Transgenic crops, EU precaution, and developing countries

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Abstract: Agricultural biotechnologies have the potential to offer higher incomes for farmers in developing countries and lower-priced and better-quality food, feed and fibre. That potential is being heavily compromised, however, because of strict regulatory systems in the European Union and elsewhere governing transgenically modified (GM) crops. This paper examines why the EU has taken the extreme opposite policy position on GM food to equally affluent North America, what has been the impact on developing country welfare of the limited adoption of GM crop varieties so far, and what impact GM adoption by developing countries themselves could have on their economic welfare.

Keywords: agricultural biotechnology; trade policy; regulation of standards; developing countries.

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1 Introduction

The pace of improving the productive efficiency and quality of the world's food crops had been slow up until the 19th century (Diamond, 1997). Then, following a century of wheat improvements (Olmstead and Rhode, 2002), hybrid varieties dramatically increased average corn yields from the 1940s (Griliches, 1958) and dwarf varieties of high-yielding wheat and rice caused what became known as the Green Revolution in Asia and elsewhere from the 1960s (Evenson and Gollin, 2003; Ruttan, 2004). Those technological developments of the past six decades contributed to an acceleration of the long-term decline in real international food prices to below 1930s' levels by the late 1980s (Tyres and Anderson, 1992),[1] which in turn led to complacency about the need for further agricultural R&D. As a result, growth in public funding for such research fell substantially in both rich and poor countries (Falcon and Naylor, 2005) – despite overwhelming evidence that this is a very high payoff investment area (Alston et al., 2000). In particular, the aid agencies and foundations reduced their support for the Consultative Group on International Agricultural Research (CGIAR) and for complementary national agricultural research systems in developing countries – which quickly led to fears that food crop productivity growth would slow (Runge et al., 2003).

The emergence in the 1990s of new agricultural biotechnologies, and in particular transgenic crop varieties, seemed to offer new hope that the private sector might fill this lacuna. But to those early hopes were added three other concerns. One was that a small number of huge biotech firms would capture most of the gains from the new agricultural biotechnology. A second was that those firms would not invest in poor countries where profits would be slim because of poor protection of intellectual property rights and small commercial seed markets. And the third concern was that Europeans and others would reject the technology because of environmental and food safety concerns, thereby thwarting export market prospects for adopters of the transgenic crops (Pinstrup-Andersen and Schioler, 2000; Paarlberg, 2003). That third concern was vindicated by the European Union's imposing in late 1998 of a de facto moratorium on the production and importation of food products that may contain genetically modified organisms (GMOs). It helped to constrain widespread adoption to just three GM food or feed crops (maize, soybean and canola) in three countries where production had already taken off by 1998, namely the USA, Argentina and Canada. Even when the other important GM crop is added (cotton), those three countries continue to dominate (Table 1).

True, the EU replaced its moratorium in May 2004 with new regulatory arrangements, but they involve such onerous and laborious segregation, identity preservation and labelling requirements as to be almost as restrictive of exports of GM products as the moratorium was. With a number of other countries also imposing strict labelling regulations on GM foods (Carter and Gruere, 2006), biotech firms are increasingly diverting their R&D investments away from food. At the same time, the public agricultural research system has remained shy about investing heavily in this technology – including the CGIAR which depends heavily on rich-country grants from EU member states.

Table 1 Area of GM crops

By country and product, 2002–2004	*2002* (*m. ha*)	*2003* (*m. ha*)	*2004* (*m. ha*)
USA	39.0	42.8	47.6
Argentina	13.5	13.9	16.2
Canada	3.5	4.4	5.4
Brazil	0.0	3.0	5.0
China	2.1	2.8	3.7
Paraguay	0.0	0.0	1.2
India	0.0	0.1	0.5
South Africa	0.3	0.4	0.5
Uruguay	0.0	0.1	0.3
Australia	0.1	0.1	0.2
All other countries	0.2	0.1	0.4
Total	58.7	67.7	81.0

