

# **Climate Change and Food Security to 2050: A Global Economy-wide Perspective**

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## Abstract

Recent analyses of the possible adverse effects of climate change on agriculture in developing countries have raised food security concerns, especially for farm households whose crop productivity is expected to fall. The present study uses the GTAP global economy-wide model to capture at the same time the expected positive effects on temperate zone crop productivity, which will more or less offset the upward pressure on farm product prices from yield falls in developing countries. Also modelled is an expected adverse effect of higher temperatures and humidity on the productivity of unskilled workers in the tropics, but since they work in nonfarm as well as farm activities the net effect of that shock on agriculture's competitiveness is an empirical matter. The results suggest there may be less cause for concern over food security than some earlier studies indicated, but the degrees of uncertainty involved in such modelling are sufficient to warrant a precautionary approach.

**Keywords:** Climate change, crop and labour productivity growth, global computable general equilibrium model projections

**JEL codes:** D58, F17, Q17, Q24, Q54

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Following the upward spike in international prices of many primary commodities in 2008, and in light of on-going climate changes, policy makers and the general public have once again become concerned about global food security. While prices in international markets for food and energy raw materials have come down from their mid-2008 peak, they rose again for grains in mid-2010 and they remain high by historical standards. More than that, the trend in food prices has been noticeably upward over the past decade, in contrast to its trend over the 20<sup>th</sup> century; and, since the introduction of biofuel subsidies and mandates in the US and EU a few years ago, food prices seem to be closely tracking fossil fuel prices – again in contrast to the second half of the 20<sup>th</sup> century (Figure 1).

Affluent people in high-income countries can cope with higher prices of farm products, but the poorest households of those countries, and a far higher proportion of non-farm households in developing countries, suffer when food prices are high. Even some farm households can be worse off, for example those who produce predominantly cash crops whose prices have not risen with those for staple food crops. Food crises can erupt into urban riots, as happened in numerous food-deficit developing countries in 2008, and can even bring down governments. When followed by natural disasters (as with the earthquake in Haiti in 2010), the outcome can be catastrophic.

Climate change is expected to have a non-trivial influence on food security for several decades even if global mitigation strategies were to be introduced immediately. It is showing up not only in warmer temperatures but also in more-frequent extreme weather events and in altered precipitation patterns and thus water availability. The associated crop productivity changes may be beneficial in cooler temperate regions in the higher latitudes, but it is widely expected to reduce farm land and labour productivity in the tropics – and globally, notwithstanding some expected improvements in high latitudes (see, e.g., Cline 2007, Mendelsohn 2009, Nelson et al. 2009).

What would be the market and economic welfare effects of these expected changes in productivity of global agricultural resources? If they were progressively to lower world food output, the international food price trend would move onto a higher trajectory, depending on how each country and commodity market responded to climate change. Thus it is not necessarily the case that most farm families in developing countries are going to be losers economically from climate change: it is always possible that the change in the price of their output more than compensates for any fall in their farm productivity.

This paper seeks to provide a sense of how climate change might impact on the world's markets for farm products if there is no mitigation or adaptation other than in response to price changes. We make use of the global GTAP model (Hertel 1997) to first provide projections of the world economy to 2030 and 2050 without any climate or policy changes, and then to compare those baseline numbers with projections which incorporate assumed impacts of climate change over the next four decades on farm productivity (based on damage function analyses reported in recent studies). Only the two most direct biophysical changes are modelled. The first is in crop land productivity, drawing on the interpretation of damage functions by Hertel, Burke and Lobell (2010). The second relates to the impact of higher temperatures and humidity on the productivity of unskilled labour in the already hot and humid tropics, drawing on the interpretation of its debilitating effects by van der Mensbrugge and Rosen (2010). The paper concludes by mentioning some caveats and areas for further empirical analysis.

National and global economic welfare effects also are estimated in the GTAP model. Their magnitudes are shown to be very small, suggesting that there must be other costs of climate change not examined here to warrant the sorts of major policy responses being called for (such as carbon emission taxes and border tax adjustments). However, it needs to be kept in mind from the outset that we are imposing only a small subset of the shocks expected to come from climate change, and we are using a comparative static model that – unlike a dynamic stochastic model – cannot capture the sporadic additional costs to farmers and others of more-frequent extreme weather events, such as floods, droughts, frosts, hail and wind.

### **Projecting a baseline to 2030 and 2050 with the GTAP model**

The standard GTAP model (Hertel 1997) is perhaps the most widely used CGE model for economy-wide global market analysis, in part due to its robust and explicit assumptions. In its

simplest form, the model assumes perfect competition and constant returns to scale in production. The functional forms are nested constant elasticities of substitution (CES) production functions. Land and other natural resources, labour (skilled and unskilled), and produced physical capital substitute for one another in a value added aggregate, and composite intermediates substitute for value-added at the next CES level in fixed proportions. Land is specific to agriculture in the GTAP database, and is allowed to be highly mobile amongst alternative agricultural uses over this four-decade projection period. A Constant Elasticity of Transformation (CET) revenue function transforms land from one use to another. The closer the transformation elasticity is to zero, the more unresponsive is land supply to changing relative returns to land across agricultural uses. There is also a very low elasticity of transformation between alternative uses of natural resources. In the default GTAP closure, labour and capital are assumed to be mobile across all uses within a country but immobile internationally.

On the demand side there is a regional representative household whose expenditure is governed by Cobb-Douglas aggregate utility function which allocates net national expenditures across private, government, and saving activities. The greatest advantage of this regional household representation is the unambiguous indicator of economic welfare dictated by the regional utility function.<sup>1</sup> Government demand across composite goods is determined by a Cobb-Douglas assumption (fixed budget shares). Private household demand is represented by a Constant Difference of Elasticities (CDE) functional form, which has the virtue of capturing the non-homothetic nature of private household demands as well as permitting the user to calibrate the model to specific own-price elasticities of demand.

Bilateral international trade flows are handled through the Armington (1969) specification by which products are differentiated by country of origin. These Armington elasticities are the same across regions but are sector-specific, and the import-import elasticities have been estimated at the disaggregated GTAP commodity level (Hertel et al. 2007). For present purposes, where we are dealing with very long-term changes, we have doubled the usual short-to-medium term Armington elasticities for non-primary products and, for primary products, we have set them all at the level of the highest one (which was for natural gas, at nearly 70). The justification for the latter specification is that over such a long

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<sup>1</sup> Altering taxes in the GTAP model does not imply a reduction in government revenue and expenditure, as government expenditures are not tied to tax revenues. A tax reduction, for example, leads to a reduction in excess burden, so regional real income increases and real expenditure – including government expenditure – may also rise.

period as four decades, primary products will be highly substitutable among different countries of origin.

The standard macro-economic closure assumes that the levels of each region's employment of each of the productive factors is fixed in aggregate, and that the regional balance of trade is determined by the relationship of regional investment and savings, where international capital mobility seeks to equalize *expected* (but not necessarily actual) rates of return across regions. Foreign investment is allocated in fixed shares across regions, so that regional investment moves in line with global savings and international capital reallocation is excluded.

The full GTAP 7.0 database comprises 113 regions in addition to the 57 sectors/product groups, but to make the model more manageable we have aggregated it to 23 sectors/product groups and 23 regions (see Appendix Tables A1 and A2). It is initially calibrated to the year 2004. The standard GTAP protection database (see Narayanan and Walmsley 2008) has been altered to include a more-complete set of estimates of distortions to agricultural prices in developing countries, based on Valenzuela and Anderson (2008).<sup>2</sup> Those distortion estimates suggest that, despite reforms of the past 25 years, there was still a considerable range of industry assistance rates across commodities and countries in 2004, including a strong anti-trade bias in national agricultural and trade policies for many developing countries. Furthermore, non-agricultural protectionism is still rife in some developing countries, and agricultural price supports in some high-income countries remain high.

To project the world economy to 2030 and 2050, we assume policies as of 2004 and the stock of agricultural land do not change in each region but that population, labour, capital and real GDP grow at the rates shown in Appendix Tables A3 and A4, from which the implied rates of total factor productivity and GDP per capita growth are derived as shown in the final two columns of each of those two tables. The exogenous growth rates are based on World Bank and OECD projections (see, e.g., Duval and de la Maisonneuve 2009). The rate of total factor productivity growth is assumed to be the same in each of the non-primary sectors, and to be somewhat higher in the primary sectors as detailed in the footnotes to Appendix Tables A3 and A4. Those higher rates are set so as to ensure the price of primary products in 2030 and 2050 (relative to the aggregate change for all products, shown in

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<sup>2</sup> That distortions database is documented fully in Anderson and Valenzuela (2008) and is based on the methodology summarized in Anderson et al. (2008).

Appendix Table A5) are little different from those in 2004, and to be consistent with World Bank projections over the next four decades. Agricultural prices could have been made to fall by assuming faster productivity growth in the farm sector than in other sectors – as occurred in the past half century (Martin and Mitra 2001), and as projected in GTAP-based projection studies in the late 20<sup>th</sup> century (e.g., Anderson et al. 1997) – but that is considered less likely for the next four decades given the slowdown in agricultural R&D investment and its consequent slowing of farm productivity growth since 1990 (Alston, Babcock and Pardey 2010).

Given the differences across regions in those growth rates, and the fact that sectors differ in their relative factor intensities, the structures of production, consumption and trade across sectors within countries and also between countries is going to be different in 2030 and 2050 than in 2004. In particular, the developing countries (especially those of Asia) will become a considerably larger share of the projected global economy over the next four decades. In the baseline projection the developing countries' share of world GDP rises from 22 percent in 2004 to 26 percent in 2030 and 47 percent in 2050—with China's share alone growing from 4 to 17 percent (Appendix Table A6). The developing countries will also see the share of agriculture in their GDP decline, from 10 to 6 percent for that grouping as a whole (Appendix Table A7). As a consequence of these two changes, the developing countries' share of global agricultural GDP rises slightly, from 50 percent in 2004 to a projected 56 percent by 2050 (Appendix Table A8).

### **Alternative scenarios for 2030 and 2050**

Given the baseline projections summarized above, we then use the GTAP model to simulate the market and welfare effects first of the direct impact of climate change on crop yields in different parts of the world, and then also of the projected impacts of climate change on unskilled labour productivity in developing countries.

#### ***Crop productivity effects***

The direct impacts of climate change on crop productivity have been examined by many analysts, and there still remains considerable uncertainty as to even their sign let alone their

magnitude. Nonetheless, for present purposes we adopt the same rates for the period from 2004 to 2030 as the medial rates used by Hertel, Burke and Lobell (2010),<sup>3</sup> with a few minor adjustments, such as for Australia so as to be more consistent with the 2008 Garnaut Review (see also Gunasekera et al. 2007). Those yield shocks are summarized in Table 1. Given that climate change is expected to accelerate after the first one-third of this decade, we then assume those impacts on crop yields in the first 26 years will be twice as large two decades later, in 2050.

