Why are US and EU policies toward GMOs so different? Estimating intra-national distributive impacts using GTAP

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Abstract

While GTAP has been used extensively to analyse national and global impacts of trade and other policies, it has been exploited much less for understanding the much larger (in proportional terms) distributive outcomes within countries of such shocks, or of shocks that have a feedback effect on trade policies. Yet we know that redistributive effects are at the heart of trade and other regulatory policy formation. This paper uses GTAP to examine how the adoption of new agricultural biotechnologies affects the welfare of key groups within both adopting and non-adopting countries (a) in the absence of trade or other policy responses and (b) in their presence. This adds to our understanding as to why countries have adopted such widely differing policies towards GMOs.

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Introduction

Genetically modified (GM) agricultural products provide enhanced productivity and yield improvements under a wide variety of conditions (Marra, Pardey, and Alston 2002). They are also bringing new dimensions to global science and technology policy, international standards setting, and global trade policy. Some groups believe GM products require new types of oversight to reduce potential environmental and food safety risks associated with their production and/or consumption, including restrictions on their international trade. Other groups, who believe that environmental and food safety risks are low, criticize policies that reduce trade in these products for being very costly and perhaps illegal.[1] Reconciling those groups' differing viewpoints in international fora is essential if the full global benefits from creating and adopting the new biotechnologies, and thereby lowering food costs, are to be reaped without incurring excessive environmental and food safety risks.

Those two different views are reflected in the European Union and the United States policy positions regarding the production, use and trade of agricultural biotechnology products. The EU has imposed a moratorium on the import and introduction of these products because it claims these products represent undetermined risks to the food safety and environmental health of member countries.[2] In contrast, the US has widely adopted GM crops following their first approval in the mid-1990's. In the US consumer resistance to these crops has developed only gradually and remains much lower than in the EU.

Neither of these extreme policy positions is likely to be optimal. Negative production externalities call for some type of tax on GM production, while the consumers' demand for unobservable information about the products they might consume call for a credible labelling system. The divergence in regulatory approaches between the US and the EU is puzzling, given the many economic similarities of these economies. Some analysts have argued that these differences stem from fundamental differences in consumer attitudes and expectations (e.g., Bernauer and Miens 2001).[3] Yet we know that in high-income countries consumers, even with the support of environmental groups, are traditionally weak policy lobbyists relative to producer groups (Hillman 1989). This paper therefore explores the hypothesis that differences in US and EU farmers' interests provide an additional or alternative explanation. It

[1] Trade restrictions are costly not only for the usual comparative static reasons but also because they reduce the incentive to produce and exploit new biotechnologies; and they may be illegal to the extent that they contravene international trade agreements, most notably under the WTO.

[2] In October 2002 the European Union adopted tough regulations on authorising imports of new GM crops. However, EU member country governments are unlikely to support new crop approvals without additional rules requiring identity preservation of GM products (Financial Times 2002).

[3] Bernauer (2003) also cites distrust of EU food regulators and the nature of EU federalism as further reasons for the extreme EU policy position.

does so by examining distributional effects of actual policies to see if they can shed light on these differing GM policy choices.

We know from theory that policies affecting crop production and trade alter returns to land, labour and capital and thereby create incentives for factor owners to influence national policy. In this paper we describe a simplified analytical framework for using the GTAP model to examine how intra-national distributional implications of GM policies could contribute to GM policy choices.

Multi-country general equilibrium models that have been designed to capture the impacts of policies on international trading relationships, such as GTAP, typically provide detailed accounts of their impact on prices and quantities of intermediate and final products but limit their welfare analysis to the 'average' household. That is, they typically ignore the intra-national distributional impacts necessary to provide useful insights into the political economy underlying trade policy decisions at the national level.[4] This paper adds information about the earning and spending profiles of vested interest groups so as to evaluate the intra-national distributive impacts of GM technology and trade policies.