By product and variety, 2004	*Global GM area* (*m. ha*)	*Crop's share of global GM area* (%)	*Share of crop's global area under GM* (%)
Soybean: herbicide tolerant	*48.4*	*60*	*56*
Canola: herbicide tolerant	*4.3*	*5*	*19*
Maize: Bt (insect resistant)	11.2	14	na
Herbicide tolerant	4.3	5	na
Bt/herbicide tolerant	3.8	4	na
All maize	*19.3*	*24*	*14*
Cotton: Bt (insect resistant)	4.5	6	na
herbicide tolerant	1.5	2	na
Bt/herbicide tolerant	3.0	4	na
All cotton	*9.0*	*11*	*28*
Total of four crops	81.0	100	29
Total of all crops	na	na	5

Source: James (2004) and earlier issues

How are these events affecting developing countries, where the welfare of poor households (whether net buyers or net sellers of food) is far more dependent on agricultural productivity growth than is the case in rich countries? This paper addresses that question by breaking it down into the following four sub-questions:

- why did this 'Gene Revolution' begin with maize, soybean and canola (along with cotton) rather than with the world's most important food crops, namely wheat and rice?
- why has the European Union (EU) taken an extreme opposite policy position on GMOs to equally affluent North America?
- what has been the impact on developing country welfare of the limited adoption of GM varieties so far and of the EU's reaction to that?
- what impact could GM adoption by developing countries themselves have on their economic welfare, including if and when GM varieties of wheat and rice also are made available?

Each of these questions is addressed in turn, drawing on empirical data and some simulation results from a model of the global economy, before the paper concludes with some policy implications from the analysis. China and India are the most significant developing countries to consider, in the sense that they house the majority of the world poor, they comprise almost one-third of the world's production and consumption of grain (and even more of cotton), and they (especially China) have the potential to rapidly apply and disseminate this new biotechnology. But Sub-Saharan Africa is also of crucial concern, given its extreme poverty and strong dependence still on agriculture for employment and export earnings and, in some cases, on food aid imports (which could be problematic if food provided as aid is not GM-free, as was the case for US shipments to Southern Africa in 2002).

2 Why GM maize, soybean and canola (and cotton) first?

The answer to this first question has to do largely with where those crops are grown and sold. According to FAO statistics (see www.fao.org), the USA alone accounts for 30–40% of global production and consumption of maize and soybean, and during 1998–2002 the USA, Canada and Argentina enjoyed a combined share of global exports of 80% for maize, 64% for soybean and 42% for canola. These 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. By contrast, those countries account for less than one-sixth of global wheat production and less than one-twentieth of global rice production. That concentration means regulatory approval for soybean and maize in just three countries could potentially offer biotech firms access to the lion's share of those products' global seed markets, unlike for wheat and rice.

There was also likely to be less consumer resistance to GM crops that were to be processed into oil or fed to livestock prior to ending up in final products for human consumption, again in contrast to wheat and rice which can be and are consumed with less processing. Once that consumer acceptance was secured, biotech firms may have believed they would find it easier to persuade other (especially poorer) countries that rich countries are willing to produce and consume food that may contain GMOs.

In the case of maize, another reason for it being among the first crops to be genetically modified is that it is not a self-pollinating variety, which makes it easy to charge an annual technology fee as part of the seed price.

As for cotton, it too is a non-trivial crop in the USA and, importantly, was far less prone to criticism from food consumer groups. Its more-rapid spread to developing countries also is related to the lesser concern it creates for food safety authorities.

3 Why has the EU such an extreme policy stance toward GMOs?

The conventional explanation for the US-EU difference in GM regulations is that Europeans care more about the natural environment than do Americans, and trust their food safety regulators less. This seems incomplete, however, for two reasons. One is that consumers and even environmentalists typically do not wield a great deal of political clout relative to producer interests (Bernauer, 2003). The other is that there appears to be no hard evidence to date to justify the concerns reflected in the precautionary stance taken by EU member countries. Consider these in reverse order.

