The EU trades canola a lot among its members but is almost self-sufficient, so when intra-EU exports are excluded then Canada and Australia account for more than 80 % of residual world trade in canola. The three big exporters of GM maize, soybean, and canola also account for one-third of global beef exports and more than 40 % of global exports of pig and poultry meat. This contrasts with the other key cereals, wheat and rice, which are far less concentrated among the GM adopters. China and India add counterweight to wheat production and consumption; and China and India account for half of global rice production and consumption and, with Thailand and Vietnam, for two-thirds of global rice exports. Hence, there will be somewhat different distributional effects from the introduction of GM varieties for those products than for the feedgrain–oilseed–livestock complex, with much stronger consequences for developing country farmers and consumers. Because of maize import restrictions and considerable domestic production of feed barley, the EU accounted for less than 4 % of global imports of maize. Soybean imports have been less restricted, however (because of the EU's long-standing GATT binding of a zero tariff on soybean), as have canola imports. The EU accounts for more than one-third of global imports of both soybean and canola (Anderson and Jackson, 2005a: Tables 3 and 4).

US farmers clearly have a strong interest in a low degree of GMO regulation of production, so that they can exploit the new technology before it is disseminated beyond the US. They also have a strong interest in a low degree of GMO consumer regulation both at home and in their export markets, given that they supply more than half of global exports (including intra-EU trade). Over the past decade, feedgrains and oilseeds (mostly maize and soybean) accounted for 18 % of the gross value of agricultural output in the US, and the livestock sector that uses those products as inputs accounted for another 44 %.

The interests of EU farmers, on the other hand, are less clear-cut. While they could benefit directly from more-productive technologies, other things equal, the first-available GM food crops (maize and soybean) are of minor direct importance to them. Also, GM technology would be less profitable in the densely settled European landscape, where non-GM crops and nature areas are much closer and so there would need to be more buffer zoning per hectare of GM crop there than in broad-acre landscapes such as in the US. For many small farmers the potential productivity gains may be more than offset by the management costs of buffer zoning, so there would be a greater proportion of EU than US farmers wanting to continue to produce just non-GM crops. That proportion would be even higher the greater the opposition by environmental and consumer groups to the selling of GM foods in Europe (where most EU-produced crop output is sold, in contrast to the US where more than one-quarter is exported to other regions) – and even more so now that tough labelling laws and low unintentional GM tolerance levels have been legislated, since that requires producers to put a high-cost segregation and identity preservation system in place if and when GM varieties are approved in the EU.

Another important influence on EU farmer interests is the extent to which their crop products are internationally competitive. Given that North America and Argentina have already adopted GM technology, EU food producers – despite not adopting GM varieties – may be more competitive in their own and in third-country markets *vis-à-vis* the GM adopters if consumers in those markets are sufficiently GM averse, and more so the tougher are consumer policies towards GM foods. If those tough standards were to apply to feed ingredients as well (as is now the case in the EU), then EU livestock producers also could support anti-GM policies since they too are unlikely to benefit as much from the GM technology as the more maize-and-soybean-intensive North American livestock producers.

These possibilities will change over time of course, and, if consumer and environmental concerns subside in the years ahead, one can imagine a time when GM food technology becomes the norm everywhere, not just in parts of the Americas. But that time may still be a long way off. Brooks and Barfoot (2003), for example, expect less than 10 % of a few crops at most being under GM varieties in the EU by 2013.

Given the above, under what circumstances over the medium term might it be conceivable that EU farmers are better off by denying themselves access to GM technology, and how would current GM-adopting farmers and players in other countries fare in those various circumstances ? This question can only be addressed using an empirical model of the world's food markets, to which we turn after first describing that model and using it to estimate the production, trade, and aggregate national economic welfare effects of GM food technology adoption without and with government and consumer reactions.

2. The GTAP model modifications and scenarios

We use a well-received empirical model of the global economy (the GTAP model) to examine the effects of some countries adopting the new GMO technology without and then with government and consumer responses in other countries. 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 Version 5.4 database used for these applications draws on the global economic structures and trade flows of 1997, around the time of the take-off in adoption of GM crop varieties and just prior to the EU imposing its *de facto* moratorium. To make the results easier to digest, the GTAP model has been aggregated to depict the global economy as having 16 regions (to highlight the main participants in the GMO debate), and 14 sectors (with the focus on the primary agricultural sectors affected by the GMO debate and their related processing industries).[3]

The scenarios analysed here assume that GM-driven productivity growth has occurred only in a subset of countries and only for a few of the GTAP sectors. Specifically, coarse grain (primarily maize in the countries considered) and oilseeds (primarily soybean and canola in the countries considered) are included in all scenarios, but to illustrate what might happen soon we also look at adoption of GM rice and wheat in some countries.

The following scenarios are based on a simplifying assumption, namely, 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, thus rightward shifting the supply curve for the GM crop to that extent.[4] Demanders of primary agricultural products such as maize and soybean meal for livestock feed will benefit from lower input prices, which in turn will affect the market competitiveness of grain-fed versus grass-fed livestock producers.