GTAP is useful in carrying out this type of analysis due to its detailed global data and disaggregated agricultural sector. In addition, since GTAP models include existing trade distortions, modelling efforts that build upon this framework describe more realistically the potential result of policies by capturing the interactions between additional trade barriers and the existing system of global trade distortions. This paper uses version 5 of the GTAP database to model the productivity impacts of GM technology adoption in a subset of regions, assuming that the primary genetically modified crops are oilseeds and coarse grains. With that base projection, we then explore contrasting economic consequences of these technologies when countries adopt import barriers to GMOs versus when they choose labelling strategies of varying rigour.

Simulating GM agricultural policies

The global, economy-wide GTAP model can capture the effects of productivity increases of GM crops, of consumer aversion to consuming GM products, and of the substitutability of GM and non-GM products as intermediate inputs into final consumable food. The version used here was adapted by Stone et al. (2002) and is aggregated to 9 regions, 13 sectors, and four types of factors: agricultural land, non-human capital, skilled labour, and basic (unskilled) labour. All factors are assumed to be perfectly mobile within the economy (although sensitivity analysis is performed to determine the impact on the welfare and income results of assuming sluggish land).

Production

Data on global adoption of GM technologies reveal a wide divergence in adoption across countries (see James 2002). Therefore, the GTAP model includes assumptions about the level of GM adoption in countries. For the purposes of this paper the shares of GM crops are based upon estimates made by Stone et al. (2002).

[4] More recently attention has focussed on extending multi-country models to examine how trade policies affect poverty (Hertel et al. 2002; Decaluwé et al. 1999). These types of analyses use multi-country models in conjunction with detailed expenditure data from household surveys to highlight the differential impact of policies across income groups. Such efforts are, however, very data intensive.

In these GTAP simulations 40% of North American (NA) coarse grain production and 65% of its oilseed production is assumed to be GM. In contrast, only 10% of EU coarse grains and oilseed production is assumed to be GM. These are conservative estimates of current levels of GM adoption in NA and probably over-estimate current levels of EU adoption but they reflect estimates by James (2002). In addition, 10% of coarse grains and oilseed production in Australia, China, Japan, and Korea and 15% of coarse grains and oilseed production in the Rest of the World are assumed to be GM. Neither the Middle East nor New Zealand is assumed to produce GM crops.

To distinguish GM from non-GM productivity, the coarse grain and oilseeds sectors are each sub-divided into GM and non-GM product and an output augmenting, Hicks neutral, productivity shock is implemented on the GM component of these two commodities to capture their higher productivity.[5] This assumes that GM technology uniformly reduces the level of primary factors and intermediate inputs needed per unit of output.[6]

In the CES production nest, producers choose first between imported and domestic inputs, and then choose whether or not to use GM or non-GM intermediate inputs in their production of final goods. This model structure supports the analysis of segregated markets in our scenario that examines mutual adoption of a labelling system. In addition, Armington elasticities, which determine the substitutability between domestic goods and imports, are doubled, following the work of other modellers focusing on long-run results. That change traded quantities to adjust more readily to exogenous shocks.

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 are set at low levels to capture the perceived low substitutability of these products. In addition, preference shift parameters are included to capture the group of consumers that, because of food safety or environmental concerns, refuses to consume GM crops regardless of their price.

In order to capture consumers' apprehensions about eating GM foods, a 25 percent reduction in demand for imported GM grains and oilseeds in specific countries is assumed, following Anderson and Nielsen (2001) and Stone et al. (2002).

Factor Ownership

GTAP provides a comprehensive decomposition of changes in national economic welfare as measured by the equivalent variation in income. However, national and world measures of welfare changes ignore the distributional implications within countries of GM policies. They therefore fail to provide insights into the potential political economy of GM policy choices. While the total benefits from trade decrease when inefficient policies such as import bans are implemented, some groups within national economies will be beneficiaries. Hence further assumptions about the

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[5] GM wheat and rice are yet to be widely commercialised and so are not considered in our analysis.

[6] 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), Nielsen, Thierfelder and Robinson (2001)). For studies that differentiate the degrees of factor/input saving, see Huang et al. (2002) and Van Meijl and van Tongeren (2002).

intra-national distribution of factor ownership are required to disaggregate GTAP welfare measures.