On the consumer or 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 such concerns are inconsistent with statements made by the EU scientific community (European Commission, 2001), and with a recent report commissioned by the UK government (King, 2003, p.23). The latter report, by eminent scientists, extensively reviews available evidence and finds no adverse effects anywhere in the world. So like previous similar reports it concludes that, on balance, "the risks to human health are very low for GM crops currently on the market" (King, 2003, p.23). A newer report, by the Food Safety Department of the UN's World Health Organization, concludes: "GM foods currently on the international market have passed risk assessments and are not likely to, nor have been shown to, present risks for human health" (WHO, 2005, p.v).

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. The Nuffield Council on Bioethics also concluded in a recent discussion paper:

> "We do not take the view that there is currently enough evidence of actual or potential harm to justify a blanket moratorium on either research, field trials or the controlled release of GM crops into the environment." (Thomas et al., 2004, p.62)

Might another element of the explanation for the EU's policy stance be that it is not against the interests of affected producers? Two key groups are the farm input-supplying firms and the potential growers of GM crops. Graff and Zilberman (2004) argue that, in the face if increasing stringency in pesticide regulations, European chemical companies directed their R&D to more environmentally friendly farm chemicals. The US firms, on the other hand, chose to respond to tougher pesticide regulations by taking advantage of the country's strong public-sector life science infrastructure through directing its R&D dollars into biotech programs. Since the early 1990s global farm chemical sales have been flat whereas sales of genetics by such companies have been booming. And even within the chemicals market, US firms have increased their share markedly at the expense of European firms, presumably because of the tie-in with genetics especially in the case of herbicide-tolerant soybean. The patent data reported in Graff and Zilberman (2004) also support the view that EU firms are weak in the new agricultural biotechnology and strong in the slow-growing conventional technology. Their interests therefore are better served by EU foot-dragging on agricultural biotech policy than by the more-liberal regulations adopted in North America.

Are there also reasons why EU farmers would not be opposed to such foot-dragging? Consider the following practicalities. If buffer zoning were to be required to reduce the risk that GM crops cross-pollinate with native grasses or to improve pollination of the GM variety, such regulations would be more costly (and hence more discouraging of adoption) in closely settled, small-plot, densely populated environments such as in Western Europe than in broad-acre settings such as in North and South America. Also, if domestic GM production diminished the region'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. Since buyers of EU crop products (mostly Europeans) are more inclined to affect farm profitability in these ways than are buyers of American GM crop products, this adds to the likelihood that EU farmers would prefer to remain GM free.

Even if there were to be a net gain to EU farmers as a group from GM adoption (although empirical analysis reported below suggest they would not), 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 the EU's generic reputation as a safe food supplier. That sub-group is likely to be relatively large at this stage at least, given that maize and soybean are minor crops in the EU, that opposition by environmental and consumer groups to the selling of GM foods in Europe remains very vocal, and that new tough labelling laws and low unintentional GM tolerance levels were legislated in 2004 that would require EU producers to put a high-cost segregation and identity preservation system in place if and when GM varieties are planted.

These possibilities will change over the long term of course, and consumer concerns in particular may well subside in the years ahead as they did for many other initially unpopular new food technologies such as milk pasteurisation. But history warns that such attitudinal changes may be slow in coming. Hence there is value in estimating the medium-term effects on economic welfare of current GM technologies and related trade policies, to which we now turn.

4 How has national welfare been affected to date in adopting countries, in the EU, and in non-adopting developing countries?