The widespread adoption of GM varieties in some parts of the world will affect other regions via international trade flows. To the extent that trade is not further restricted and not currently subject to binding quantitative restrictions, world market prices for these products will tend to decline and thus benefit regions that are net importers of these products. For exporters, the lower price may or may

3 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 Dimaranan and McDougall (2002) for the GTAP 5.4 database used here. The model is solved with GEMPACK software (Harrison and Pearson, 1996).

4 Due to the absence of sufficiently detailed empirical data on the agronomic and hence economic impact of cultivating GM crops, the productivity shock applied here represents an average shock (over all specified commodities and regions). Changing this shock (e.g. doubling it) 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 former are ignored in the computable general equilibrium 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.

not mean their trade in value terms goes down, depending on price elasticities in foreign markets. Welfare among exporting countries would decrease for non-adopters but could also decrease for some GM-adopting countries if the adverse terms of trade change were to be sufficiently strong. Hence the need for empirical analysis, particularly when the countries in focus are large global players in some of the markets affected.

We have modified the GTAP model so it can capture the effects of productivity increases of GM crops, some consumer aversion to products containing GMOs, and substitutability between GM and non-GM products as intermediate inputs into final consumable food. There are five types of productive factors in the version used here: skilled labour, unskilled labour, agricultural land, other natural resources, and other (non-human) capital. All factors except natural resources (used only in primary production) are assumed to be perfectly mobile throughout the economy.

Production

Depending upon the simulation, the Unites States and Canada are assumed to be the major adopters of GM crops. Not all other countries are assumed to adopt GM crops in every scenario but, in simulations where we explore what would happen if they did adopt, we assume they would do so to a lesser extent than the first GM-adopting countries. None of these countries is as intensive in the use of maize, soybean, and canola as the first GM adopters, and few have the same degree of broad-acre agriculture. Hence they are more likely to be constrained by government in how they plant GM varieties. In addition, unlike the first GM-adopters, some may have segregation and identity preservation costs imposed on them, which further reduces the profitability for them of GM adoption.

In these GTAP simulations we assume 45 % of US and Canadian coarse grain production is GM. When they adopt, all Latin American countries and Australia are assumed to adopt GM coarse grains at two-thirds the level of the US (i.e., 30 % of coarse grain production is GM), while all other countries are assumed to adopt GM coarse grains at one-third the level of US adoption (i.e., 15 % of coarse grain production is GM). For oilseeds, we assume that 75 % of oilseed production in the US, Canada, Argentina, and Brazil is GM. Again Other Latin American countries and Australia are assumed to adopt at two-thirds the extent of the major adopters and the remaining regions adopt at one-third the extent of the major adopters. For the rice scenarios, major adopters, including the US, Canada, China, India, and all other Asian countries are assumed to produce 45 % of their crop using GM technologies. All other regions adopt at two-thirds this rate (i.e., 30 % of rice crop is GM). GM wheat adoption is assumed to occur at the same extent as coarse grain adoption for all regions.

The adopting sectors are each sub-divided into GM and non-GM varieties, and an output-augmenting, Hicks-neutral productivity shock is implemented on the GM varieties of these commodities to capture their higher productivity. This assumes that GM technology uniformly reduces the level of primary factors and intermediate inputs needed per unit of output.[5] When a region does not adopt GM technologies, no regional factor productivity shock is included and there is no distinction between GM and non-GM production in these regions. In the constant-elasticity-of-substitution production nest, producers choose first between imported and domestic inputs according to the model's Armington (1969) elasticities, and then choose whether or not to use GM or non-GM intermediate inputs in their production of final goods.

Consumption

In order to capture consumer aversion to GM products, two changes are made to the traditional GTAP demand structure. First, elasticities of substitution between GM and non-GM products in the European Union, Australia, and New Zealand where consumers are GM-averse are set at low levels to capture the perceived low substitutability of these products. (Sensitivity of the results to those assumed elasticity values are reported below.) In addition, preference shift parameters are included to capture the group of consumers in some countries that, because of food safety and/or environmental concerns, refuses to consume GM crops regardless of their price. In such cases a 25% reduction in final demand for output of crops that may contain GMOs is assumed, following Nielsen and Anderson (2001).

Factor ownership

GTAP provides a comprehensive decomposition of changes in national economic welfare as measured by the equivalent variation in income. National and world measures of welfare changes hide the distributional implications within countries of GM policies, however, and so fail to provide insights into the political economy of GM policy choices. While the total economic benefits from trade typically decrease when inefficient policies such as import bans are implemented, some groups within national economies will be beneficiaries. Hence post-simulation analysis is desirable.