In this analysis, economies are assumed to be composed of three groups of households: farmers, basic wage earners, 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 specific information about the availability and use of land, unskilled labour, skilled labour and other capital in the agricultural sector and other sectors. Table 1 includes the factor shares for agriculture as found in the GTAP database that are used as the basis for determining factor ownership information. Factor income shares for non-farm activities of farm households are assumed to be the same as those for other capital owners. Non-farm activities are assumed to use factors in the same proportion as activities conducted by the typical capital-owning household. Factor shares for this household are a weighted sum of factor shares used in agricultural production and the factor income shares of capital owners. The shares of farm household income from non-farm activities is assumed to be 90% in Japan and Korea, 50% in China and the EU, 35% in North America (NA), 25% in Australasia, and 20% in other developing countries (DCs). Basic wage earners receive all their income from unskilled non-farm labour. Capital-owning households gain income from ownership of land, skilled labour, and capital used in non-agricultural sectors. (See Appendix A for formal description of income calculations.) The GTAP database also provides data on expenditure shares.[7]

Scenarios

Three separate policy simulations were conducted to examine the impact of GM regulations. In the first scenario, selected regions adopt GM grain and oilseeds. This scenario captures the effects of productivity shocks on GM technologies. This scenario represents the base case conditions in which some countries have adopted GM coarse grain and oilseeds and experienced productivity increases from these crops, in the absence of any policies to control the adoption, importation or labelling of GM products. Following Stone et al. (2002), these model simulations assume that GM oilseeds have a 6% productivity gain and GM coarse grains have a 7.5% productivity gain, modelled as a shock to factor and input demand in GM sectors "afeall".

The second scenario is the same as scenario 1 except it assumes that this productivity shock occurs in conjunction with an EU moratorium on GM imports from North America (NA). Under this scenario there is no segregation between GM and non-GM products and therefore the import ban is imposed on all coarse grains and oilseeds from NA. Hence, this scenario is modelled by increasing the tariff on imports of all coarse grains and oilseeds from NA to the EU to a prohibitive level.

The third scenario involved a similar simulation to scenario two but with the impacts of a moratorium imposed also by Japan, Korea and Australasia.

The fourth scenario is as for scenario one except it assumes the EU and North America implement labelling policies that allow consumers to choose between non-GM products and those that may contain GM content. In this scenario all countries adopt labelling regulations and diehard consumers in the EU, Australia, New Zealand,

[7] The role of government transfers in income change is not included in this analysis. Future studies could incorporate information from the GTAP database concerning these transfers and how they change under different policy scenarios.

Korea and Japan avoid consuming coarse grains and oilseeds.[8] This is modelled by a 25% reduction in final consumption of coarse grains and oilseeds in those countries.

Macro and trade effects of new biotechnology

Productivity Shock without policy reactions

The first scenario captures the impact of enhanced productivity of biotechnology crops. Table 2 presents the results from this simulation and highlights the role of technical change in these welfare-improving effects. World welfare improves by US$2.7 billion, with more than half of these benefits accruing to North America. In the EU more than half the (much smaller) welfare impacts come from improved allocative efficiency, as resources move out of heavily subsidized agricultural sectors due to increased import competition from North America. In this first scenario, all regions experience improved welfare, as measured by the equivalent variation, except for Australia and New Zealand whose terms of trade deterioration outweighs the smaller technological improvements.

Productivity Shock with policy reactions

A series of policy reactions are modelled in conjunction with the productivity shock described above: an trade moratorium on biotechnology products by the EU, a trade moratorium on biotechnology products by the EU, Australia, New Zealand, Japan and Korea, and a labelling regime adopted by the EU, Australia, New Zealand, Japan and Korea.

When the EU alone imposes a moratorium on imports of biotechnology products, the world experiences a negative welfare impact of US$1.5 billion. In this scenario, while all countries except the EU experience welfare improvements, the large negative allocative effect on the EU, driven by the expansion of heavily subsidized agricultural sectors, outweighs the total positive impacts from the new technology in the remaining regions.[9] In NA the gain from the new technology is somewhat offset by an adverse terms of trade change plus an allocative efficiency loss caused by the movement of resources from lightly assisted coarse grains and oilseeds to more-heavily assisted crops. By contrast, developing countries experience greater positive impacts in the EU moratorium scenario due to their improved terms of trade. (However, it should be kept in mind that these results do not capture the dynamic impact of dampened research investment that the EU moratorium would induce, thereby over-estimating the benefits obtained by this groups in the long run.)