To estimate the welfare consequences of policies affecting GM crop adoption, a recent study employs a model of the world economy known as GTAP and reports several sets of simulation results (Nielsen and Anderson, 2001; Stone, et al., 2002; van Meijl and van Tongeren, 2004).[2] It begins with GM adoption for just coarse grains and oilseeds but then adds rice and wheat, and then cotton, to get a feel for the relative economic importance to different regions and the world as a whole of current vs. prospective GM crop technologies. The impacts of GM food crop adoption by just the USA, Canada and Argentina are considered first, without and then with policy reactions by the EU. The simulation is then re-run with the EU added 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. A change of heart in the EU would reduce the reticence of the rest of the world to adopt GM food crop varieties, so the effects of all other countries then adopting is explored as well.

Specifically, the base case in the GTAP model, which is calibrated to 1997 just prior to the EU moratorium being imposed, is compared with an alternative set of simulations whereby the effects of adoption of currently available GM varieties of maize, soybean and canola by the first adopters (Argentina, Canada and the USA) is explored without and then with the EU de facto moratorium on GMOs in place.[3] Plausible assumptions about the farm productivity effects of these new varieties and the likely percentage of each crop area that converts to GM varieties are taken from the latest literature including Marra et al. (2002), Qaim and Zilberman (2003) and Huang et al. (2004).[4]

The global benefits of GM adoption by the USA, Canada and Argentina is estimated to be US$ 2.3 billion per year net of the gains to the biotech firms (which are ignored in all that follows) if there were no adverse reactions in the EU or elsewhere. About one-quarter of that is shared with the major importing regions of the EU and Northeast Asia, while Brazil, Australia and New Zealand lose very slightly because of an adverse change in their terms of trade (column 1 of Table 2). But when account is taken of the EU moratorium, which is similar to an increase in farm protection there, the gain to the three GM-adopting countries is reduced by one-third. The diversion of their exports to other countries lowers international prices so welfare for the food-importing regions of the rest of the world improves – but only very slightly. Meanwhile the EU is worse off by $3.1 billion per year minus whatever value EU consumers place on having avoided consuming GMOs (column 2 of Table 2). If the EU instead were to allow adoption and importation of GM varieties, it would benefit because of its own productivity gains and so too would net importers of these products elsewhere in the world, while countries that are net exporters of coarse grains and oilseeds (both GM adopters and non-adopters) would be slightly worse off (only slightly because coarse grains and oilseeds are minor crops in the EU compared with North America – see column 3 of Table 2).

However, if by adopting the technology in the EU the rest of the world also 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, and almost all of the extra global gains would be enjoyed by developing countries. If one believes the EU's policy stance is determining the rest of the world's reluctance to adopt GM varieties of these crops, then the cost of the EU's moratorium to people outside the EU15 has been up to $0.4 billion per year for the three GM-adopting countries and $1.1 billion per year for other developing countries (column 4 of Table 2).

Table 2 Economic welfare effects of adoption of GM coarse grain and oilseed varieties by various regions, without and with EU reactions (equivalent variation in income, 1997 US$ million)

	USA, Canada and Argentina adopt GM coarse grain and oilseed varieties		*USA, Canada, Argentina and EU adopt*	*All countries adopt*
	With no moratoria responses	*With EU moratorium*	*With no moratoria*	*With no moratoria*
	Sim 1a	*Sim 1b*	*Sim 1c*	*Sim 1d*
USA	939	628	928	897
Canada	72	7	70	65
Argentina	312	247	307	287
Brazil	–36	256	–53	317
Other Latin America	125	184	128	356
Australia and New Zealand	–14	–2	–15	–4
EU-15	267	–3145	406	595
Eastern Europe	7	–10	8	35
China	107	111	110	235
India	0	3	0	252
Japan + Korea	322	341	335	430
Other Developing Asia	36	44	37	134
Sub-Saharan Africa	1	21	2	69
Rest of World	*152*	*75*	*167*	*380*
World	*2290*	*–1243*	*2429*	*4047*

Source: Anderson and Jackson (2005a)

Those estimates understate the global welfare cost of the EU's policy in at least three respects, however.