We examine the effects on intra-regional distribution of income by dividing the economy into three groups of households: farmers, unskilled labourers, and owners of human and other capital. Income of each group comes from a combination of factors. Farm households earn income from farm and non-farm activities. The existing GTAP database provides information about the availability and use of land, unskilled labour, skilled labour, other natural resources and other capital in the agricultural sector, and likewise in other sectors. Non-farm activities

5 Because it makes little difference to the results being analysed here, we simply follow previous analysts in assuming that the productivity effects of genetic modification do not differ across crops or inputs (Nielsen and Anderson, 2001; Anderson, Nielsen, and Robinson, 2002). For studies that differentiate the degrees of factor/input saving, see Huang *et al.* (2004) and van Meijl and van Tongeren (2004).

of farm households are assumed to earn income from factors in the same proportion as activities conducted by the typical urban capital-owning household. Hence factor shares for farm households are a weighted sum of factor shares used in agricultural production and the factor income shares of capital owners.[6] The shares of farm household income from non-farm activities are assumed to be 90 % in Japan and Korea, 50 % in China and the EU, 35 % in US and Canada,[7] 25 % in Australia, New Zealand, and Eastern Europe, and 20 % in all Latin American countries, India, South and South-east Asia, South African Customs Union, and the Rest of the World. The remaining Sub-Saharan African countries are assumed to gain 10 % of their farm household income from non-farm activities. Unskilled labourers are assumed to receive all their income from unskilled non-farm labour. The expenditure shares are assumed to be the same for all households, so real household incomes are calculated simply by deflating by the consumer price index.

Simulations

Several sets of simulations are considered below to address the questions posed in the introduction. We begin with GM adoption for just coarse grains and oilseeds but then add rice and wheat, to get a feel for the relative economic importance to different regions and the world as a whole of current versus prospective GM food crop technologies. We look at the impacts of GM adoption by just the US, Canada, and Argentina first, without and then with some policy reactions in other countries. Then we add the EU to the list of adopters to explore the tradeoffs for the EU between productivity growth via GM adoption and the benefits of remaining GM-free given the prior move to adopt in the Americas. Following Stone *et al.* (2002), these model simulations assume that total factor productivity is higher for GM than for non-GM varieties by 6 % for oilseeds and 7.5 % for coarse grains; in the later cases of rice and wheat, a modest 5 % productivity difference is assumed so as to provide a conservative estimate of its impact.[8]

6 This measure of impact on farmer income is different from the partial equilibrium measure of producer surplus used by, for example, Lindner and Jarrett (1978) who show that even with a completely inelastic demand curve a parallel shift (but not a pivotal shift) downwards in the supply curve will not reduce producer surplus. The measure of farm household income change used here can generate a loss for producers partly because it is a general equilibrium measure that also captures off-farm earnings of farm households, but also because the technology shock only applies to the GM varieties which then have to compete with the (sometimes preferred) non-GM varieties of that crop. Hence the price-depressing impact can more than offset the effect of the productivity improvement on profits of GM adopters.

7 This is the average for commercial farmers. In the US, commercial farmers are only one-third of the total number of farmers. Another one-quarter of them are considered simply rural residents. If the remaining two-fifths, known as 'intermediates', are included in the definition, then the share of farm household income earned from non-farm sources rises to 75 % (USDA, 2001). Sensitivity analysis of the post-simulation results is therefore reported below to show what difference the definition makes to the US results.

8 In this paper we ignore the GM variety known as 'golden rice', which aims not to boost farm productivity but rather to boost the health of rice consumers through enhancing it with pro-vitamin A

The base case is compared with several alternative scenarios. One involves an EU moratorium on GM imports from Argentina, the US, and Canada, where it is assumed there is no segregation between GM and non-GM products and therefore the EU import ban (modelled as a prohibitive tariff) is imposed on all coarse grains and oilseeds from those three GM adopters. Another scenario assumes the EU, Japan, and Korea implement labelling policies that allow consumers to choose between non-GM products and those that may contain GM content. In this option, diehard consumers in the EU, Korea, and Japan avoid consuming coarse grains and oilseeds. (This is modelled as a 25 % reduction in final consumption of coarse grains and oilseeds in those countries.) A third alternative scenario is that the EU abandons its stand against GM products in favour of the American stance, while all other countries remain non-adopters. And a final scenario assumes that such a change of heart in the EU would induce the rest of the world to adopt GM varieties of coarse grains and oilseeds as well.

All those scenarios ignore the fact that GM technology also could apply to other crops, so we also examine the welfare and distributional effects of adding GM rice and wheat. Were GM varieties of those commodities to be adopted, it is likely that China and possibly India would be part of the adopting group, so they are included in the latter simulations.

3. Model results[9]

In the absence of any adverse reactions abroad, the GM-adopting countries expand their output and net exports of coarse grains and oilseeds (and meat), while the opposite happens in the rest of the world. Consumption of these products expands in all regions because they are now cheaper, but especially in the GM-adopting regions, since in this model the Armington assumption ensures that imported products are an imperfect substitute for domestically produced products.[10] However, when the EU moratorium is imposed on imports from GM-adopting countries, the international prices of coarse grains and oilseeds fall more – so much so as to cause GM-adopting countries to reduce their output of these crops slightly. In Europe, the opposite occurs because the import ban drives up domestic prices (Anderson and Jackson, 2005a: Table 10).

If instead the EU were to also adopt GM varieties, EU production and net exports are higher instead of lower, increases in production and exports by the first GM-adopters are slightly less, and decreases in production and net exports by the

(Beyer *et al.*, 2002). For an economic analysis of its possible benefits as compared with those from GM rice that simply boosts farm productivity, see Anderson, Jackson, and Nielsen (2005).