Two points are worth noting about those shocks. First, those shock are generally positive for high-income temperate countries except for rice, coarse grains (i.e. maize) and cotton (and, in Australia's case, for fruits and vegetables whose yields are expected to suffer because of a shrinkage in water availability), while they are generally negative for developing countries (with China and the Middle East/North Africa region being the main exceptions). And second, those yield shocks are very small over a period as long as four decades, when compared with the annual productivity growth rates reported in Appendix Tables A3 and A4. More than that, farm land is projected to account throughout the next four decades for less than one-tenth of GDP in even the most agrarian of developing economies and to be below 1 percent in some high-income countries (Appendix Table A9). Hence the net economic effects of these direct crop yield impacts of climate change will necessarily be small in proportional terms – even though they may have large impacts on very seriously affected regions within some countries, such as the hot irrigated horticultural and rice- and cotton-growing regions of Australia and the United States.

The effects of those climate changed-induced direct crop productivity impacts on national agricultural self sufficiency for the sector as a whole in 2030 and 2050, as compared with the baseline in those years, are very small (barely 1 percent, see Table 2. Some of the effects on the production, consumption and trade components of those self sufficiency ratios, summarized in percentage terms in Tables 3 and 4 for 2030 and 2050, are somewhat larger than the effects on self sufficiency, but are still small overall. The projected volume of agricultural output would shrink by no more than 5 percent in any of the developing countries shown in those tables (but would rise in very few of them).

Typically the farmgate price of products is projected to move in the opposite direction to farm production in response to these yield shocks though. Hence agricultural value added

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<sup>3</sup> Hertel, Burke and Lobell (2010) acknowledge the wide confidence band around that median effect by also noting the 5 and 95 percentile effects, and showing the wide difference that makes to the economic and poverty effects generated by their economywide model.



(which also takes account of changes in input prices such as animal feedstuffs) sometimes shows the opposite sign to the volume of farm output (column 4 of Tables 3(a) and 3(b)). In particular, agricultural value added rises in all but a few developing countries.

Note from the top of Tables 3(a) and 3(b) that the aggregate price of agricultural products in international markets in 2030 and 2050 changes hardly at all as a result of the productivity shocks (less than 0.3 percent). It even happens to be slightly negative, rather than positive as predicted by numerous commentators, which means the mainly adverse effects on farm supplies in developing countries is slightly offset by the mainly positive effects on farm output in high-income countries.

Consumption volumes are affected little by this one impact of climate change, but typically in the same direction as the production change. As a result, the value of agricultural trade changes very little. In the case of high-income countries, exports would be just 1.2 percent higher and those countries' farm imports would be 0.8 percent less in 2030 because of the assumed crop productivity impacts of climate change. The percentage changes for developing countries as a group would be slightly larger and of the opposite signs to those for high-income countries (bottom two rows of Table 3). Thus the developing country share of global exports (imports) of farm products would fall (rise).

The impact of those price and quantity changes on overall national economic welfare is summarized in Table 4. For the world as a whole, the negative impact seems very small, at around \$4 billion per year by 2030 and just \$3 billion by 2050 – a small fraction of 1 percent of projected real income. That aggregate conceals larger proportional changes at the country level, especially for developing countries, but even so they appear to be very minor (final column of Table 4). Those national economic welfare effects are shown in that table to come not only from (a) the factor productivity shocks themselves but also from (b) the impact of producer and consumer responses to them on the welfare costs of distortionary policies such as tariffs and subsidies and (c) the change in the country's international terms of trade. Note that the latter two indirect effects are non-trivial, and in some countries they are larger than the direct productivity effect. Also, the third effect (via changes in the terms of trade) in some cases is quite different by 2050 than in 2030. This is partly because the international prices for the myriad products, and their traded quantities, are affected to different extents by the productivity shocks. Particularly striking examples are China and India: in 2030 the terms of trade changes reduce slightly their national welfare, whereas by 2050 their welfare is enhanced considerably by the terms of trade changes (c.f. Tables 3(a) and 3(b)).

These projected changes from the assumed crop productivity effects of climate change are but one of the influences expected from temperature and humidity changes over coming decades. We turn now to an additional expected influence, namely via its debilitating impact on unskilled workers in developing countries which van der Mensbrugghe and Rosen (2010) indicated could be far more important.

### *Effects also on unskilled labour productivity*

Almost all unskilled labourers in tropical developing countries have no access to air conditioning in their workplace, especially as most work outside on farms. Since temperatures and humidity are expected to rise from already very high levels in most of those countries, the productivity of such workers is sure to fall in the absence of counter measures. By contrast, in high-income countries the temperature rises generally will be from cool or at most moderate rather than high current levels, and in any case many unskilled workers there work inside with air conditioning.

We follow van der Mensbrugghe and Rosen (2010) in attempting to simulate the effect of climate change on all unskilled workers in tropical and desertified developing countries, by adding to the crop yield shock a shock to unskilled labour productivity in both agricultural and non-farm sectors. There are no precise predictions of the likely magnitude of that shock, so we simply adopt the modest assumption that it involves a 3 percent decline in unskilled labour productivity by 2030 and another 3 percent by 2050 in all developing countries other than the relatively temperate ones of Argentina, Korea, South Africa and Taiwan and the most affluent ones (Hong Kong and Singapore).

The effects of adding this additional shock on agricultural markets is summarized in Table 5. For developing countries as a group the generally negative impact of the two shocks on the volume of agricultural production is roughly double or more the effect of the crop productivity shock alone. But there is an even larger difference in the decline in consumption of farm products, so the impact on trade is muted. The developing country share of global exports (imports) of farm products would still be higher (lower) by 2050 than in the absence of the productivity shocks, but the change would be less than if only crop productivity was affected (c.f. the bottom right-hand corners of Tables 3 and 5). The main exception is China, whose value of agricultural exports diminishes by nearly twice as much with this pair of shocks as with just the crop shock. This is because most of its unskilled labour is employed in

agriculture by 2050, so most of the brunt of the labour productivity shock is borne by farming which makes the non-farm sector more competitive.

The welfare effects are now far bigger than in the previous scenario, because the shock to unskilled labour applies to all sectors of developing countries, not just to agriculture. Even so they amount to no more than one-quarter of one percent of real income globally and up to one percent of welfare in some developing countries by 2050 (Table 6).

### **Caveats**

The above analysis is very partial in nature, in several respects. First, it examines the effects of just two of the many impacts that climate changes are expected to have on the global economy. van der Mensbrugghe and Rosen (2010), for example, also take into account the effects on energy demand, water availability, tourism and sea level rise. Not surprisingly, therefore, they get a much higher impact of climate change on global economic welfare – indeed twice as big, and of opposite sign, as the welfare effect of freeing trade policies globally in 2050 (-1.8 percent, compared with 0.9 percent from freeing trade).

Second, we have only analysed the effects to 2050. The effects of climate change are expected to increase exponentially, however, so in the absence of mitigation they would be much larger in the second half of the 21<sup>st</sup> century. This is supported by the dynamic simulations to 2100 generated by Rosen and van der Mensbrugghe (2010).

Third, the nature of each simulated shock obviously determines the size of its effects. The crop productivity shocks we adopt, like most other analysts', help farm output in higher latitudes and hurt it in many parts of the tropics. The net effect in our case is virtually no aggregate global agricultural output change (see last row of Table 3). By contrast, van der Mensbrugghe and Rosen (2010) assume larger positive shocks in temperate regions and smaller negative shocks in the tropics and so project a small net global economic welfare gain from the changes in crop productivity. They also adopt a damage function approach to the effect of temperature rise on labour productivity (based on such studies as Kjellstrom et al. 2009), in contrast to our simple exogenous labour shock. More sophisticated damage functions with respect to crop productivity also could be adopted, especially now that the GTAP database is being enhanced to enable better modelling of land use changes (see Hertel 2010) and the impact of changes in water availability in irrigated versus non-irrigated areas (see Calzadilla et al. 2010). Given the great uncertainty associated with the magnitude – and

in some cases even the sign of – potential shocks, analytical results ideally should include confidence bands around them or at least high and low alternatives to the median case presented.

Fourth, the standard version of the GTAP model used in the present study does not capture the complexity of energy markets. In particular, there are no biofuels markets, so the linkage that has recently emerged between biofuel crops and fossil fuels is not built into the projections. Modellers have certainly begun incorporating elements of that linkage, but even then there will be the challenge of anticipating how governments might alter biofuel subsidies and mandates over the next 40 years (given the newness of many of those policies and the uncertainty still surrounding the net environmental benefits of such supports to biofuel producers).

Fifth, as mentioned at the outset of this paper, the debilitating impact on welfare and food security from extreme weather events is not captured by the comparative static model we have employed. More-frequent extreme weather events such as floods, droughts, frosts, hail and wind can affect all sectors but are especially damaging to farm incomes whenever they strike. Analysis of the welfare effects of climate change ought to recognise these income distributional consequences, particularly on the poor. Economy-wide modellers are only now beginning to focus on those possible poverty consequences (see, e.g., Hertel, Burke and Lobell 2010).

And finally, we have assumed throughout that policies are unchanged through the projection period, and in particular that no new mitigation strategies or technologies are adopted to slow climate change, nor are trade, subsidy or tax policies changed. This is an obvious area for extending the analysis. If a carbon tax was gradually phased in by all countries, for example, climate change presumably would eventually slow down. However, it probably would not before 2050, and meanwhile that set of carbon taxes would alter the international competitiveness of various industries around the world. Carbon-intensive industrial sectors such as China's would be likely to lose comparative advantage, thereby making China's farmers more competitive. And China might not be able to avoid that outcome simply by not adopting a carbon tax, because in that case other countries that have adopted such a tax may impose border tax adjustments on goods imported from China (Mattoo, Subramanian, van der Mensbrugge and He 2009a,b) .

## **Conclusions**

Given the above caveats, it would of course be premature to draw implications for agricultural, trade and climate change policies from the empirical results presented in this paper. They are presented simply to illustrate some of the ways in which one or two of the shocks expected from on-going climate change can affect agricultural markets directly or indirectly, and thereby also economic welfare. When those effects are expected to be positive in some countries and negative in others, as in the case of farm products, the net impact on world food prices and hence real incomes of both farm and nonfarm households in the decades ahead can only be determined with the use of a global economy-wide model projected forward.

For what it is worth, in terms of global food security the results from the present analysis are less pessimistic than some earlier studies. One of the more widely cited is by Cline (2007), who predicts that by the 2080s, even with carbon fertilization, agricultural output will be 8 percent lower in developing countries, 8 percent higher in high-income countries, and 3 percent lower globally. Projections in a more recent study by Nelson et al. (2009) suggest that by 2050 climate change will have had, assuming no carbon fertilization, only a little downward impact on coarse grain production but will have reduced global rice production by one-eighth and wheat by one-quarter globally and nearly one-third in developing countries. Nelson et al. (2009) expect real international prices of grain and livestock in 2050 would be between 35 and 70 percent higher than in 2000 without climate change and more than 10 percentage points higher again with climate change, even with carbon fertilization. If those rather than the present study's results turn out to be closer to reality, food security concerns and associated policy responses such as expanding agricultural R&D investments will be vindicated.