- The fact that the EU's stance has induced some other countries to also impose similar moratoria on GM food crops (if not cotton) has not been taken into account. Sri Lanka was perhaps the first developing country to ban the production and importation of GM foods. In 2001 China did the same (with some relaxation in 2002), having been denied access to the EU for some soy sauce exports because they may have been produced using GM soybeans imported by China from the USA.
- 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 as biotech firms redirect their investments towards pharmaceuticals and industrial crops instead of food crops.
- 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 commercial release.

How have EU farm households been affected by the EU moratorium? The above simulation study finds that their real incomes are somewhat higher with the EU moratorium than they would be if there was no moratorium and they were allowed to adopt GM varieties of maize, soybean and canola. This is because the price decline for those products would fully offset the productivity gain from adopting GM varieties. This provides another reason why it is unsurprising that EU farmers have not been lobbying for a pro-GM policy stance.

5 What impacts could GM food adoption by developing countries have?

A second set of simulations from the Anderson and Jackson (2005a) study involves a repeat of the first set except that China and India are assumed to join America in adopting existing GM crop varieties, and GM rice and wheat varieties are assumed to be made available to the GM adopting countries' farmers, again without and then with an EU import moratorium. In this case it is simply assumed that total factor productivity in GM rice and wheat production would be 5% greater than with current non-GM varieties. If China were to decide to approve the release of GM rice and wheat varieties, India would probably follow soon after. China and India account for 55% of the world's rice market and 30% of the wheat market, being close to self sufficient in both. They therefore do not have to worry greatly about market access abroad. If that led to enough other non-EU countries accepting GM varieties of these grains, this could well lead North American and Argentina also to adopt them.

Allowing China and India to join the GM-adopters' group, and adding rice and wheat to coarse grain and oilseeds, almost doubles the potential global gains from this biotechnology. The global economic welfare gain if there were no moratoria by the EU or others is estimated to be $3.9 billion with just rice added, or $4.3 billion if wheat is also added, instead of the $2.3 billion per year when just the original three countries and commodities are involved. 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 would accrue to China and India, with other developing countries, as a net grain-importing group, enjoying most of the residual via lower-priced imports.

What about when the EU moratorium is in place? The cost to the rest of the world (again assuming the EU policy is discouraging GM adoption elsewhere) rises from $1.5 billion to $2.9 billion per year. And the adding of further crops to the GM family would continue to multiply that latter estimate.

Were the EU to embrace GM food and all countries adopted GM grains and oilseeds, the estimated global gains would rise to $7.5 billion per year, $4.4 billion of which would accrue to developing countries.

A third set of simulations adds to the second set the adoption of GM coarse grain, oilseeds rice and wheat by the South African Customs Union (SACU), and focuses on what difference it would make if Southern African Development Community (SADC) countries other than SACU members either banned imports of GM varieties or allowed their farmers and consumers access to them, again with and without the EU import moratorium. This set is of interest because recently South Africa approved the release of GM maize and the initial take up has been very impressive, including by smallholders (Gouse et al., 2005). Also, Kenya and Egypt are engaging in GM field trials (Thomson, 2004). Africa lagged far behind Asia and Latin America following the Green

Revolution with dwarf cereal varieties that began in the 1960s. And its relatively low rate of investment in agricultural R&D was even slower in the 1990s (Beintema and Stads, 2004), contributing importantly to that continent's relatively slow growth in per capita food production (Evenson and Gollin, 2003). Partly as a result, Africa now accounts for one-third of the world's people living on less than $1 a day (up from one-tenth two decades ago – Chen and Ravallion, 2004).