9 This section draws on Anderson and Jackson (2005c).

10 The price falls are less than in Nielsen and Anderson (2001) because the present study distinguishes GM from non-GM varieties and applies the productivity shocks only to the former, whereas the earlier study applied it to all production in GM-adopting countries.

rest of the world are slightly more because international prices of coarse grains and oilseeds fall more (see Anderson and Jackson, 2005a: Table 11).

A comparison of the welfare effects of this second scenario and those from the EU moratorium provides a conservative estimate of the cost of the EU's recent policy compared with following the North American strategy of embracing GM technology, but only if the EU stance has no effect on other countries' GM policies. In so far as the rest of the world is delaying adoption solely *because* of the EU stance, on the other hand, then an upper-bound estimate of the cost of the EU's policy can be found by comparing a scenario in which all countries adopt GM varieties of coarse grains and oilseeds with the EU moratorium case (which effectively has applied even in the 12 months since its replacement with strict labelling regulations, because of the slow pace of the approval process).

The aggregate economic welfare effects of these various cases are summarized in Table 2 for all scenarios. Several points can be drawn from that table, the first being that the global benefits of the first group's GM adoption is substantial (US$2.3 billion per year) if there are no adverse reactions elsewhere, and about one-quarter of it is shared with the major importing regions of the EU and Northeast Asia; but Brazil, Australia, New Zealand, and the rest of Sub-Saharan Africa lose very slightly.

Second, when the EU imposes its moratorium, this is similar to an increase in farm protection there and causes the EU to be worse off by $3.1 billion per year (less whatever value EU consumers place on having avoided consuming GM products), as well as reducing by one-third the gain to GM-adopting North America, while improving welfare for Brazil considerably but for food-importing regions of the rest of the world only very slightly.

Third, if instead the EU left it for individual EU consumers to respond and one-quarter of them simply avoided these products because they may contain GMOs, the welfare effects are almost the same as in the base case, because even though there is less EU consumption there is also less protected production in high-cost Europe and so less wastage of resources there.

Fourth, if the EU were to take the opposite view and allow GM adoption, it would gain more because of its own productivity gains and so too would net importers of these products elsewhere in the world, while net exporters of coarse grains and oilseeds (both GM adopters and non-adopters) would be slightly worse off. Hence the net global gains would be just 7% more than in the base case because coarse grains and oilseeds are minor crops in the EU compared with North America – assuming the EU moratorium has no impact on the GM policies of other countries.

However, if by adopting that opposite stance in the EU the rest of the world became uninhibited about adopting GM varieties of these crops, global welfare would be increased by nearly twice as much as it would when just North America and Argentina adopt, the EU too would gain more in this scenario as compared with just the EU alone joining the GM adopters because of improved terms of

Table 2. Economic welfare effects of GM coarse grain and oilseed adoption by various regions (equivalent variation in income, US$ million)

	US, Canada, and Argentina adopt				
	With no moratoria responses	With EU moratorium	With EU consumers free to boycott	US, Canada, Argentina and EU adopt	All adopt
United States	939	628	936	928	897
Canada	72	7	67	70	65
Argentina	312	247	310	307	287
Brazil	−36	256	−46	−53	317
Other Latin America	125	184	130	128	356
Australia	−9	−4	−10	−10	2
New Zealand	−5	2	−5	−5	−6
EU-15	267	−3,145	326	406	595
Eastern Europe	7	−10	9	8	35
China	107	111	113	110	235
India	0	3	1	0	252
Japan + Korea	322	341	178	335	430
Other Asia	36	44	39	37	134
Sub-Saharan Africa	1	21	2	2	69
Rest of World	152	75	169	167	380
WORLD	**2,290**	**−1,243**	**2,219**	**2,429**	**4,047**

Source: Authors' GTAP model simulation results.

trade, and almost all of the extra global gains would be enjoyed by developing countries (final column of Table 2).

The cost of the EU's policy stance can be thought of as in the range of the difference between columns 4 and 2 and the difference between columns 2 and 5 of Table 2, depending on how much one believes the EU's stance is determining the rest of the world's reluctance to adopt GM varieties of these crops. For the EU that cost range is (406 + 3,145 =) $3,551 million to (595 + 3,145 =) $3,740 million per year, while for the world as a whole the range is 2.43 + 1.24 =) $3.67 billion to (4.05 + 1.24 =) $5.29 billion per year. But even that $5.3 billion number understates the global welfare cost of the EU's policy in at least three respects. First, we have not included in the second scenario in Table 2 (the EU moratorium) the fact that the EU's stance has already induced some other countries to also impose similar moratoria. Second, these are comparative static simulations that ignore that fact that GM food R&D is on-going and that investment in this area has been reduced considerably because of the EU's extreme policy stance. And, third, the above results refer to GM adoption just of coarse grains and oilseeds. The world's other two major food crops are rice and wheat, for which GM varieties have been developed and are close to being ready for release. How much impact might they have, should governments choose to approve them?