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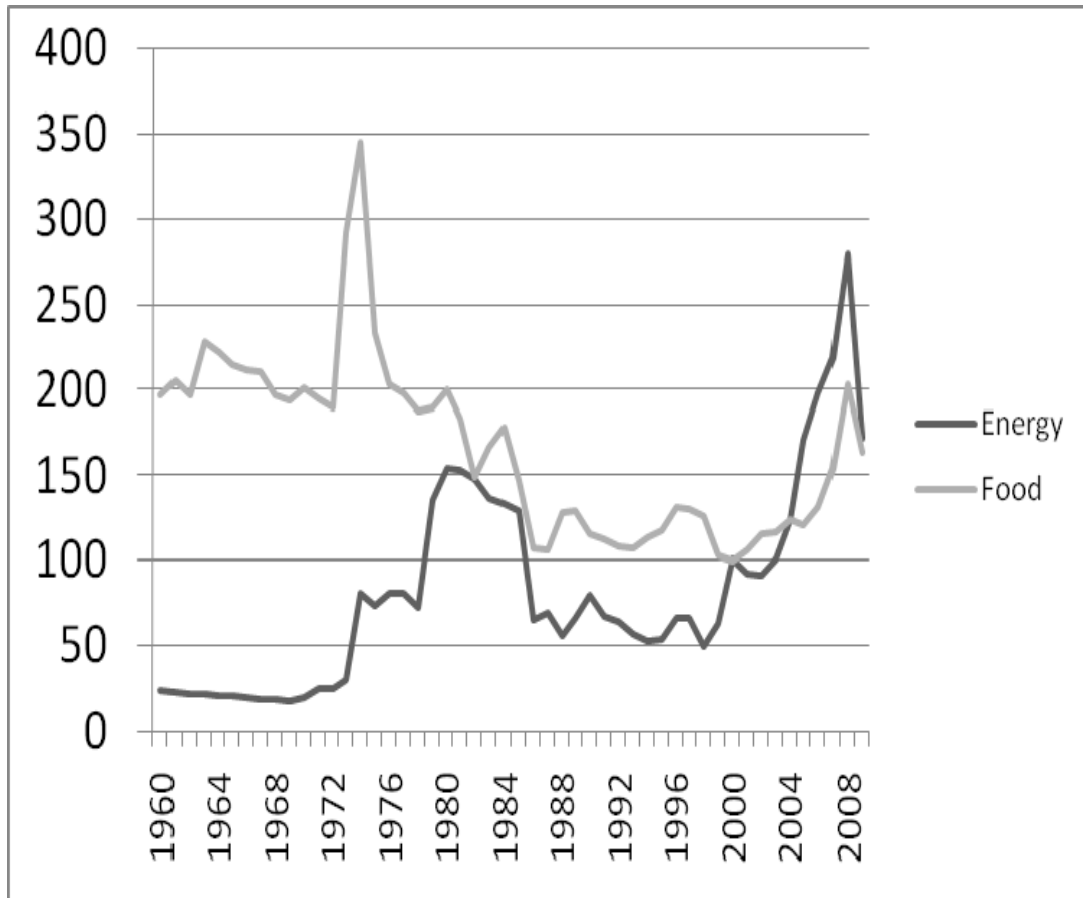
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Figure 1: International price indexes for food and fossil fuel energy raw materials, 1960 to 2009

(2000 = 100)



Source: World Bank, Commodity Price Data (Pink Sheets, see <http://go.worldbank.org/5AT3JHWYU0>)

Table 1: Exogenous Yield Shocks (%) attributed to Climate Change in 2030, by region and sector

Regions	Rice	Wheat	Coarse grains	Fruits Veg	Oil seeds	Cotton	Other crops
USA	-3	2	3	2	2	-3	2
Canada	-3	7	-10	2	10	-3	2
EU27 and EFTA	7	7	-5	7	7	7	7
Russia	7	7	-5	7	7	7	7
Rest of Europe/C. Asia	7	7	-5	7	7	7	7
Australia	-3	7	-5	-3	2	-3	7
New Zealand	7	7	-5	7	2	7	7
Japan	9	4	0	4	9	9	4
Korea	12	12	5	12	12	12	12
HongKong/Sing/Taiwan	12	12	5	-3	12	12	12
China	0	2	-10	-8	0	0	-8
Indonesia	-3	-3	-10	7	-3	-3	-3
Malaysia	-3	-3	-10	-3	-3	-3	-3
Thailand	-3	-3	-10	-3	-3	-3	-3
Rest of East Asia	-3	-3	-10	-3	-3	-3	-3
India	-5	-3	-10	-3	-3	-3	-3
Rest of South Asia	-5	-3	-10	-3	-3	-3	-3
Argentina	-3	-3	-10	-3	-3	-3	-3
Brazil	-3	-3	-10	-3	2	-3	-3
Rest of Latin America	-3	-3	-5	-3	-3	-3	-3
Middle East/Nth Africa	2	2	-5	2	2	2	2
South Africa	-8	-8	-20	-8	-8	-8	-8
Rest Sub-Saharan Africa	-3	-3	-10	-3	-3	-3	-3

Source: Hertel, Burke and Lobell (2010)

Table 2: Effects of economic growth, and of crop yield changes due to climate change, on agricultural self sufficiency, from 2004 to 2030 and 2050 (percent)

Regions	Base-2004	Base-2030	CC-2030	CC-2030 Yield +Labor	Base-2050	CC-2050 Yield	CC-2050 Yield + Labor
USA	103.4	130.2	130.3	130.2	152.3	152.2	152.3
Canada	108.3	125.4	125.1	125.0	125.3	125.2	125.3
EU27 and EFTA	94.0	114.4	115.6	115.6	123.5	124.3	124.3
Russia	89.2	94.5	94.8	94.9	94.6	95.0	95.3
Rest of EE/C Asia	100.2	106.6	107.7	107.6	120.7	121.7	121.7
Australia	137.9	164.3	164.3	164.5	186.2	186.7	187.2
New Zealand	161.2	187.4	189.0	188.9	207.5	206.0	206.3
Japan	82.5	96.8	97.7	97.6	114.0	114.2	114.5
Korea	81.4	83.6	86.6	86.5	88.9	91.0	90.9
HK/Sing/Taiwan	65.9	67.4	67.9	67.9	59.2	59.4	59.4
China	97.2	46.3	45.5	45.3	26.2	25.9	25.5
Indonesia	94.7	74.1	73.8	73.8	63.6	63.2	63.1
Malaysia	60.3	37.3	37.0	37.0	26.9	26.7	26.7
Thailand	111.9	98.0	97.0	96.9	97.4	97.0	96.7
Rest of East Asia	99.5	82.3	81.4	81.4	75.4	74.5	74.6
India	101.2	89.4	88.5	88.4	94.5	94.1	94.0
Rest of Sth. Asia	95.7	81.8	81.2	81.3	74.9	74.4	74.4
Argentina	142	153.2	150.0	149.6	171.5	168.3	167.6
Brazil	122.5	141.6	141.1	141.4	157.6	157.0	157.4
Rest of L America	101.7	93.2	92.5	92.5	90.5	89.5	89.6
M. East/N. Africa	83.6	86.7	86.8	86.6	92.2	92.3	92.0
South Africa	106.9	140.8	136.2	136.2	166.9	161.9	162.0
Rest of SS Africa	102.2	96.0	94.9	94.7	104.2	103.3	103.1
<b>High-income countries</b>	<b>96.1</b>	<b>118.3</b>	<b>116.8</b>	<b>116.8</b>	<b>261.4</b>	<b>131.3</b>	<b>131.4</b>
<b>Developing countries</b>	<b>99.8</b>	<b>77.1</b>	<b>76.3</b>	<b>76.2</b>	<b>69.9</b>	<b>69.1</b>	<b>68.8</b>

Source: Authors' simulations, assuming the crop productivity shocks of climate change are those shown in Table 1 by 2030 and twice those by 2050.

Table 3: Effects of crop productivity shocks due to climate change on agricultural production, consumption and trade, 2030 and 2050  
(percent deviation from baseline in projected year)

(a) 2030: Average difference in world agric prices in 2030 = -0.25%

Regions	Farmer price	Agricultural production volume	Agricultural consumption volume	Agricultural value added	Agricultural value of exports	Agricultural value of imports
USA	0.0	0.0	-0.1	0.0	0.1	-0.7
Canada	0.4	-0.5	-0.2	-0.4	-0.1	0.0
EU27 and EFTA	-0.9	1.4	0.3	0.7	2.0	-1.0
Russia	-0.3	0.5	0.2	-0.1	1.3	-1.0
Rest of Europe/C. Asia	-1.0	1.4	0.3	0.4	3.2	-1.0
Australia	0.3	-0.1	0.0	-0.5	0.4	0.4
New Zealand	-0.4	1.0	0.1	-0.2	1.0	-0.9
Japan	-1.1	1.1	0.2	0.8	2.8	-0.7
Korea	-2.6	4.6	1.0	-1.4	7.2	-2.9
HongKong/Sing/Taiwan	-0.2	1.0	0.2	-0.4	2.1	-0.1
China	1.6	-1.8	-0.1	-0.5	-0.7	0.9
Indonesia	0.9	-0.7	-0.2	-0.3	-1.6	0.8
Malaysia	0.5	-0.9	-0.1	0.6	-2.5	0.2
Thailand	0.9	-1.1	-0.1	0.2	-1.5	1.1
Rest of East Asia	0.6	-1.3	-0.2	0.8	-2.7	0.8
India	2.3	-1.5	-0.5	-1.5	-1.0	2.5
Rest of South Asia	1.1	-1.0	-0.2	-0.5	-1.0	2.5
Argentina	1.1	-1.9	0.2	0.2	-3.3	1.0
Brazil	0.3	-0.7	-0.3	0.2	-1.4	1.5
Rest of Latin America	0.6	-1.0	-0.2	0.2	-3.6	1.0
Middle East/Nth Africa	-0.6	0.3	0.1	0.8	-0.4	-0.4
South Africa	1.8	-3.5	-0.2	-0.1	-5.9	0.9
Rest Sub-Saharan Africa	1.9	-1.5	-0.4	-0.8	-4.1	2.0
<b>High-income countries</b>	<b>-0.5</b>	<b>0.7</b>	<b>0.2</b>	<b>0.3</b>	<b>1.2</b>	<b>-0.8</b>
<b>Developing countries</b>	<b>1.1</b>	<b>-1.0</b>	<b>-0.2</b>	<b>-0.5</b>	<b>-1.5</b>	<b>0.9</b>
<b>World</b>	<b>0.2</b>	<b>0.0</b>	<b>0.0</b>	<b>-0.1</b>	<b>0.4</b>	<b>0.4</b>

Table 3 (continued): Effects of crop productivity shocks due to climate change on agricultural production, consumption and trade, 2030 and 2050  
(percent deviation from baseline in projected year)