In the scenario with the general moratorium response, the allocative and terms of trade impacts on NA and the EU are similar to but much larger than in the EU moratorium scenario. Japan and Korea experience large negative welfare impacts, due

[8] In this simulation, segregation is assumed to be not required for labelling. Products from countries that produce both GM and non-GM grains and oilseeds label their products "may contain GMOs." This assumption reflects the difficulty in credibly segregating bulk commodities such as coarse grains into separate GM and conventional product streams. US policy makers often cite these types of difficulties to justify their aversion to identity preservation schemes. Since this simulation does not examine the implications of identity preservation then, unlike in (Stone et al. 2002), it does not include segregation costs.

[9] For more on the impact of price-distorting policies on the gains from new biotechnologies, see Anderson and Nielsen (2002).

to the combined negative allocative and terms of trade effects. By contrast, China and other developing countries experience larger positive and terms of trade impacts than in the EU moratorium scenario due to decreased competition from NA coarse grains and oilseeds. Japan and Korea, countries that benefited from the EU moratorium, in this case experience large negative welfare impacts due to a large efficiency loss, as heavily subsidized agricultural sectors expand to meet the demand not met by North American coarse grains and oilseeds.

In the labelling scenario, global benefits are US$2.66 billion, or only very slightly less than in the pure productivity response. In contrast to the moratoria scenarios, both NA and EU benefit from labelling. NA experiences a small negative terms of trade impact and a small but positive allocative impact, while the EU experiences a positive allocative impact due to the movement of resources out of heavily subsidized agricultural production.

Distributional effects of new biotechnology

Analysis of the distributional consequences of these policy scenarios provides additional perspective on these macro-level results. Table 3 reports the percentage change in factors prices under the four modelling scenarios and Table 4 reports the calculated percentage changes in real incomes of various households.

Productivity shock without policy reactions

Results indicate that farm households in GM-adopting countries experience a decrease in income due to the relatively large decreases in the land rental rates associated with the productivity shock, given the large income share that land represents for farm households (Table 4).[10] North American farm households experience the largest decrease in real income due to the heavy adoption of GM products and the subsequent decreased demand for land inputs. That is, GM-adopting farmers are not just sharing the benefits of the technology with consumers, via food price declines, but are becoming worse off if the extent of adoption is as much as modelled here. Farm households in Australia-New Zealand and some developing countries also lose, at least slightly, from the technology's widespread adoption by NA (Column 1, Table 4). The loss results from the lower price of coarse grains and oilseeds in international markets and hence lower returns to land producing these or substitute crops. Chinese farmers benefit from the productivity shock as labour and capital returns, which are sources of off-farm income for farm households, increase. Unskilled labourers and other non-farm households benefit from the productivity enhancing effects of GM technologies in all regions. The boost to real incomes of non-farm households in less-adoptiong countries results from lower food prices and a greater demand for their factors of production. The non-farm sector expands when

[10] The small size of the percentage changes in income accurately reflects the change in income relative to GDP. The factor income changes are composed of changes in the factor prices in each region and the relative importance of these factors in income among different groups. Because the scenarios modelled primarily affected the agricultural sector, land values experience relatively large changes, whereas labour and capital values change very little. These changes in factor prices are aggregated based upon their share of house. Since land represents a relatively small share of household income the impact of large changes in land values is buffered. Despite the relatively small size of these results, they indicate of how different groups might be impacted by GMO policies. Developing countries in general experience increased factor incomes across the three groups portrayed here.

farm output declines in those less-adopting countries because of the improved competitiveness of GM-adopting countries.

Productivity shock with policy reactions

In the policy simulation in which EU countries impose trade restrictions on GM crops, farm households in those countries benefit through increased land values while other groups there experience declining incomes due to declines in wages and capital rental rates Column 2 in Table 4 also shows that in AUS-NZ, JAP-KOR, China and Other DCs all household groups experience an increase in real income due to lower food prices and the resulting decrease in expenditure on food.