If rice and wheat were to be approved in the current GM-adopting countries they also would be likely to be adopted in China and India. This is because those two large developing countries account for 55 % of the world's rice market and 30 % of the wheat market and are close to self sufficient in both. That means they do not have to worry as much about EU market access. We re-ran the simulations allowing China and India to join the GM-adopters group, and added to coarse grains and oilseeds both rice and wheat.

The effects on aggregate economic welfare, and it distribution, of adding these two extra countries and commodities are dramatic (even though we ignore the potential health benefits from the GM variety known as 'golden rice'). The global economic welfare gain if there is no policy response by the EU or others is $3.9 billion with just rice added or $4.3 billion if wheat is also added, instead of $2.3 billion per year (compare column 1 of Tables 2 and 4). North America gains only a little more from the addition of GM rice and wheat, which might seem surprising given the importance to it of wheat, but it is because its productivity gain is almost offset by a worsening of its terms of trade as a consequence of their and the other adopters' additional productivity. Two-thirds of the extra $2.0 billion per year from adding rice and wheat accrues to China and India, with other developing countries, as a net importing group, enjoying most of the residual via lower-priced imports.

What about this case if the EU moratorium were still in place? A comparison of the differences between columns 1 and 2 in Tables 2 and 4 reveals an increase in the cost to the EU of its strict policy, from $3.4 to $5.1 billion per year (again not counting the benefit to EU consumers of knowing they are not consuming GMOs), while for the rest of the world the difference is small. But again a more appropriate comparison if the EU policy is discouraging GM adoption elsewhere is between the EU moratorium case and the case where all countries including the EU adopt, shown in the final column of Table 3. That difference is $5.5 billion for the EU and $8.4 billion for the world as a whole. Those numbers compare with $3.7 and $5.3 billion, respectively, in the earlier situation that excluded rice and wheat – an increase of 1.6 times the estimated global cost of the EU's policy. And the adding of further crops to the GM family would continue to multiply that estimate.

As with all CGE modelling results, the above are subject to qualifications, perhaps the most important being the way consumer preferences are handled. The estimated market and welfare effects vary with the elasticities of substitution assumed between GM and non-GM varieties of a product, as detailed in Anderson, Nielsen, and Robinson (2002). To reduce the risk of exaggerating the effects we chose very low elasticities for Europe and Northeast Asia and moderate ones elsewhere. Even so, we have no satisfactory way of valuing any loss of welfare for consumers who would like to avoid consuming foods containing GMOs but cannot if they are introduced into their marketplace without credible labelling. We have assumed that loss to be zero in all but the third scenario reported in Table 2 (where we arbitrarily assumed a one-quarter reduction in EU final demand for

Table 3. Economic welfare effects of GM adoption by the US, Canada, Argentina plus China, and India (equivalent variation in income, US$ million)

	NA, ARG, CHN, IND adopt coarse grains, oilseeds and rice and wheat		All countries incl. EU adopt coarse grains, oilseeds, and rice and wheat
	Without policy response	With EU moratorium	Without policy response
US	1,045	754	1,041
Canada	83	−23	64
Argentina	350	285	312
Brazil	−37	284	430
Other Latin America	155	236	453
Australia	−18	−10	−1
New Zealand	−6	2	−7
EU-15	355	−4,717	810
Eastern Europe	10	−15	54
China	841	833	899
India	669	654	669
Japan + Korea	494	521	1,198
Other Asia	70	92	701
Sub-Saharan Africa	12	38	202
Rest of World	284	173	682
WORLD	**4,308**	**−892**	**7,506**

Source: Authors' GTAP model simulation results.

coarse grains and oilseeds because in that scenario those products may contain imported GM varieties). One additional way to cope with this issue is to introduce a cost of segregation and identity preservation. We did that implicitly by choosing conservative cost savings due to the new technology, saying they were net of any fees charged for segregation and identity preservation. According to Burton et al. (2002) such fees may be as high as 15 % of farm gate price, which would make it unprofitable to market many GM varieties if that was a required condition of sale. Others suggest those costs could be miniscule on the grounds that such segregation is increasingly being demanded by consumers of many conventional foods anyway (e.g., different grades or varieties of each crop) so the marginal cost of expanding such systems to handle GM-ness would not be great, at least in countries willing to pay for product differentiation.

4. What impact do the results have on farm household incomes?

How have the policy responses by the EU and followers impacted on farmers in high-income countries and – from a poverty alleviation perspective – on farmers and unskilled non-farm labourers in developing countries? The effects on real farm household incomes, summarized in Table 4, show Argentinean farmers are slightly better off and farmers in the US and Canada are only slightly worse off as a result of their adoption of GM varieties. Even though the productivity gains are more than offset by the price declines for North American farmers (since they are such a dominant part of the global market for maize and soybean), if any one sub-group of them did not adopt they would be even worse off by suffering the price decline but not enjoying the productivity growth. Note from columns 2 and 3 of Table 4 that their welfare has been worsened greatly by the EU moratorium, but only a small amount by the EU allowing consumers to vote with their Euros. Farmers in the EU, on the other hand, while only slightly worse off if there is GM adoption in the Americas, are made better off if the EU moratorium on American imports is imposed. However, that advantage disappears if either EU consumers are allowed to choose for themselves or if EU farmers are allowed to adopt these GM varieties (in which case the price decline evidently fully offsets the productivity gain for them – see columns 1 to 4 of row 8 of Table 4). In short, American farmers are made worse off,[11] and EU farmers better off, by the EU ban on production and imports of products that may contain GMOs, compared with the alternatives of embracing the new technology as in America or even just allowing EU consumers the right to choose. Even if farmers are not playing a major role in determining GM policies in these regions, the results suggest they would not be unhappy with current policies.