(b) 2050: Average difference in world agric prices in 2050 = -0.10%

Regions	Farmer price	Agricultural production volume	Agricultural consumption volume	Agricultural value added	Agricultural value of exports	Agricultural value of imports
USA	-0.2	0.0	0.1	0.5	-0.3	-1.1
Canada	0.9	-1.7	-1.6	-0.5	-1.2	-0.4
EU27 and EFTA	-1.7	2.3	1.6	1.3	1.6	-0.9
Russia	-0.6	0.8	0.3	0.0	1.1	-0.6
Rest of Europe/C. Asia	-1.9	2.3	1.4	1.2	1.7	-1.1
Australia	0.2	-0.1	-0.4	0.1	0.1	-0.1
New Zealand	-0.9	1.3	2.0	0.7	0.4	-0.9
Japan	-1.9	1.7	1.5	1.5	0.2	-0.7
Korea	-2.2	3.9	1.5	-1.5	4.2	-1.0
HongKong/Sing/Taiwan	-0.7	0.7	0.3	1.4	-0.4	-0.3
China	1.1	-1.9	-0.5	0.7	-7.3	0.0
Indonesia	0.9	-0.9	-0.3	0.0	-4.2	0.5
Malasya	-0.1	-0.9	-0.4	1.9	-4.9	-0.5
Thailand	0.1	-0.8	-0.3	1.5	-1.2	0.0
Rest of East Asia	-0.2	-1.3	-0.1	2.4	-4.4	-0.2
India	1.6	-1.2	-0.8	-1.0	-0.3	0.7
Rest of South Asia	1.1	-1.3	-0.6	-0.1	-1.5	0.3
Argentina	1.0	-2.5	-0.7	1.1	-4.1	0.1
Brazil	0.4	-0.9	-0.5	0.4	-1.0	3.2
Rest of Latin America	0.2	-1.3	-0.2	1.4	-4.9	0.3
Middle East/Nth Africa	-1.3	0.6	0.5	2.0	-1.2	-1.1
South Africa	2.1	-5.5	-2.6	1.9	-7.6	0.0
Rest Sub-Saharan Africa	1.6	-1.5	-0.6	-0.4	-1.3	2.1
<b>High-income countries</b>	<b>-0.9</b>	<b>0.7</b>	<b>0.8</b>	<b>0.9</b>	<b>0.6</b>	<b>-0.9</b>
<b>Developing countries</b>	<b>0.7</b>	<b>-1.0</b>	<b>-0.4</b>	<b>0.3</b>	<b>-1.3</b>	<b>0.1</b>
<b>World</b>	<b>-0.1</b>	<b>0.0</b>	<b>0.0</b>	<b>0.5</b>	<b>-0.1</b>	<b>-0.1</b>

Source: Authors' simulations, assuming that climate change involves twice the crop productivity shocks shown in Table 1 by 2030 or 2050 relative to the baseline in that year.

Table 4: Effects on national economic welfare of crop productivity losses, 2030 and 2050

(2004 US\$ million, deviation from baseline in projected year)

(a) 2030

Regions	Due to changes in:			Total economic welfare	Total economic welfare as % of Income
	Factor productivity	Terms of trade	Resource use efficiency		
USA	245	697	226	1166	0.01
Canada	30	229	-81	178	0.01
EU27 and EFTA	3270	-1091	-363	1815	0.01
Russia	194	71	46	310	0.03
Rest of Europe/C. Asia	839	-31	310	1119	0.09
Australia	-86	356	36	306	0.03
New Zealand	89	-94	2	-4	0.00
Japan	675	-97	-265	313	0.01
Korea	1110	-226	-989	-106	-0.01
HongKong/Sing/Taiwan	46	67	-9	104	0.01
China	-2954	-885	1372	-2467	-0.04
Indonesia	-220	45	12	-163	-0.03
Malaysia	-36	10	26	0	0.00
Thailand	-241	33	64	-144	-0.04
Rest of East Asia	-311	64	2	-246	-0.06
India	-4076	-225	479	-3821	-0.23
Rest of South Asia	-690	153	51	-486	-0.11
Argentina	-229	277	-197	-149	-0.06
Brazil	-354	-105	-35	-494	-0.05
Rest of Latin America	-1055	37	379	-639	-0.02
Middle East/Nth Africa	248	265	62	573	0.03
South Africa	-360	325	-20	-54	-0.02
Rest Sub-Saharan Africa	-1267	128	21	-1118	-0.17
<b>High-income countries</b>	<b>5256</b>	<b>40</b>	<b>-89</b>	<b>5203</b>	<b>0.01</b>
<b>Developing countries</b>	<b>-10389</b>	<b>-37</b>	<b>1218</b>	<b>-9210</b>	<b>-0.05</b>
<b>World</b>	<b>-5134</b>	<b>1</b>	<b>1127</b>	<b>-4006</b>	<b>-0.01</b>

Table 4 (continued): Effects on national economic welfare of crop productivity losses, 2030 and 2050

(2004 US\$ million, deviation from baseline in projected year)

(b) 2050

	Due to changes in:				
	Factor productivity	Terms of trade	Resource use efficiency	Total economic welfare	Total economic welfare as % of Income
USA	582	-1818	95	-1141	-0.01
Canada	-141	940	-212	586	0.03
EU27 and EFTA	7854	-7626	-1720	-1493	-0.01
Russia	303	241	108	652	0.04
Rest of Europe/C. Asia	2067	-1716	686	1037	0.05
Australia	-269	489	43	262	0.02
New Zealand	220	-404	-17	-202	-0.09
Japan	1222	-2009	-637	-1423	-0.03
Korea	1791	-1062	-1092	-364	-0.01
HongKong/Sing/Taiwan	46	-123	5	-73	0.00
China	-2239	6547	1648	5957	0.05
Indonesia	-421	134	-3	-290	-0.03
Malaysia	-58	107	44	93	0.02
Thailand	-299	23	182	-95	-0.01
Rest of East Asia	-487	20	-19	-486	-0.07
India	-6609	2929	923	-2757	-0.09
Rest of South Asia	-1228	1034	109	-84	-0.01
Argentina	-494	495	-421	-420	-0.11
Brazil	-842	-28	-79	-949	-0.06
Rest of Latin America	-1941	109	643	-1189	-0.03
Middle East/Nth Africa	666	436	180	1282	0.04
South Africa	-976	598	-90	-468	-0.09
Rest Sub-Saharan Africa	-2470	692	245	-1533	-0.13
<b>High-income countries</b>	<b>11838</b>	<b>-11903</b>	<b>-1654</b>	<b>-1722</b>	<b>0.00</b>
<b>Developing countries</b>	<b>-15561</b>	<b>11911</b>	<b>2275</b>	<b>-1376</b>	<b>0.00</b>
<b>World</b>	<b>-3723</b>	<b>7</b>	<b>621</b>	<b>-3095</b>	<b>0.00</b>

Source: authors' simulations

Table 5: Effects on agricultural production, consumption and trade of crop productivity losses and decreases in unskilled labour productivity, 2030 and 2050

(percent deviation from baseline in projected year)

(a) 2030: average difference in world agric prices = -0.07%

	Farmer price	Agricultural production volume	Agricultural consumption volume	Agricultural value added	Agricultural value of exports	Agricultural value of imports
USA	0.1	-0.1	-0.1	0.1	-0.1	-0.7
Canada	0.5	-0.7	-0.4	-0.2	-0.4	0.0
EU27 and EFTA	-0.8	1.3	0.3	0.6	1.9	-1.0
Russia	-0.3	0.5	0.0	-0.2	1.7	-1.2
Rest of Europe/C. Asia	-0.9	1.2	0.2	0.4	2.7	-0.9
Australia	0.3	0.2	0.1	-0.6	0.8	0.1
New Zealand	-0.3	0.9	0.1	-0.1	0.9	-0.8
Japan	-1.0	1.0	0.2	0.8	2.5	-0.6
Korea	-2.4	4.5	1.1	-1.5	6.9	-2.8
HongKong/Sing/Taiwan	-0.1	0.9	0.3	-0.4	2.0	0.0
China	2.4	-3.0	-1.0	-0.2	-3.1	0.6
Indonesia	1.1	-1.5	-1.0	0.4	-2.4	0.1
Malaysia	0.5	-1.7	-1.0	1.4	-2.1	-0.6
Thailand	1.0	-1.3	-0.2	0.2	-1.9	1.2
Rest of East Asia	0.8	-2.1	-0.9	1.3	-3.0	0.4
India	2.6	-2.4	-1.2	-1.0	-2.6	1.8
Rest of South Asia	1.4	-1.6	-1.0	-0.1	-1.2	0.3
Argentina	1.0	-2.0	0.4	0.4	-3.9	0.9
Brazil	0.3	-0.9	-0.8	0.7	-1.2	0.6
Rest of Latin America	0.9	-1.8	-1.0	0.7	-4.0	0.5
Middle East/Nth Africa	-0.2	-0.8	-0.6	1.2	-1.7	-0.5
South Africa	1.9	-3.5	-0.3	-0.1	-6.0	0.7
Rest Sub-Saharan Africa	2.3	-2.7	-1.4	-0.1	-5.8	1.7
<b>High-income countries</b>	<b>-0.5</b>	<b>0.7</b>	<b>0.1</b>	<b>0.3</b>	<b>1.1</b>	<b>-0.9</b>
<b>Developing countries</b>	<b>1.1</b>	<b>-1.8</b>	<b>-0.9</b>	<b>-0.1</b>	<b>-2.2</b>	<b>0.5</b>
<b>World</b>	<b>0.2</b>	<b>-0.4</b>	<b>-0.4</b>	<b>0.1</b>	<b>0.2</b>	<b>0.1</b>



Table 5 (continued): Effects of on agricultural production, consumption and trade of crop productivity losses and decreases in unskilled labour productivity, 2030 and 2050

(percent deviation from baseline in projected year)

(b) 2050: average difference in world agric prices = -0.28%

Regions	Farmer price	Agricultural production volume	Agricultural consumption volume	Agricultural value added	Agricultural value of exports	Agricultural value of imports
USA	-0.1	0.2	0.1	0.3	0.0	-1.4
Canada	1.1	-1.7	-1.7	-0.7	-1.1	-0.5
EU27 and EFTA	-1.6	2.4	1.7	1.3	1.6	-1.0
Russia	-0.7	1.2	0.4	-0.3	1.9	-0.7
Rest of Europe/C. Asia	-1.7	2.3	1.4	1.1	1.6	-1.2
Australia	0.0	0.6	0.1	-0.4	1.0	-0.9
New Zealand	-0.8	1.2	1.8	0.6	0.5	-1.0
Japan	-1.9	2.0	1.5	1.1	0.6	-1.0
Korea	-1.9	3.8	1.5	-1.7	4.3	-0.8
HongKong/Sing/Taiwan	-0.5	0.6	0.3	1.3	-0.3	-0.2
China	2.6	-3.6	-0.8	0.5	-13.6	0.2
Indonesia	1.0	-1.7	-1.0	0.6	-4.5	-0.1
Malaysia	0.1	-1.6	-1.1	2.7	-4.6	-1.1
Thailand	0.4	-1.3	-0.6	1.7	-1.8	0.1
Rest of East Asia	0.1	-2.0	-0.9	2.7	-4.3	-0.7
India	2.3	-2.3	-1.7	-0.9	-1.1	0.2
Rest of South Asia	1.5	-1.9	-1.2	0.2	-1.6	-0.1
Argentina	1.0	-2.5	-0.3	1.2	-4.6	0.2
Brazil	0.4	-1.1	-1.0	0.7	-0.9	2.4
Rest of Latin America	0.5	-1.9	-1.0	1.8	-4.9	-0.2
Middle East/Nth Africa	-0.9	-0.4	-0.2	2.5	-2.2	-1.4
South Africa	2.0	-5.5	-2.6	1.9	-7.6	-0.6
Rest Sub-Saharan Africa	1.9	-2.7	-1.7	0.5	-2.7	1.4
<b>High-income countries</b>	<b>-0.5</b>	<b>0.6</b>	<b>0.8</b>	<b>0.7</b>	<b>0.8</b>	<b>-1.1</b>
<b>Developing countries</b>	<b>1.1</b>	<b>-2.9</b>	<b>-0.9</b>	<b>0.5</b>	<b>-1.9</b>	<b>0.1</b>
<b>World</b>	<b>0.2</b>	<b>-0.5</b>	<b>-0.3</b>	<b>0.6</b>	<b>-0.2</b>	<b>-0.2</b>