When more countries adopt a moratorium on NA's GM exports, farmer households in AUS-NZ, China, and other DCs benefit from the improvement in their competitive positions (Column 3, Table 4). While results from this scenario indicate that farm household incomes in developing countries increase when significant numbers of countries adopt a trade moratorium on GM products, these gains must be put in the context of the relative efficiency of these outcomes. Recall from Table 2 that the negative change in global welfare in this scenario is nearly four times the size of the negative changes in the EU moratorium case, primarily due to large negative allocative effects.

In the labelling scenario, the directions of the real income changes are the same as those in the scenario involving a productivity shock without a policy response. Farm households in NA, EU, Australia-New Zealand and Other DCs experience slightly lower real incomes than in the first scenario for similar reasons as described above. In China farm households experience an increase in real income due to the increases in wages of unskilled labour and returns to capital plus decreased food prices. These results, combined with the results reported in Table 2, indicate that while labelling provides a far more efficient mechanism for addressing consumer concerns over GM products as compared to trade moratoria, the economic distribution of benefits within regions may generate interest group antagonism towards these policy options.

Sensitivity analysis

Sensitivity analyses were conducted to determine the importance of parameter and adoption assumptions in the model results. Firstly, when land is mobile the productivity shock to GM products draws more land into these sectors. An alternative assumption is to assume land movement is sluggish, in which case welfare in North America (the major GM adopting region) rises by 16% less than in the first case shown in Table 2. That difference in North American welfare is due to a larger negative terms of trade impact and a smaller positive allocative efficiency impact. In contrast, under the sluggish land assumption European welfare is greater by 25% in the EU moratorium case and 19% greater in the broader moratorium scenario, as compared with the first scenario in Table 2. Those improvements are a function of improved allocative efficiency effects.

Secondly, using the default Armington elasticities instead of doubling them has relatively modest welfare, the largest being for the broader trade moratorium scenario. In that scenario North America experiences an increase in welfare when the substitutability of imported and domestic products is decreased (due to less deterioration in its terms of trade), while in all other regions welfare worsens slightly.

The effect of altering our assumptions on the extent of GM adoption by various regions was also examined. As mentioned above, in the scenarios modelled here all regions put some proportion of their crops to GM varieties, with North America adopting by far the largest proportion and many others only a small fraction. Changing the latter to zero adoption makes very little difference to the results, however.

Implications for NA and EU farm lobbyists

These results show clearly that NA farmers would be much worse off, and that EU farmers are much better off, if the EU and other countries ban the import of GM products than if their importation is allowed – and moreso the more other countries copy the EU's ban. Labelling, on the other hand, would have a very much less adverse impact on NA farmers than an import ban (although the costs of segmentation have not been incorporated into the present study) – and it would have a negative impact on EU farmer incomes.

These results are therefore not inconsistent with the hypothesis that producer interest group are playing a role in determining policy in the two regions: NA farmers would be least worse off with no anti-GM reaction abroad, but would be far worse off with import bans than with labelling; while EU farmers would be harmed by not only no policy reactions but also by labelling, in contrast to the import ban which helps them considerably. Moreover EU farmers benefit even more if other food-importing countries also ban imports from GM-adopting countries.

Results from the moratoria simulations suggest that when rich countries introduce trade barriers against GM products, developing countries benefit. However, the above analysis does not take into account that moratoria will slow the investment in agricultural biotechnology, and so reduce the future 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 rice enhanced with Vitamin A. The costs of delaying investments in those GM technologies will fall heavily on the world's poor (Nielsen and Anderson 2003).

In contrast to trade moratoria, labelling policies provide a mechanism for supporting consumer preferences to avoid GM technologies without imposing large inefficiencies on the global economic system. Their adoption in place of the current bans will provide both rich-country and poor-country consumers with greater choice than at present. However, more research is required to include the costs of separating GM-inclusive and GM-free products and explore the incidence of that cost as between farmers and others (and rich and poor countries). Further exploration is also needed of the gains or losses to developing country farmers should their adoption of GM technology be more widespread (the next Green Revolution).