The right-hand half of Table 4 refers to GM adoption also of rice and wheat, with China and India joining the GM adopters. This would depress international grain prices even more but the gain to Argentinean farmers from higher wheat productivity would more than compensate, while North American farmers would be slightly worse off than if GM approval remains restricted to coarse grains and oilseeds. Farmers in China and India in this case would gain, and those gains to Chinese and Indian farm households would be only slightly diminished by the EU moratorium (since they export very little food to the EU).

Since there are also large national economic welfare gains from adoption for China (Table 3), how can these results be reconciled with China's decision each year to delay approving GM food production and its move to ban imports of GM products in 2001 (subsequently weakened in 2002 but only after strong protests from the US)? China's policy is all the more puzzling given that China (a) has the technology and could release numerous GM crop varieties including rice almost immediately (Huang and Wang, 2002; Huang *et al.*, 2004), (b) exports very few food products and then mostly to East Asia and so is not likely to suffer serious problems of market access, particularly in the years ahead, as industrialization causes China's export competitiveness in land-intensive crops to diminish, and

11 As part of our sensitivity analysis, we recalculated the first row of Table 5 assuming the share of farm household income in the US earned off the farm was 0.75 instead of 0.35 (to allow for smaller farms, even though they typically would not be very influential in lobbying). Even though the magnitude of all the effects on real US farmer incomes was reduced (by about 60 %), the signs remained the same.

Table 4. Percentage change in farm household real income in selected regions, various GM adoption and policy response scenarios

	GM coarse grains and oilseeds				GM coarse grains, oilseeds, rice, and wheat			
	US, Canada, and Argentina adopt			US, Canada, Argentina and EU adopt	US, Canada, Argentina, China and India adopt		All countries except EU adopt	All countries including EU adopt
	With no moratoria responses	With EU moratorium	With EU consumers free to boycott	With no moratorium responses	With no moratoria responses		With EU moratorium	With EU moratorium
United States	−0.18	−0.36	−0.20	−0.19	−0.20	−0.43	−0.51	−0.29
Canada	−0.26	−0.57	−0.28	−0.27	−0.29	−0.63	−0.769	−0.36
Argentina	0.01	−0.10	0.00	0.00	0.07	−0.15	−0.16	−0.07
Brazil	−0.00	0.15	−0.01	−0.02	−0.01	0.12	−0.15	−0.03
Other Latin America	−0.06	−0.06	−0.07	−0.07	−0.07	−0.06	−0.17	−0.14
Australia	−0.04	−0.03	−0.04	−0.04	−0.07	−0.04	−0.19	−0.17
New Zealand	−0.03	0.00	−0.03	−0.03	−0.02	0.00	−0.05	−0.18
EU-15	−0.03	0.74	−0.05	−0.05	−0.04	0.86	1.69	−0.07
Eastern Europe	−0.03	0.08	−0.03	−0.03	−0.03	0.11	−0.05	−0.08
China	−0.02	−0.02	−0.03	−0.02	0.06	0.05	0.11	0.12
India	0.00	0.00	−0.03	−0.03	0.01	−0.02	−0.03	−0.01
Japan + Korea	−0.01	−0.01	−0.01	−0.01	0.00	−0.02	0.09	0.00
Other Asia	−0.04	−0.03	−0.04	−0.04	−0.03	−0.02	−0.09	−0.04
South Africa	−0.03	0.02	−0.04	−0.04	−0.03	0.03	−0.03	−0.07
Rest of Sub–Saharan Africa	−0.01	0.04	−0.01	−0.01	−0.01	0.04	0.11	0.01
Rest of World	−0.04	0.03	−0.04	−0.04	−0.04	0.03	−0.02	−0.09

Source: Authors' GTAP model simulation results.

(c) as a poor country would gain from GM adoption of those crops about 20 times as much as North America when the gain is expressed as a share of GDP (and India would gain nearly 40 times as much). Officially the reason is that food safety tests are still under way, but an alternative or additional possibility is that China is stalling until it has its own GM varieties ready for release so as to avoid paying foreign firms for intellectual property rights.[12]

5. Implications for poverty alleviation in developing countries

Our results show that the EU moratorium has benefited food-importing developing countries (and Japan and Korea), because of an improvement in their terms of trade. However, the above analysis does not take into account that moratoria will slow the investment in agricultural biotechnology, and so reduce future market and technological spillovers to developing countries from that prospective R&D. Furthermore, future generations of GM products are likely to provide health and nutritional benefits to consumers, as in GM rice enhanced with pro-vitamin A (Beyer *et al*., 2002). The costs of delaying investments in those GM technologies will fall heavily on the world's poor consumers (Anderson, Jackson, and Nielsen, 2005). More importantly from the viewpoint of poverty reduction in poor countries, unskilled non-farm labourers – who have gained little from the current limited adoption of GM food varieties – would gain much more as adoption spreads (Table 5).