Source: authors' simulations

Table 6: Effects on national economic welfare of crop productivity losses **and** decreases in unskilled labour productivity, 2030 and 2050

(2004 US\$ million, deviation from baseline in projected year)

(a) 2030

	Factor productivity	Terms of trade	Resource use efficiency	Total economic welfare	Total economic welfare as % of Income
USA	244	-1227	-45	-1028	-0.01
Canada	30	-439	-130	-539	-0.04
EU27 and EFTA	3262	-3387	-784	-910	-0.01
Russia	194	-2443	-441	-2690	-0.26
Rest of Europe/C. Asia	836	-994	255	97	0.01
Australia	-86	-1170	-92	-1347	-0.12
New Zealand	89	-116	-7	-34	-0.02
Japan	674	109	-300	482	0.01
Korea	1108	578	-1029	657	0.04
HongKong/Sing/Taiwan	45	165	14	224	0.02
China	-42915	12165	-7571	-38321	-0.69
Indonesia	-5029	-298	-231	-5558	-0.93
Malaysia	-2912	347	-117	-2682	-0.87
Thailand	-240	337	76	174	0.05
Rest of East Asia	-3139	-30	-385	-3554	-0.89
India	-17432	2232	-928	-16127	-0.96
Rest of South Asia	-4410	591	-322	-4142	-0.95
Argentina	-228	115	-212	-325	-0.13
Brazil	-9560	-314	-1412	-11286	-1.04
Rest of Latin America	-15544	-921	-6728	-23192	-0.90
Middle East/Nth Africa	-10224	-3966	-1335	-15524	-0.77
South Africa	-359	-102	-63	-524	-0.15
Rest Sub-Saharan Africa	-6292	-1247	-610	-8150	-1.23
<b>High-income countries</b>	<b>5243</b>	<b>-9667</b>	<b>-1544</b>	<b>-5969</b>	-0.01
<b>Developing countries</b>	<b>-117131</b>	<b>9652</b>	<b>-20853</b>	<b>-128330</b>	-0.67
<b>World</b>	<b>-111888</b>	<b>-16</b>	<b>-22395</b>	<b>-134298</b>	-0.22

Source: authors' simulations

Table 6 (continued): Effects on national economic welfare of crop productivity losses and decreases in unskilled labour productivity, 2030 and 2050

(2004 US\$ million, deviation from baseline in projected year)

(b) 2050

	Factor productivity	Terms of trade	Resource use efficiency	Total economic welfare	Total economic welfare as % of Income
USA	583	-21726	-2153	-23296	-0.11
Canada	-143	-1939	-654	-2736	-0.15
EU27 and EFTA	7831	-22858	-5836	-20863	-0.12
Russia	305	-6438	-746	-6879	-0.46
Rest of Europe/C. Asia	2060	-4961	469	-2432	-0.13
Australia	-272	-5708	-637	-6617	-0.39
New Zealand	220	-509	-61	-350	-0.15
Japan	1230	-7574	-1275	-7618	-0.14
Korea	1787	1718	-1154	2351	0.09
HongKong/Sing/Taiwan	45	365	46	456	0.02
China	-66560	69422	-12935	-10073	-0.09
Indonesia	-8242	-1101	-431	-9775	-0.89
Malaysia	-4893	1041	-229	-4080	-0.72
Thailand	-298	764	227	692	0.11
Rest of East Asia	-4920	-391	-668	-5979	-0.86
India	-28586	11354	-779	-18011	-0.58
Rest of South Asia	-7295	2025	-525	-5795	-0.74
Argentina	-493	125	-476	-845	-0.22
Brazil	-14365	-679	-2053	-17097	-1.00
Rest of Latin America	-22981	-2410	-10037	-35427	-0.88
Middle East/Nth Africa	-15376	-7564	-2043	-24983	-0.73
South Africa	-975	-1082	-267	-2323	-0.44
Rest Sub-Saharan Africa	-10365	-2123	-831	-13318	-1.17
<b>High-income countries</b>	<b>11814</b>	<b>-71713</b>	<b>-10893</b>	<b>-70791</b>	<b>-0.14</b>
<b>Developing countries</b>	<b>-183517</b>	<b>71464</b>	<b>-32155</b>	<b>-144207</b>	<b>-0.42</b>
<b>World</b>	<b>-171704</b>	<b>-245</b>	<b>-43049</b>	<b>-214998</b>	<b>-0.25</b>

Source: authors' simulations

Appendix Table A1: Aggregations of regions in the GTAP model

<b>Regions-Aggregation</b>	<b>Comprising GTAP regions</b>
1 USA	United States of America; Rest of North America
2 Canada	Canada
3 EU27 and EFTA	Austria; Belgium; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Ireland; Italy; Latvia; Lithuania; Luxembourg; Malta; Netherlands; Poland; Portugal; Slovakia; Slovenia; Spain; Sweden; United Kingdom; Switzerland; Norway; Rest of EFTA; Bulgaria; Romania
4 Russia	Russian Federation
5 Rest of E. Europe/C. Asia	Albania; Belarus; Croatia; Ukraine; Rest of Eastern Europe; Rest of Europe; Kazakhstan; Kyrgyzstan; Rest of Former Soviet Union; Armenia; Azerbaijan; Georgia; Iran Islamic Republic of; Turkey
6 Australia	Australia
7 New Zealand	New Zealand
8 Japan	Japan
9 Korea	Korea
10 Hong Kong, Singapore, Taiwan	Hong Kong; Taiwan; Singapore
11 China	China
12 Indonesia	Indonesia
13 Malaysia	Malaysia
14 Thailand	Thailand
15 Rest of East Asia	Cambodia; Lao People's Democratic Republ; Myanmar; Philippines; Viet Nam; Rest of Southeast Asia, Rest of Oceania; Rest of East Asia
16 India	India
17 Rest of South Asia	Bangladesh; Pakistan; Sri Lanka; Rest of South Asia
18 Argentina	Argentina
19 Brazil	Brazil
20 Rest of Latin America	Mexico; Bolivia; Chile; Colombia; Ecuador; Paraguay; Peru; Uruguay; Venezuela; Rest of South America; Costa Rica; Guatemala; Nicaragua; Panama; Rest of Central America; Caribbean
21 Middle East/North Africa	Rest of Western Asia; Egypt; Morocco; Tunisia; Rest of North Africa
22 South Africa	South Africa
23 Rest Sub-Saharan Africa	Nigeria; Senegal; Rest of Western Africa; Central Africa; South Central Africa; Ethiopia; Madagascar; Malawi; Mauritius; Mozambique; Tanzania; Uganda; Zambia; Zimbabwe; Rest of Eastern Africa; Botswana;; Rest of South African Customs

Source: Authors' compilation from [www.gtap.org](http://www.gtap.org)

Appendix Table A2: Aggregations of sectors in the GTAP model

	Sectors-Aggregation	Comprising GTAP sectors
1	Rice	Paddy rice; Processed rice
2	Wheat	Wheat
3	Coarse grains	Cereal grains nec
4	Fruit & veg	Vegetables, fruit, nuts
5	Oilseeds	Oil seeds, Vegetable oils and fats
6	Sugar	Sugar cane, sugar beet; Sugar
7	Cotton	Plant-based fibers
8	Other crops	Crops nec
9	Beef/sheep	Cattle,sheep,goats,horses; Meat of cattle, sheep, goats, horses; Wool, silk-worm cocoons
10	Pork/chicken	Animal products nec; Meat products nec
11	Dairy	Raw milk; Dairy products
12	Forestry	Forestry
13	Coal	Coal
14	Oil	Oil
15	Gas	Gas
16	Minerals nec	Minerals nec
17	Fish and processed food	Fishing; Food products nec; Beverages and tobacco products
18	Light manufacturing	Textiles; Wearing apparel; Leather products, Wood products; Paper products, publishing; Metal products; Motor vehicles and parts; Transport equipment nec; Manufactures nec
19	Heavy manufacturing	Petroleum, coal products; Chemical,rubber,plastic prods; Mineral products nec; Ferrous metals; Metals nec; Electronic equipment; Machinery and equipment nec
20	Utilities & Construction	Water; Construction; Trade
21	Electricity Gas dist.	Electricity; Gas manufacture, distribution
22	Transport	Transport nec; Sea transport; Air transport
23	Other Services	Communication; Financial services nec; Insurance; Business services nec; Recreation and other services; PubAdmin/Defence/Health/Education; Dwellings

Source: Authors' compilation from [www.gtap.org](http://www.gtap.org)

Appendix Table A3: Assumed annual rates of growth in factor endowments and real GDP, and implied total factor productivity and real GDP per capita growth rates, from 2004 to 2030 (% per year)