Since the vast majority of those poor people in Sub-Saharan Africa are dependent on agriculture for their livelihood and much of their food, the new biotech revolution provides a potential opportunity for raising the welfare of hundreds of millions of Africans. Yet African countries exporting food products fear that they will find the EU and other food-importing countries discounting or denying access to their products if their farmers adopt GM technology or even if they import GM food (because of the risk of contamination of domestically produced non-GM food). A critical question is: would African food exporters gain more from reduced American competition in the EU market than from trying to develop and adopt new GM crop varieties? If that improved competitiveness required in turn a ban on imports of all food and feed from GM-adopting countries by those African countries so as to avoid contamination (as ostensibly feared by Mozambique, Zambia and Zimbabwe when they were offered food aid from the USA in 2002), would the domestic economic loss to net buyers of food outweigh the gains to farmers in those countries from such an import ban? How would welfare in the rest of Sub-Saharan Africa be affected if SACU and perhaps other members of SADC choose to adopt GM varieties of food crops?

Assuming no adverse reaction by consumers or trade policy responses by governments, Anderson and Jackson (2005b) shows that the adoption of GM varieties of coarse grains and oilseeds by SACU in the absence of the EU moratorium would benefit SACU an extra $6 million per year while helping the rest of Sub-Saharan Africa by $1 million. However, in the presence of the EU ban, SACU would be $1 million worse off and the rest of Sub-Saharan Africa an extra $1 million better off. If SADC members other than SACU follow the EU in placing a ban on imports of products that may contain GMOs, SACU is made worse off by $4 million while the rest of SADC is hurt even more, by $14 million per year (assuming consumers there are indifferent to consuming food that may contain GMOs). By contrast, if the rest of SADC were to adopt GM varieties along with SACU, its welfare would be boosted by $26 million instead of reduced by $10 million, and SACU's would be up by a further $4 million annually – despite the assumed continuance of the EU moratorium.

6 What difference can GM cotton make to developing country welfare?

The spread of GM cotton to developing countries is beginning to pick up speed. As of 2004, it accounted for one-ninth of the world's total area of GM crops, and GM varieties accounted for 28% of all land sown to cotton (Table 1). But the US and China account for almost all of that, where the proportion of plantings that are GM are four-fifths and two-thirds, respectively. The only other countries with high GM adoption rates by 2004 are Australia and South Africa, both with slightly more than four-fifths of their cotton areas under GM varieties.

What impact has that adoption by those four countries had on global welfare, and how much greater would be that impact if other producing countries (almost all of whom are developing economies, and some of whom have begun releases recently) were to promote widespread adoption of GM cotton varieties? To answer that question, results are drawn from global simulation modelling. Again starting with the 1997 GTAP baseline, we first simulate the effect of a 6% total factor productivity shock to cotton production in the USA, Australia, China and South Africa (a conservative estimate of the gain to farmers, according to Marra et al., 2002; Qaim and Zilberman, 2003; Huang et al., 2004). That is then compared with a shock in which all other countries adopt. The total factor productivity shock in that second simulation is also 6% except for India and Sub-Saharan Africa (excluding South Africa), where it is 15%. Even that higher value is conservative for those countries, according to Qaim and Zilberman (2003), because their yields per hectare with conventional varieties are less than one-third those in the rest of the world and the GM field trials in India have been boosting yields by as much as 60%.

The results from the first cotton simulation (presented as Sim 2a in column 2 of Table 3, suggest the world has been better off by $424 million per year (again in 1997 US dollars, and again not counting whatever net profits accrue to the biotech and seed firms), because of the adoption of GM cotton varieties by the USA, China, Australia and South Africa.[5] Most of those gains accrue to those adopting countries, but cotton-importing countries also gain because of the almost 1% lower average price of cotton in international markets. However, other cotton-exporting developing countries – most notably other Sub-Saharan Africa, whose output and exports fall by 2–3% – lose from the terms of trade change.

Once all other countries adopt as in Sim 2b in Table 3, the global benefits quadruple and Sub-Saharan Africa and Asia benefit most.[6] South Africa's cotton output and exports would fall instead of rising as in Sim 2a, but the rest of Sub-Saharan Africa would see its cotton output and exports rise 10 and nearly 20%, respectively instead of falling as in Sim 2a. Other Asian developing countries that are net importers of cotton also gain even if they grow little or no cotton, because the international price of that crucial input into their textile industry would be lower by an average of 4.0% in this scenario (as compared with just 1% from the GM adoption in just four main countries to date).