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Table 1. Factor shares in agriculture

Region	Land	Unskilled labour	Skilled labour	Other capital
NA	0.12	0.34	0.06	0.48
EU	0.07	0.45	0.08	0.40
Australia+New Zealand	0.12	0.45	0.07	0.36
Japan+Korea	0.14	0.41	0.09	0.36
China	0.24	0.55	0.01	0.19
Other DCs	0.22	0.40	0.02	0.36

Source: GTAP Version 5 database

Table 2: Decomposition of global economic welfare impacts of GM adoption without and with policy responses (US$ million)

		Equivalent Variation		
Without policy responses				
	Total	**Allocative efficiency**	**Terms of trade**	**Technical Change**
NA	1482	168	-96	1386
EU	362	219	35	120
Australia+New Zealand	-5	1	-12	6
Japan +Korea	114	40	80	5
China	139	21	11	108
Other DCs	596	87	-17	527
Total	2687	535	0	2152
With EU moratorium response				
NA	624	-349	-381	1374
EU	-3137	-3352	65	129
Australia+New Zealand	16	3	7	6
Japan +Korea	121	29	88	5
China	123	6	10	108
Other DCs	710	-33	211	531
Total	-1544	-3696	0	2153
With broader moratorium response				
NA	252	-293	-746	1359
EU	-3400	-3678	143	129
Australia+New Zealand	96	-46	136	7
Japan +Korea	-3995	-3646	-430	13
China	246	-22	158	111
Other DCs	1359	87	738	537
Total	-5442	-7598	-1	2157
With labelling response				
NA	1446	137	-102	1385
EU	558	406	47	120
Australia+New Zealand	-9	4	-19	6
Japan +Korea	-90	-161	78	5
China	147	24	14	108
Other DCs	613	105	-19	527
Total	2664	514	0	2150

[a] Includes Latin America, Rest of Asia, Africa, Middle East, Eastern Europe and the former Soviet Union

Source: Authors' GTAP model results

Table 3: Percentage change in factor prices under four scenarios

	Farm Land	Skilled Labour	Unskilled Labour	Other Capital
Without any policy response				
NA	-1.16	0.02	0.03	0.02
EU	-0.71	0.00	0.00	0.00
Australia-New Zealand	0.00	-0.01	0.00	-0.01
Japan-Korea	0.00	0.00	0.00	0.00
China	-0.12	0.00	0.02	0.01
Other DCs	-0.01	0.00	0.00	0.00
With EU moratorium response				
NA	-1.83	-0.01	0.00	-0.01
EU	9.46	-0.06	-0.08	-0.08
Australia-New Zealand	0.00	0.00	0.00	0.00
Japan-Korea	0.00	0.00	0.00	0.00
China	-0.05	-0.01	0.00	0.00
Other DCs	0.00	0.00	0.00	0.00
With broader moratorium response				
NA	-3.56	-0.03	0.00	-0.02
EU	10.42	-0.04	-0.07	-0.06
Australia-New Zealand	0.02	0.05	0.02	0.05
Japan-Korea	0.03	-0.05	-0.03	-0.05
China	1.02	0.09	-0.03	-0.02
Other DCs	0.03	0.02	0.00	0.01
With labelling response				
NA	-1.23	0.02	0.03	0.03
EU	-1.45	0.00	0.01	0.01
Australia-New Zealand	0.00	-0.01	0.00	-0.01
Japan-Korea	0.00	0.00	0.00	0.00
China	-0.14	0.00	0.02	0.02
Other DCs	-0.01	0.00	0.00	0.00

Source: Authors' GTAP model results

Table 4: Percentage change in real incomes

	Without policy response	With EU moratorium	With broader moratorium	With labelling response
NA				
Farmers	-0.13	-0.20	-0.38	-0.14
Unskilled Labourers	0.02	0.04	0.02	0.06
Capital Owners	0.02	0.03	0.05	0.10
EU				
Farmers	-0.03	0.30	0.37	-0.07
Unskilled Labourers	0.00	-0.08	-0.08	0.01
Capital Owners	0.00	-0.06	-0.08	0.01
Australia-New Zealand				
Farmers	-0.02	0.00	0.19	-0.03
Unskilled Labourers	0.00	0.01	0.04	0.00
Capital Owners	0.00	0.01	-0.02	0.01
Japan-Korea	0.01	0.01	-0.26	0.01
Farmers	0.00	0.01	-0.25	0.00
Unskilled Labourers	0.00	0.01	-0.25	0.00
Capital Owners				
China				
Farmers	0.02	0.02	0.11	0.02
Unskilled Labourers	0.02	0.03	-0.05	0.03
Capital Owners	0.04	0.04	-0.14	0.04
Other DCs				
Farmers	-0.01	0.05	0.15	-0.02
Unskilled Labourers	0.02	0.00	-0.03	0.02
Capital Owners	0.02	0.00	-0.05	0.03