Regions	Popul- ation	Unskilled labor	Skilled labor	Capital	Real GDP	Implied TFP <sup>a</sup>	Implied realGDP per capita
USA	0.7	0.8	-0.2	3.2	2.6	1.4	1.9
Canada	0.4	0.4	-0.6	3.1	2.6	1.2	2.3
EU27 and EFTA	-0.1	0.0	-0.7	1.9	1.9	1.2	2.0
Russia	-0.6	-0.7	-1.0	3.2	3.2	1.2	3.8
Rest E. Europe/C. Asia	0.6	0.7	1.4	3.9	4.0	1.2	3.5
Australia	0.6	0.8	-0.2	3.7	3.4	1.5	2.8
New Zealand	0.7	1.0	0.0	3.6	3.4	1.2	2.7
Japan	-0.3	-0.7	-1.4	2.3	1.4	1.0	1.7
Korea	0.3	-0.4	2.0	4.9	4.7	1.9	4.4
HongKong/Sing/Taiwan	0.4	0.2	0.6	4.9	4.5	1.8	4.1
China	0.6	0.5	5.0	9.5	6.9	1.2	6.3
Indonesia	1.1	1.3	3.7	4.8	5.1	1.6	4.0
Malaysia	1.3	1.5	5.0	5.7	5.7	1.6	4.4
Thailand	0.5	0.1	2.0	4.0	4.7	1.7	4.2
Rest of East Asia	1.2	1.5	2.9	4.1	4.4	1.2	3.2
India	1.1	1.5	3.0	5.9	5.7	1.8	4.6
Rest of South Asia	1.7	2.2	3.1	5.0	5.1	1.4	3.4
Argentina	0.9	0.3	2.9	2.7	3.4	1.5	2.5
Brazil	1.0	0.9	2.3	3.3	3.6	1.3	2.6
Rest of Latin America	1.3	1.6	2.9	3.5	3.9	1.0	2.6
Middle East/Nth Africa	1.6	2.0	2.4	4.1	4.6	1.0	2.9
South Africa	0.4	0.7	0.5	1.9	3.3	1.8	2.9
Rest Sub-Saharan Africa	2.0	2.5	2.4	3.8	4.5	1.0	2.5
<b>High-income countries</b>	<b>0.2</b>	<b>0.2</b>	<b>-0.5</b>	<b>2.6</b>	<b>2.2</b>	<b>1.2</b>	<b>2.0</b>
<b>Developing countries</b>	<b>1.2</b>	<b>1.4</b>	<b>2.9</b>	<b>5.9</b>	<b>5.1</b>	<b>1.3</b>	<b>3.9</b>
<b>World</b>	<b>1.0</b>	<b>1.2</b>	<b>1.1</b>	<b>3.5</b>	<b>3.0</b>	<b>1.3</b>	<b>2.0</b>

Additional primary sectoral TFP shocks (% per year): coal 2.7, oil 2.1, gas 1.7, mineral resources 1.0, agriculture and food 1.0, forestry 1.0.

Source: Authors' compilation drawing on World Bank and OECD projections.

Appendix Table A4: Assumed annual rates of growth in factor endowments and real GDP, and implied total factor productivity and real GDP per capita growth rates, from 2030 to 2050 (% per year)

Regions	Popul- ation	Unskilled labor	Skilled labor	Capital	Real GDP	Implied TFP <sup>a</sup>	Implied realGDP per capita
USA	0.7	0.4	-0.1	2.9	2.7	1.5	2.0
Canada	0.3	-0.1	-0.6	2.7	2.6	1.4	2.3
EU27 and EFTA	-0.1	-0.2	-0.6	2.0	2.0	1.1	2.0
Russia	-0.6	-1.0	-1.6	2.8	3.2	1.2	3.8
Rest E. Europe/C. Asia	0.7	0.8	0.6	3.1	3.5	1.0	2.8
Australia	0.6	0.3	-0.1	3.4	3.5	1.7	3.0
New Zealand	0.6	0.5	0.1	3.4	3.6	1.5	3.0
Japan	-0.3	-0.7	-1.7	1.7	1.6	1.3	1.9
Korea	0.2	0.3	0.3	4.7	4.7	1.8	4.4
HongKong/Sing/Taiwan	0.3	0.1	-0.5	4.5	4.4	1.9	4.1
China	0.5	0.3	3.0	7.0	5.5	0.8	5.0
Indonesia	1.0	1.4	1.4	4.8	5.0	1.5	4.0
Malaysia	1.2	1.6	1.6	5.0	4.9	1.4	3.6
Thailand	0.5	0.2	0.2	4.4	4.9	1.6	4.4
Rest of East Asia	1.2	1.6	1.7	4.2	4.6	1.3	3.4
India	1.0	1.5	1.5	5.4	5.0	1.2	4.0
Rest of South Asia	1.6	2.2	2.1	5.0	4.9	1.2	3.3
Argentina	0.9	1.1	1.1	3.3	3.7	1.5	2.9
Brazil	1.0	0.9	0.9	3.5	3.7	1.5	2.8
Rest of Latin America	1.3	1.7	1.6	3.6	3.9	1.0	2.6
Middle East/Nth Africa	1.6	2.0	1.7	4.2	4.5	1.0	2.8
South Africa	0.5	0.9	0.2	3.1	3.5	1.4	3.1
Rest Sub-Saharan Africa	2.0	2.6	2.0	3.6	4.4	1.0	2.4
<b>High-income countries</b>	<b>0.2</b>	<b>0.1</b>	<b>-0.4</b>	<b>2.4</b>	<b>2.4</b>	<b>1.3</b>	<b>2.6</b>
<b>Developing countries</b>	<b>1.2</b>	<b>1.5</b>	<b>1.7</b>	<b>5.7</b>	<b>4.8</b>	<b>1.1</b>	<b>4.0</b>
<b>World</b>	<b>1.0</b>	<b>1.3</b>	<b>0.9</b>	<b>3.9</b>	<b>3.4</b>	<b>1.3</b>	<b>2.6</b>

Additional primary sectoral TFP shocks (% per year):: coal 3.1, oil 2.8, gas 2.2, mineral resources 1.7, agriculture and food 1.3, forestry 2.0.

Source: Authors' compilation drawing on World Bank and OECD projections.

Appendix Table A5: Endogenous international commodity price changes resulting from updating the baseline data from 2004 to 2030 and 2050

(total percentage change relative to the aggregate for all products)

	2030/2004	2050/2004
Rice	0.0	-1.9
Wheat	5.7	5.4
Coarse grains	5.4	5.4
Fruit & veg	5.5	5.2
Oilseeds	4.9	5.0
Sugar	-2.7	-4.4
Cotton	4.6	3.9
Other crops	5.2	4.8
Beef/sheep	0.2	-1.1
Pork/chicken	0.4	-0.1
Dairy	-2.4	-4.9
<b>Agriculture &amp; food</b>	<b>2.5</b>	<b>1.6</b>
<b>Forestry</b>	<b>0.3</b>	-1.4
Coal	-5.6	0.5
Oil	-1.9	-2.2
Gas	-2.7	-3.0
<b>Energy</b>	<b>-2.4</b>	<b>-2.0</b>
Minerals nec	-1.3	3.0
Fish and processed food	1.4	2.0
Light manufacturing	-1.1	-1.3
Heavy manufacturing	-1.5	-1.6
<b>Manufacturing</b>	<b>-1.0</b>	<b>-1.1</b>
Utilities & construction	-0.8	-1.3
Electricity, gas distribution	-3.0	-1.5
Transport	-1.8	-2.6
Other services	1.0	1.2
<b>Services</b>	<b>0.2</b>	<b>0.2</b>

Source: Authors' simulations



Appendix Table A6: Regional shares of global GDP

(percent)

<b>Regions</b>	<b>2004</b>	<b>2030</b>	<b>2050</b>
USA	32.5	29.1	25.3
Canada	2.3	2.0	1.8
EU27 and EFTA	27.0	20.2	15.4
Russia	1.1	1.2	1.1
Rest E. Europe/C. Asia	1.0	1.3	1.3
Australia	1.2	1.3	1.3
New Zealand	0.2	0.2	0.2
Japan	13.1	8.7	6.1
Korea	1.5	2.2	2.8
HongKong/Sing/Taiwan	1.8	2.5	3.1
China	4.4	11.3	17.2
Indonesia	0.5	0.8	1.1
Malaysia	0.3	0.6	0.8
Thailand	0.4	0.6	0.8
Rest of East Asia	0.6	0.8	1.0
India	1.7	3.3	4.5
Rest of South Asia	0.5	0.8	1.1
Argentina	0.8	0.9	1.0
Brazil	1.6	1.8	1.9
Rest of Latin America	3.8	4.8	5.2
Middle East/Nth Africa	2.9	4.2	5.2
South Africa	0.4	0.4	0.4
Rest Sub-Saharan Africa	0.7	1.0	1.2
<b>High-income countries</b>	<b>78.3</b>	<b>63.9</b>	<b>52.6</b>
<b>Developing countries</b>	<b>21.7</b>	<b>36.1</b>	<b>47.4</b>

Appendix Table A7: Sectoral shares of national GDP, 2004, 2030 and 2050  
(percent)

(a) 2004

	Agric	Other primary	Manuf	Services	Total
USA	2	1	16	82	100
Canada	2	5	18	75	100
EU27 and EFTA	3	1	19	78	100
Russia	8	16	15	62	100
Rest E. Europe/C. Asia	10	12	17	62	100
Australia	4	5	14	78	100
New Zealand	8	2	16	74	100
Japan	2	0	19	79	100
Korea	3	0	28	68	100
HongKong/Sing/Taiwan	1	1	25	73	100
China	12	7	33	48	100
Indonesia	12	13	25	50	100
Malaysia	2	15	49	33	100
Thailand	10	3	32	55	100
Rest of East Asia	12	7	29	51	100
India	24	4	18	54	100
Rest of South Asia	20	3	14	63	100
Argentina	9	6	15	71	100
Brazil	8	2	18	71	100
Rest of Latin America	9	6	28	56	100
Middle East/Nth Africa	6	26	12	56	100
South Africa	3	3	21	73	100
Rest Sub-Saharan Africa	22	23	11	44	100
<b>High-income countries</b>	2	2	17	79	100
<b>Developing countries</b>	10	8	24	57	100
<b>World</b>	4	3	19	75	100

(b) 2030

	Agric	Other primary	Manuf	Services	Total
USA	2	2	14	83	100
Canada	2	8	14	76	100
EU27 and EFTA	3	2	16	79	100
Russia	6	22	12	61	100
Rest E. Europe/C. Asia	8	13	16	63	100
Australia	4	7	11	77	100
New Zealand	9	3	14	74	100
Japan	2	1	16	82	100
Korea	2	1	28	69	100
HongKong/Sing/Taiwan	1	1	25	73	100

China	6	5	44	45	100
Indonesia	8	13	25	53	100
Malaysia	1	13	51	35	100
Thailand	8	4	32	57	100
Rest of East Asia	9	9	30	53	100
India	19	5	18	58	100
Rest of South Asia	16	3	15	66	100
Argentina	9	8	13	70	100
Brazil	9	4	16	72	100
Rest of Latin America	8	8	27	57	100
Middle East/Nth Africa	5	25	13	56	100
South Africa	4	6	17	73	100
Rest Sub-Saharan Africa	19	23	12	45	100
<b>High-income countries</b>	3	3	15	80	100
<b>Developing countries</b>	8	8	28	56	100
<b>World</b>	4	4	19	73	100

(c) 2050

	Agric	Other primary	Manuf	Services	Total
USA	2	2	11	84	100
Canada	2	11	11	77	100
EU27 and EFTA	3	4	14	80	100
Russia	5	28	8	59	100
Rest E. Europe/C. Asia	8	14	14	64	100
Australia	4	9	9	77	100
New Zealand	9	4	13	74	100
Japan	2	1	11	86	100
Korea	2	1	27	70	100
HongKong/Sing/Taiwan	1	2	24	74	100
China	3	5	47	45	100
Indonesia	6	13	25	56	100
Malaysia	1	13	52	35	100
Thailand	7	4	31	59	100
Rest of East Asia	7	10	30	54	100
India	17	5	18	61	100
Rest of South Asia	13	4	15	68	100
Argentina	8	10	12	70	100
Brazil	11	5	13	72	100
Rest of Latin America	7	9	26	59	100
Middle East/Nth Africa	5	25	13	57	100
South Africa	4	8	15	73	100
Rest Sub-Saharan Africa	19	23	12	46	100
<b>High-income countries</b>	3	4	12	81	100
<b>Developing countries</b>	6	8	29	57	100
<b>World</b>	4	6	18	72	100