How do those prospective gains from all other countries adopting GM cotton compare with the effects of eliminating all cotton subsidies and tariffs (Sim 3 in Table 3), as called for by several cotton-exporting developing countries as part of the WTO's Doha Development Agenda? This can be seen by comparing the final two columns of Table 3. The estimated global gains from that trade liberalisation, assumed to be phased in over the next decade, would be a little less than from the global spread of GM cotton varieties ($1.2 billion compared with $1.4 billion pa in 1997 US dollars). But most of the prospective gains from subsidy and trade reform would go to high-income countries, notably the USA because of eliminating its wasteful cotton subsidies (and also Australia, because of higher cotton export prices). So only $258 million pa would go to developing countries in aggregate (and India would lose, because it is projected to be a net import of cotton by the end of the phased liberalisation in 2015), compared with the developing country gain from the spread of GM cotton of five times that amount ($1.28 billion pa, less the cost of any public research and extension needed to develop and disseminate that). That comparison suggests developing countries have even more to gain from focusing on new cotton biotechnologies than on the elimination of trade-distorting cotton subsidies and tariffs.[7] And if by embracing cotton biotech developing countries also decided to allow GM food production, they would be able to multiply that $1.28 billion gain several fold, according to the numbers presented in the previous section which suggest a $4.4 billion gain from all countries adopting GM varieties of all grains and oilseeds (or a bit less if the EU were to retain its restrictions on GM food imports).

Table 3 Economic welfare effects of adoption of GM cotton varieties by various regions, and of removal of cotton subsidies and tariffs globally (equivalent variation in income, 1997 US$ million)

	Share of global cotton exports 2001, percent[a]	*USA, China, Australia and South Africa adopt GM cotton*	*All countries adopt GM cotton*	*Difference when all other countries adopt GM cotton*	*All countries eliminate cotton subsidies and tariffs*
		Sim 2a	*Sim 2b*	*Sim2b-Sim2a*	*Sim 3*
USA	*33*	*126*	*95*	*–31*	*903*
Australia	15	21	1	–20	228
China	1	177	179	2	6
South Africa	0	2	7	5	8
Japan + Korea + Taiwan	0	55	106	51	–122
W. Europe + Canada + NZ	0	30	177	147	–69
Latin America	*5*	*14*	*115*	*101*	*60*
Other Sub-Saharan Africa	15	–11	143	154	361
India	1	–6	741	747	–281
Other Developing Asia	11	20	181	161	73
Other Developing, incl.[b]	19	–4	106	109	16
All developing countries	52	192	1474	1282	258
World	100	424	1853	1429	1198

[a]Excluding intra-EU trade (mostly from Greece).

[b]Includes Former Soviet Union.

Source: Authors' GTAP model estimates and (for final column) Anderson et al. (2006a, 2006b)

7 Conclusions and policy implications

From the viewpoint of developing countries, the above results are good news. The new agricultural biotechnologies promise much to the countries willing to adopt these new varieties. Moreover, the gains from farm-productivity enhancing GM varieties could be multiplied – perhaps many fold – if biofortified GM varieties such as golden rice were also to be embraced (Anderson et al., 2005). The estimated gains to developing countries are only slightly lower if the EU's policies continue to effectively restrict imports of affected crop products from adopting countries. More importantly, developing countries do not gain if they impose bans on GM crop imports even in the presence of policies restricting imports from GM-adopting countries: the consumer loss net of that protectionism boost to Asian and Sub-Saharan African farmers is far more than the small gain in terms of greater market access to the EU (Paalberg, 2005).[8]

The stakes in this issue are thus very high, with welfare gains that could alleviate poverty directly and substantially in those countries willing and able to adopt this new biotechnology. Developing countries need to assess whether they share the food safety and environmental concerns of Europeans regarding GMOs. If not, their citizens in general, and their poor in particular, have much to gain from adopting GM crop varieties. Unlike for North America and Argentina, who are heavily dependent on exports of maize and oilseeds, the welfare gains from GM crop adoption by Asian and Sub-Saharan African countries would not be greatly jeopardised by rich countries banning imports of those crop products from the adopting countries. If the reason for China's reluctance to approve GM food crop 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).