If the reason for China's reluctance to approve GM varieties for domestic production is because it wants to restrict approval to indigenously developed GM varieties so as to capture the intellectual property earnings domestically, then one can only hope – for the sake of their consumers and farmers – that such varieties will be ready soon (and that India and subsequent potential GM adopters will be willing to use Chinese or other GM varieties rather than cause further delays, while their biotech researchers catch up).

And what about Sub-Saharan Africa, where almost one-third of the world's people living on less than $1 a day reside (up from one-tenth two decades ago)? It might be thought that, given their strong trade ties with the EU, SSA countries would benefit more from less competition in EU markets for GM-free food than

12 What about Australia and New Zealand (ANZ), which have chosen so far not to approve GM food production? ANZ would lose slightly less in net economic welfare terms from joining with all others in adopting GM varieties of these four crops (Table 3), but the difference is less than $1 per capita per year. Even if that was sufficient to offset the negative value ANZ consumers place on not knowing if they may be consuming GM products, rows 6 and 7 of Table 4 shows the average ANZ farm household income would not improve from GM adoption by it and others – even with rice and wheat included – regardless of whether the EU moratorium remains. Hence one should not expect ANZ farmers to be pushing hard for rapid approval of GM production until consumer concerns fade. Nor are there any huge ANZ-owned biotech firms developing the technology and hence lobbying for its adoption in those relatively small markets in the same way as there are in the US. For more on the impacts on ANZ, see Anderson and Jackson (2004, 2005a).

they would gain from adopting GM varieties. However, a new set of GTAP simulations suggests the opposite would be far more likely: farm productivity gains in SSA would swamp the gains through improved terms of trade as a result of the EU ban on imports from GM-adopting countries (Anderson and Jackson, 2005c).

6. Implications for the global trading system

As discussed in more detail elsewhere (Anderson and Nielsen 2001a,b), these findings have worrying implications for the WTO rules-based global trading system. If it is in the interests of farmers in food-importing countries of Europe and elsewhere to forego adopting this new biotechnology in order to reduce their competitive disadvantage *vis à-vis* more-efficient export-oriented producers in America and elsewhere, then those protected producers have no incentive to oppose consumer and environmental groups' lobbying for tough GMO standards – and it may not even be in the interests of Cairns Group farmers in Australia and New Zealand to oppose that stance (Anderson and Jackson, 2004, 2005a). Such standards could provide a replacement for the traditional forms of government assistance to agriculture that are under pressure to be dismantled in agricultural-protectionist countries, following the Uruguay Round of trade negotiations. Not only would that negate the benefits of negotiating lower farm support programs in the current Doha round of WTO negotiations, but it promises to raise the level of friction in the WTO's Dispute Settlement Body.

The complex nature of the genetic modifications required to produce GM products that has lead to diverse national regulatory approaches for GM products has created conditions in which spontaneous policy convergence is unlikely. The way these regulatory goals are achieved depends on, among other things, existing national regulatory structure, the agricultural production systems, and consumer perception of these products. Attaining harmonized policy outcomes depends on the interaction among national policies and existing international policy frameworks.

Many WTO Agreements encourage governments to harmonize regulatory policies, for example by referencing standards from international organizations, so as to reduce unnecessary trade distortions and reduce the potential for conflict. However, WTO Members do not always agree on the way WTO Agreements should be interpreted in the contexts of the diverse characteristics of GM products (particularly their potential food safety and environmental impacts) and divergent regulatory goals. Individual regulations in the food and animal and plant health area may be written so that they have multiple purposes, not all of which are covered by a single Agreement. Some parts of the regulations may have goals that relate to measures under the SPS Agreement, while other parts may fall under the TBT or other Agreements.

The SPS Agreement covers all measures whose purpose is to protect human or animal health from food-borne risks, human health from animal- or plant-carried

Table 5. Percentage change in real incomes of unskilled non-farm labourers in developing countries, various GM adoption and policy response scenarios

	NA and ARG adopt GM coarse grain and oilseeds			NA, ARG, CHN and IND adopt GM coarse grain, oilseed, rice & wheat		ALL COUNTRIES adopt GM coarse grain, oilseed, rice & wheat
	Without policy response	With EU moratorium	With EU consumers free to boycott	Without policy response	With EU moratorium	
Unskilled non-farm labourers						
Argentina	0.12	0.14	0.12	0.12	0.10	0.08
Brazil	0.03	−0.03	0.03	0.03	−0.07	0.07
Other Latin America	−0.03	0.03	0.03	0.03	0.03	0.01
China	−0.00	0.00	0.00	0.18	0.21	0.20
India	0.00	0.00	0.00	0.29	0.32	0.33
Other South and SE Asia	−0.00	0.00	0.00	0.03	0.01	0.19
South Africa	0.00	0.00	0.00	0.00	0.00	0.03
Rest of Sub-Saharan Africa	0.00	0.06	0.00	0.00	0.06	0.05

Source: Authors' GTAP model simulation results.

diseases, and animal and plants from pests or diseases. For a trade-distorting measure to be acceptable under SPS, there would have to be a scientific justification on food, plant, or animal safety grounds. This scientific justification is linked to the obligation to perform a risk assessment related to the purpose of the measure or to base the measure on international standards. In cases where the scientific information is insufficient, WTO Members have the right to implement provisional measures. However, these rights are linked to obligations to seek to obtain additional information in order to conduct a more objective risk assessment and to review the SPS measures within a reasonable period of time.