Appendix Table A8: National share of world agricultural GDP

(percent)

<b>Regions</b>	<b>2004</b>	<b>2030</b>	<b>2050</b>
USA	12.7	13.9	15.0
Canada	1.3	1.3	1.1
EU27 and EFTA	21.2	18.0	15.7
Russia	2.9	2.3	1.8
Rest E. Europe/C. Asia	4.4	4.4	4.2
Australia	1.6	1.9	2.1
New Zealand	0.5	0.5	0.6
Japan	5.0	3.6	3.2
Korea	1.2	1.2	1.4
HongKong/Sing/Taiwan	0.5	0.5	0.5
China	12.2	11.5	8.9
Indonesia	2.2	2.1	2.1
Malaysia	0.2	0.2	0.2
Thailand	0.9	1.0	1.1
Rest of East Asia	1.5	1.3	1.3
India	10.0	12.8	14.9
Rest of South Asia	2.5	2.9	3.0
Argentina	0.8	0.8	0.8
Brazil	3.2	4.0	5.1
Rest of Latin America	6.4	5.8	5.7
Middle East/Nth Africa	3.7	4.1	4.4
South Africa	0.4	0.6	0.6
Rest Sub-Saharan Africa	4.5	5.1	6.1
<b>High-income countries</b>	<b>49.7</b>	<b>46.0</b>	<b>43.7</b>
<b>Developing countries</b>	<b>50.3</b>	<b>54.0</b>	<b>56.3</b>

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Appendix Table A9: Primary factor shares of total GDP, 2004, 2030 and 2050

(a) 2004

(%)

Regions	Unskilled labor	Skilled labor	Capital	Land	Other natural resources
USA	40.7	31.4	27.3	0.3	0.3
Canada	38.4	23.3	36.3	0.2	1.8
EU27 and EFTA	34.1	24.4	40.9	0.3	0.4
Russia	28.6	12.8	51.1	1.8	5.7
Rest E. Europe/C. Asia	29.5	12.2	53.2	1.5	3.7
Australia	34.9	24.9	38.2	0.6	1.4
New Zealand	33.5	17.8	47.4	0.7	0.6
Japan	36.7	22.5	40.5	0.2	0.1
Korea	35.3	15.8	47.3	1.4	0.2
HongKong/Sing/Taiwan	31.1	21.8	46.4	0.4	0.3
China	39.7	11.1	43.4	3.3	2.5
Indonesia	32.0	8.0	50.5	5.7	3.8
Malaysia	36.8	11.8	45.8	1.1	4.6
Thailand	21.7	8.9	63.9	4.1	1.3
Rest of East Asia	30.4	11.5	50.4	4.7	2.9
India	34.8	10.8	44.2	9.0	1.2
Rest of South Asia	35.5	12.2	43.5	7.6	1.1
Argentina	38.0	17.1	40.6	2.3	2.0
Brazil	35.5	20.0	42.5	1.1	0.9
Rest of Latin America	30.7	15.1	49.8	2.2	2.2
Middle East/Nth Africa	22.4	11.1	56.7	0.6	9.2
South Africa	31.5	17.8	49.4	0.4	1.0
Rest SubSaharan Africa	31.9	9.0	49.5	2.6	7.0
<b>High-income countries</b>	36.9	26.2	36.0	0.3	0.5
<b>Developing countries</b>	32.9	13.7	47.7	2.8	2.8
<b>World</b>	36.1	23.8	38.2	0.8	1.0

Source: Authors' compilation drawing on World Bank and OECD projections.

Appendix Table A9 (continued): Primary factor shares of total GDP, 2004, 2030 and 2050

(%)

(b) 2030

Regions	Unskilled labor	Skilled labor	Capital	Land	Other natural resources
USA	39.6	28.8	30.1	0.6	1.0
Canada	36.2	20.7	38.1	0.5	4.6
EU27 and EFTA	32.2	22.3	43.7	0.6	1.2
Russia	23.5	11.6	49.3	1.3	14.3
Rest E. Europe/C. Asia	25.6	11.7	53.0	1.7	7.9
Australia	32.3	21.8	40.9	0.9	4.0
New Zealand	30.8	15.5	50.2	1.6	1.8
Japan	34.7	20.2	44.5	0.3	0.2
Korea	29.1	15.4	54.2	0.9	0.4
HongKong/Sing/Taiwan	26.1	19.1	53.5	0.3	0.9
China	29.5	10.7	54.8	1.4	3.6
Indonesia	27.8	8.4	51.8	4.1	8.0
Malaysia	32.2	12.7	46.1	0.7	8.3
Thailand	18.5	9.1	66.8	3.2	2.4
Rest of East Asia	26.6	11.7	52.1	3.7	5.8
India	29.5	11.2	48.4	8.3	2.6
Rest of South Asia	31.2	12.5	46.6	7.3	2.5
Argentina	34.2	18.0	40.4	3.0	4.4
Brazil	32	20.0	42.9	2.7	2.3
Rest of Latin America	27.7	15.6	49.5	2.4	4.8
Middle East/Nth Africa	19.5	10.8	51.3	1.2	17.2
South Africa	29.1	17.1	49.3	1.2	3.4
Rest SubSaharan Africa	27.9	9.0	44.0	5.3	13.8
<b>High-income countries</b>	35.2	24.0	38.5	0.6	1.7
<b>Developing countries</b>	27.8	13.0	51.4	2.6	5.3
<b>World</b>	33.0	20.8	42.3	1.2	2.7

Source: Authors' compilation drawing on World Bank and OECD projections.

Appendix Table A9 (continued): Primary factor shares of total GDP, 2004, 2030 and 2050

(c) 2050

(%)

Regions	Unskilled labor	Skilled labor	Capital	Land	Other natural resources
USA	38.1	27.0	32.3	0.8	1.8
Canada	33.5	18.8	39.1	0.6	7.9
EU27 and EFTA	29.9	20.7	45.7	1.0	2.6
Russia	20.2	10.6	47.2	0.9	21.2
Rest E. Europe/C. Asia	23.3	11.2	52.3	2.3	11.0
Australia	29.5	19.8	42.7	1.2	6.8
New Zealand	28.2	14.2	52.1	2.5	3.1
Japan	33.2	18.2	47.3	0.6	0.6
Korea	25.7	13.9	59.1	0.8	0.6
HongKong/Sing/Taiwan	22.7	16.5	58.9	0.3	1.6
China	24.2	10.0	61.5	0.6	3.7
Indonesia	24.6	7.8	54.1	3.5	10.0
Malaysia	29.5	11.8	48.2	0.6	9.9
Thailand	16.4	8.6	69.3	2.6	3.1
Rest of East Asia	23.8	11.4	53.5	3.5	7.8
India	26.3	10.7	52.6	7.2	3.2
Rest of South Asia	28.3	12.2	49.6	6.7	3.2
Argentina	31.8	17.4	40.1	4.0	6.7
Brazil	29.6	19.2	43.6	4.0	3.6
Rest of Latin America	25.7	15.2	49.7	2.8	6.6
Middle East/Nth Africa	17.5	10.2	50.0	1.7	20.6
South Africa	26.4	15.9	49.5	2.0	6.1
Rest SubSaharan Africa	25.6	8.8	41.5	6.9	17.2
<b>High-income countries</b>	33.4	22.4	40.1	0.9	3.1
<b>Developing countries</b>	24.4	12.0	54.9	2.4	6.3
<b>World</b>	30.0	18.5	45.7	1.5	4.3

Source: Authors' compilation drawing on World Bank and OECD projections.

Appendix Table A10: Unskilled labour share of agricultural and non-agricultural GDP, 2004, 2030 and 2050

(%)

	Agricultural GDP			Non-agricultural GDP		
	2004	2030	2050	2004	2030	2050
USA	45.0	44.5	43.2	40.6	39.5	37.9
Canada	42.3	42.1	39.8	38.3	36.0	33.4
EU27 and EFTA	55.0	53.4	49.1	33.6	31.5	29.3
Russia	51.4	57.5	65.4	26.7	21.3	17.9
Rest E. Europe/C. Asia	52.5	54.3	51.7	27.0	23.0	20.9
Australia	48.0	45.3	43.3	34.3	31.8	28.9
New Zealand	56.2	55.1	52.5	31.6	28.5	25.7
Japan	44.7	49.8	49.9	36.6	34.4	32.9
Korea	39.9	46.2	45.4	35.2	28.8	25.3
HongKong/Sing/Taiwan	49.4	51.5	50.7	30.9	25.8	22.5
China	57.1	68.4	77.5	37.3	27.2	22.4
Indonesia	42.5	42.6	39.8	30.5	26.4	23.6
Malaysia	40.7	42.0	38.7	36.7	32.0	29.5
Thailand	39.3	41.9	43.6	19.8	16.6	14.5
Rest of East Asia	44.9	43.1	39.2	28.4	25.0	22.7
India	40.3	38.7	38.3	33.0	27.3	23.8
Rest of South Asia	35.3	32.0	29.5	35.6	31.0	28.1
Argentina	46.9	46.0	39.6	37.1	33.1	31.1
Brazil	25.3	25.1	24.7	36.5	32.8	30.2
Rest of Latin America	45.7	42.8	38.2	29.1	26.5	24.8
Middle East/Nth Africa	55.1	51.9	45.7	20.2	17.7	16.2
South Africa	35.2	30.3	25.2	31.3	29.0	26.5
Rest SubSaharan Africa	68.0	57.3	49.9	22.0	21.0	19.9
<b>High-income countries</b>						
<b>Developing countries</b>						
<b>World</b>						

Source: Authors' compilation from GTAP model projections



Appendix Table A11: Agriculture's share of total employment of unskilled labour, 2004, 2030 and 2050

(%)

	<b>2004</b>	<b>2030</b>	<b>2050</b>
USA	1.8	2.2	2.7
Canada	2.4	2.8	2.5
EU27 and EFTA	4.1	4.9	5.4
Russia	13.6	14.8	15.7
Rest E. Europe/C. Asia	17.8	17.6	17.1
Australia	5.4	6.0	6.2
New Zealand	13.1	15.6	17.5
Japan	1.9	2.4	2.9
Korea	3.3	3.4	3.3
HongKong/Sing/Taiwan	2.0	2.0	1.9
China	17.4	13.3	10.4
Indonesia	16.5	12.6	10.3
Malaysia	2.5	1.7	1.3
Thailand	17.7	17.3	17.7
Rest of East Asia	18.1	13.8	11.2
India	28.0	25.0	24.9
Rest of South Asia	20.3	16.6	13.8
Argentina	11.3	11.5	10.5
Brazil	5.9	7.3	8.8
Rest of Latin America	14.0	11.6	9.8
Middle East/Nth Africa	15.0	13.9	12.1
South Africa	3.6	4.2	4.0
Rest SubSaharan Africa	46.0	39.0	36.9
<b>High-income countries</b>	<b>3.2</b>	<b>3.8</b>	<b>4.2</b>
<b>Developing countries</b>	<b>14.8</b>	<b>12.9</b>	<b>11.6</b>
<b>World</b>	<b>5.2</b>	<b>6.1</b>	<b>6.5</b>