Labelling policies potentially provide a more efficient mechanism than trade moratoria for accommodating consumers' preferences for non-GM food. They would involve a cost to the global economy – and especially to developing country exporters – because of the necessary segregation and identity preservation systems, but their adoption in place of the current EU ban would provide both rich-country and poor-country consumers with greater choice than at present. However, more economic modelling research is required to include the costs of segregating GM-inclusive from GM-free food products and to explore the incidence of the identity preservation cost between GM and non-GM farmers, between farmers as a group and others, and between rich and poor countries. As Baldwin (2001) argues, the more costly are the segregation and identity preservation systems necessary to meet rich-country labelling standards, the more they will disadvantage exports from poor countries relative to rich countries.

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Notes

[1]The other key contributor was the post-war growth of agricultural protectionism in developed and newly industrialising countries (Tyers and Anderson, 1992).

[2]This section draws on results presented in Anderson and Jackson (2005a), which in turn has been inspired by earlier global modelling analysts including Nielsen and Anderson (2001), Stone et al. (2002), and van Meijl and van Tongeren (2004).

[3]This has to be done in a slightly inflating way in that the GTAP model is not disaggregated below 'coarse grains' and 'oilseeds'. However, in the current adopting countries (Argentina, Canada and the USA), maize, soybean and canola *are* the dominant coarse grains and oilseed crops.

[4]We assume 45% of USA and Canadian coarse grain production is GM and, when they adopt, all Latin American countries and Australia are assumed to adopt GM coarse grains at two-thirds the level of the USA while all other countries are assumed to adopt GM coarse grains at one-third the level of US adoption. For oilseeds, we assume that 75% of oilseed production in the USA, Canada and Argentina (and Brazil when we allow it) 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 prospective rice scenarios, major assumed adopters, including the USA, Canada, China, India, and all other Asian countries are assumed to produce 45% of their crop using GM varieties. All other regions adopt at two-thirds this rate. Prospective GM wheat adoption is assumed to occur to the same extent as coarse grain adoption for all regions. The GM varieties are assumed to enjoy higher total factor productivity than conventional varieties to the extent of 7.5% for coarse grains, 6% for oilseeds and 5% for wheat and rice. The simulations are able to estimate the equivalent variations in income, measured in 1997 US dollars, that would result from these assumed degrees of adoption and productivity growth for the GM potion of each crop and its consequence effect on markets.

[5]This is an underestimate to the extent that Bt varieties of GM cotton involve about 70% less pesticide spraying and so are less harmful both to the environment and – especially in developing countries where spraying is done manually with a back pack – to farmer health (Hossain et al., 2004).

[6]This is especially true when expressed as a share of GDP: for India that share is 26 times the global average, and for Sub-Saharan Africa it is 12 times.

[7]Of course full elimination of those subsidies and tariffs is unlikely in the foreseeable future. Partial liberalisation is a possibility for agricultural policies as a whole though, under the WTO's Doha Development Agenda. A recent study provides estimates of such a reform outcome (Anderson et al., 2006). It suggests, even with an optimistic scenario involving both developed and developing country agricultural reform commitments, that the gains for Sub-Saharan Africa (excl. South Africa) would be only $157 million pa, which is little more than the above estimate of the gain from GM cotton adoption ($154 million pa). And for South and Southeast Asia the estimated gain from Doha agricultural reform ($341 million pa) is less than 40% of that from GM cotton adoption ($908 million pa).

[8]This is consistent with the finding by Paalberg (2005) that African exports of food crops in general to the EU that might be affected adversely by GM adoption represent a very small share of the region's exports.