If the intent of the measure is not related to the protection of human, animal, or plant health, then the measure does not fall under the SPS Agreement but it could be covered by the TBT agreement. While under the SPS Agreement Members are required to justify measures scientifically, under the TBT Agreement governments may opt to deviate from international standards for non-scientific reasons, including technological problems or geographical factors. Previous disputes concerning the TBT Agreement have considered the issue of whether regulations make unjustified distinctions between like products. This question is complicated in the context of GM products which, by definition, have been altered genetically but which may not differ in characteristics that can be perceived by consumers. Under the TBT Agreement governments also have the right to implement regulations with the aim to protect consumers through the provision of information. That is manifest mainly in the form of labelling requirements, but it is still unclear whether a labelling regulation justified only by the consumer's 'right to know' about all types of characteristics of products in the market would be covered by the TBT Agreement. Yet the consumer's 'right to know' argument often plays a significant role in debates on GM policies in countries with groups of consumers who believe their national government should be able to exercise the right to provide them information.

If a government has justified GMO mandatory labelling policies based on environmental health or food safety grounds, and the SPS Agreement was found to apply, then the SPS Agreement encourages Members to harmonize their policies with international standards, particularly those created by the Codex Alimentarius, the OIE and the IPPC. However, even in this context, guidance for harmonization of GM policies is not clear. The Codex Alimentarius provides guidance in several areas relation to the evaluation of GM food products, including: 'Principles for the Risk Analysis of Foods Derived from Modern Biotechnology', 'Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant-DNA Plants', and 'Guideline for the Conduct of Food Safety Assessment of Foods Produced Using Recombiant-DNA Microorganisms'. Guidance on the evaluation of environmental risks associated with biotechnology products is less developed. The IPPC provides guidance on systemic issues for evaluating risks associated with 'Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms'. For this guideline to apply to GM products, the GM product would need to satisfy the definition of pest. Given the many different types of GM products and the varied perception of these products, the designation of 'pest' is not inevitable and therefore neither is the application of this guideline in the analysis of risk. Since there is no internationally accepted approach from among the myriad of options regarding the evaluation of environmental risks associated with GMOs, harmonization towards a single analytical approach is unlikely.

Scientific uncertainty, such as the uncertainty surrounding the long-term environmental impacts of cultivating GM crop varieties, creates further obstacles to harmonization because there are currently two international Agreements in this area. On the one hand, the Cartegena Protocol on Biosafety, which seeks to provide a framework for dealing with environmental uncertainties posed by living modified organisms, explicitly incorporates the precautionary approach but does not provide criteria by which countries can be judged to be abusing the right to implement a precautionary policy. On the other hand, the SPS Agreement, as mentioned above, includes text which allows governments to take regulatory action in the face of scientific uncertainty – but it also disciplines this right with specific obligations to seek additional information and to update their measures as the science evolves. The fact that these two international agreements both cover trade in GM products does not necessarily mean that they imply incompatible obligations. However, the extent to which their obligations converge depends on how governments choose to implement the obligations described in these Agreements. Thus the existence of these two Agreements creates an additional layer of policy complexity and does not provide significant incentives for policy harmonization.

What can be done to address these tensions regarding GM products in the international trading system? Perdikas, Kerr, and Hobbs (2001) suggest that a new WTO agreement might be developed to accommodate consumer or social 'right to know' interests. It is not obvious, however, that better outcomes would result, particularly since this type of agreement would not adequately discipline the incentive for governments to implement trade-distorting measures for purely protectionist reasons. What type of objective criteria could be used in this situation to discriminate between justified and unjustified measures?

Sheldon and Josling (2002) raise the possibility that importing countries who wish to persist with mandatory labelling or import bans that are deemed WTO-inconsistent offer increases in market access for non-GM foods in compensation for loss of market access for foods that may contain GMOs. While this proposal has the virtue that the WTO would then not be dragged into evaluating social and ethical bases for regulations, it may encourage countries to continue protectionist measures for a wider range of politically sensitive industries.

The variety of possible interpretations of international agreements in this area evidently provides countries scope for implementing vastly divergent GM policies. The tension between national sovereignty and international rules in the case of GM products is unlikely to be solved by spontaneous policy harmonization among trading partners. In the absence of incentives to seek harmonized positions, countries will continue to respond to their own internal political economy. But perhaps the process of dispute settlement in the WTO, regardless of whether it leads to rulings and recommendations by the Dispute Settlement Body, will provide a catalyst for countries to seek mutually agreeable solutions to GM conflicts.

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