Source: Derived from the authors' GTAP model results

Appendix A: Derivation of percentage change in nominal and real household income

The following definitions are drawn directly from the definition of GTAP as described in Hertel (1997)

VFA(i,j,r): *producer expenditure on i by j in r valued at agents' prices*
VPA(i,j,r): *private hhld expenditure on i in r valued at agent's prices*
pfe(i,r): *firms' price for endowment commodity i in ind j, region r*[11]
pp(i,r): *private consumption price for commodity i in region r*

Let AG, UNSK, CAP refer to three types of households: farm households, unskilled labourers, and capital owners, respectively. Let CAP_COMM represent the subset of mobile endowment commodities comprised of skilled labour, land, and capital. Let NONAG_COMM represent the set of non-agricultural production sectors: manufacturing, services and other products. Then the percentage change in nominal income to capital owners is defined as the sum of the percentage changes in the values of land, skilled labour and capital factor shares over these three sectors.

$$nominc_{CAP}(r) = \left(\frac{\sum_{j \in NONAG\_COMM} VFA(skld,j,r)}{\sum_{j \in NONAG\_COMM} \sum_{i \in CAP\_COMM} VFA(i,j,r)} * pfe(skld,r) \right) + \left(\frac{\sum_{j \in NONAG\_COMM} VFA(cap,j,r)}{\sum_{j \in NONAG\_COMM} \sum_{i \in CAP\_COMM} VFA(i,j,r)} * pfe(cap,r) \right) + \left(\frac{\sum_{j \in NONAG\_COMM} VFA(land,j,r)}{\sum_{j \in NONAG\_COMM} \sum_{i \in CAP\_COMM} VFA(i,j,r)} * pfe(land,r) \right)$$

Let AG_COMM represent the set of agricultural commodities including the food, wheat, GM wheat, coarse grains, GM coarse grains, oilseeds, GM oilseeds, cattle, cattle meat, and other food sectors. Let ϕ_r represent the share of off-farm income for farm households in region r. Then the percentage change in nominal income to agricultural households is defined as

[11] In this version of the model, land is assumed to be mobile across sectors. Therefore land rental rates are the same across all sectors, as they are for the other endowments. In some sensitivity analyses land is assumed to be sluggish which leads to variation in the percent change in land values across sectors. In these cases the compositve price for land, as calculated in the GTAP model, is used in the calculation of nominal income.

$$nominc_{AG}(r) = (1-\varphi_r)\left(\sum_{i \in ENDWM\_COM}\left(\frac{\sum_{j \in AG\_COMM} VFA(i,j,r)}{\sum_{i \in ENDW\_COM}\sum_{j \in AG\_COMM} VFA(i,j,r)} * pfe(i,j,r)\right)\right) + \varphi_r\left(nominc_{CAP}(r)\right)$$

Unskilled labour households only gain income by selling their labour. Hence, the percentage change in nominal income to these households in region r is simply the percentage change in unskilled labour wage rate:

$$nominc_{UNSK}(r) = pfe_{UNSK}(r)$$

The percentage change in real income for each type of household is defined as the percentage change in nominal factor income less the percentage change in expenditure for these households. For this analysis the percentage change in expenditure for each type of household is

$$ex(r) = \sum_{i \in PROD\_COMM}\left(\frac{VPA(i,r)}{\sum_{i \in PROD\_COMM} VPA(i,r)} * pp(i,r)\right)$$

Hence the percentage change in real income for each type of household j (j ∈ AG, UNSK, CAP) in region r may be written

$$realinc_j(r) = nominc_j(r) - ex(r)$$