Source: Authors' compilation from GTAP model projections

Table 1: Exogenous Yield Shocks (%) attributed to Climate Change in 2030, by region and sector

Regions	Rice	Wheat	Coarse grains	Fruits Veg	Oil seeds	Cotton	Other crops
USA	-3	2	3	2	2	-3	2
Canada	-3	7	-10	2	10	-3	2
EU27 and EFTA	7	7	-5	7	7	7	7
Russia	7	7	-5	7	7	7	7
Rest of Europe/C. Asia	7	7	-5	7	7	7	7
Australia	-3	7	-5	-3	2	-3	7
New Zealand	7	7	-5	7	2	7	7
Japan	9	4	0	4	9	9	4
Korea	12	12	5	12	12	12	12
HongKong/Sing/Taiwan	12	12	5	-3	12	12	12
China	0	2	-10	-8	0	0	-8
Indonesia	-3	-3	-10	7	-3	-3	-3
Malaysia	-3	-3	-10	-3	-3	-3	-3
Thailand	-3	-3	-10	-3	-3	-3	-3
Rest of East Asia	-3	-3	-10	-3	-3	-3	-3
India	-5	-3	-10	-3	-3	-3	-3
Rest of South Asia	-5	-3	-10	-3	-3	-3	-3
Argentina	-3	-3	-10	-3	-3	-3	-3
Brazil	-3	-3	-10	-3	2	-3	-3
Rest of Latin America	-3	-3	-5	-3	-3	-3	-3
Middle East/Nth Africa	2	2	-5	2	2	2	2
South Africa	-8	-8	-20	-8	-8	-8	-8
Rest Sub-Saharan Africa	-3	-3	-10	-3	-3	-3	-3

Source: Hertel, Burke and Lobell (2010)

Table 2: Effects of economic growth, and of crop yield changes due to climate change, on agricultural self sufficiency, from 2004 to 2030 and 2050  
(percent)

Regions	Base- 2004	Base- 2030	Yield shock- 2030	Yield +Labor shock 2030	Base- 2050	Yield shock- 2050	Yield +Labor shock 2050
USA	103.4	111.8	112.3	112.3	122.4	123.4	123.3
Canada	108.3	119.0	120.1	120.0	130.0	133.8	133.6
EU27 and EFTA	94.0	100.9	101.7	101.7	111.1	115.2	115.0
Russia	89.2	89.6	90.0	90.0	90.5	92.0	92.0
Rest of EE/C Asia	100.2	100.0	101.2	101.1	106.6	111.6	111.1
Australia	137.9	152.1	153.4	153.7	167.0	172.5	173.1
New Zealand	161.2	171.9	173.2	173.5	186.3	191.9	192.3
Japan	82.5	83.3	83.7	83.7	84.6	85.8	85.8
Korea	81.4	79.5	81.8	81.7	78.3	82.7	82.6
HK/Sing/Taiwan	65.9	65.2	65.7	65.4	65.5	64.7	64.6
China	97.2	90.3	89.4	89.3	85.8	82.8	82.6
Indonesia	94.7	84.2	83.9	84.0	79.0	82.7	82.8
Malaysia	60.3	45.3	44.7	44.8	39.1	37.7	38.0
Thailand	111.9	97.5	96.8	96.8	88.5	86.7	86.6
Rest of East Asia	99.5	89.5	88.8	88.8	86.0	84.2	84.1
India	101.2	95.1	94.3	94.3	87.5	85.3	85.5
Rest of Sth. Asia	95.7	86.1	85.4	85.5	78.8	77.3	77.5
Argentina	142	145.8	144.1	143.9	154.9	153.1	151.9
Brazil	122.5	132.0	131.5	131.8	144.1	143.9	144.3
Rest of L America	101.7	94.9	94.3	94.2	93.7	91.5	91.4
M. East/N. Africa	83.6	82.8	83.1	82.7	83.1	83.9	83.3
South Africa	106.9	115.4	114.5	114.6	129.0	125.8	125.7
Rest of SS Africa	102.2	97.2	96.1	95.8	96.7	93.5	93.1
<b>High-income countries</b>	<b>96.1</b>	<b>111.8</b>	112.4	112.3	126.9	129.7	129.3
<b>Developing countries</b>	<b>99.8</b>	<b>92.5</b>	91.9	91.9	88.6	86.8	86.8

Source: Authors' simulations, assuming the crop productivity shocks of climate change are those shown in Table 1 by 2030 and twice those by 2050.

Table 3: Effects of crop productivity shocks due to climate change on agricultural production, consumption and trade, 2030 and 2050  
(percent deviation from baseline in projected year)

(c) 2030: Average difference in world agric prices in 2030 = 0.23%

Regions	Farmer price	Agricultural production volume	Agricultural consumption volume	Agricultural value added	Agricultural value of exports	Agricultural value of imports
USA	0.3	0.4	-0.1	-1.2	2.5	-0.6
Canada	0.2	1.1	0.2	-1.8	3.5	0.5
EU27 and EFTA	-0.3	1.1	0.3	-0.5	3.3	-0.7
Russia	-0.2	0.7	0.2	-0.6	9.1	-1.5
Rest of Europe/C. Asia	-0.6	1.6	0.3	-0.7	12.1	-1.8
Australia	0.5	0.7	-0.1	-1.7	2.2	1.0
New Zealand	0.1	1.2	0.4	-1.5	2.1	-0.4
Japan	-0.4	0.7	0.2	0.1	13.6	-0.9
Korea	-3.5	4.3	1.4	0.1	43.8	-5.8
HongKong/Sing/Taiwan	0.3	1.2	0.4	-1.9	10.9	0.7
China	4.3	-1.8	-0.8	-4.4	-21.1	6.2
Indonesia	1.2	-0.6	-0.2	-0.7	8.3	1.7
Malaysia	1.0	-1.1	0.4	-0.1	-1.1	1.6
Thailand	2.2	-1.5	-0.7	-1.8	-1.6	3.7
Rest of East Asia	1.6	-1.3	-0.5	-0.7	-2.9	3.3
India	3.2	-1.7	-0.9	-2.0	-6.7	12.7
Rest of South Asia	1.2	-1.1	-0.3	-0.4	-3.7	4.1
Argentina	0.9	-1.8	-0.6	0.4	-3.9	1.5
Brazil	0.5	-0.7	-0.4	0.0	-1.7	0.6
Rest of Latin America	0.9	-0.9	-0.3	-0.4	-4.5	2.2
Middle East/Nth Africa	-0.1	0.6	0.2	-0.4	5.1	-0.3
South Africa	0.9	-1.2	-0.4	-1.1	-3.1	1.7
Rest Sub-Saharan Africa	2.5	-1.7	-0.6	-1.3	-6.6	2.6
<b>High-income countries</b>	<b>-0.1</b>	<b>0.8</b>	<b>0.4</b>	<b>-0.8</b>	<b>1.8</b>	<b>-0.8</b>
<b>Developing countries</b>	<b>2.3</b>	<b>-1.1</b>	<b>-0.5</b>	<b>-2.1</b>	<b>-2.6</b>	<b>3.4</b>
<b>World</b>	<b>1.2</b>	<b>-0.2</b>	<b>-0.1</b>	<b>-1.6</b>	<b>0.9</b>	<b>1.5</b>

Table 3 (continued): Effects of crop productivity shocks due to climate change on agricultural production, consumption and trade, 2030 and 2050  
(percent deviation from baseline in projected year)

(d) 2050: Average difference in world agric prices in 2050 = 1.69%

Regions	Farmer price	Agricultural production volume	Agricultural consumption volume	Agricultural value added	Agricultural value of exports	Agricultural value of imports
USA	3.0	-0.8	-1.6	-5.6	2.8	3.6
Canada	1.6	3.0	0.2	-7.2	9.5	2.8
EU27 and EFTA	0.0	4.8	1.0	-5.3	14.2	-0.4
Russia	0.4	2.2	0.5	-3.8	31.9	-0.9
Rest of Europe/C. Asia	0.2	4.9	0.2	-5.7	30.5	0.0
Australia	1.8	3.1	-0.2	-6.5	7.8	3.4
New Zealand	1.1	3.8	0.8	-6.2	7.1	0.9
Japan	-0.2	2.6	1.1	-3.0	30.1	0.5
Korea	-4.1	8.7	2.9	-5.5	101.5	-5.2
HongKong/Sing/Taiwan	1.4	-0.5	0.7	-2.2	1.4	2.7
China	12.9	-5.2	-1.8	-11.1	-40.3	17.1
Indonesia	-5.3	7.3	2.4	-1.3	116.3	-14.5
Malasya	2.5	-2.0	1.8	-0.7	0.5	4.2
Thailand	4.9	-2.9	-0.9	-3.4	2.9	10.1
Rest of East Asia	4.0	-2.9	-0.8	-1.9	-3.4	7.9
India	6.0	-4.1	-1.7	-2.5	-4.2	14.8
Rest of South Asia	2.8	-2.4	-0.5	-0.7	-7.1	6.2
Argentina	3.7	-4.1	-3.0	-1.6	-5.7	4.9
Brazil	2.1	-1.5	-1.3	-1.6	-1.7	2.4
Rest of Latin America	5.3	-3.5	-1.1	-4.8	-10.6	11.1
Middle East/Nth Africa	0.5	1.5	0.5	-2.5	12.4	0.3
South Africa	5.1	-5.5	-3.2	-9.2	-8.7	6.5
Rest Sub-Saharan Africa	9.2	-5.1	-1.8	-5.4	-16.4	10.2
<b>High-income countries</b>	<b>1.2</b>	<b>2.6</b>	<b>0.4</b>	<b>-5.4</b>	<b>7.2</b>	<b>0.4</b>
<b>Developing countries</b>	<b>6.6</b>	<b>-3.0</b>	<b>-1.1</b>	<b>-5.6</b>	<b>-3.2</b>	<b>9.0</b>
<b>World</b>	<b>4.5</b>	<b>-0.8</b>	<b>-0.6</b>	<b>-5.5</b>	<b>5.1</b>	<b>6.6</b>

Source: Authors' simulations, assuming that climate change involves twice the crop productivity shocks shown in Table 1 by 2030 or 2050 relative to the baseline in that year.

Table 4: Effects on national economic welfare of crop productivity losses, 2030 and 2050

(2004 US\$ million, deviation from baseline in projected year)

(c) 2030

Regions	Due to changes in:				
	Factor productivity	Terms of trade	Resource use efficiency	Total economic welfare	Total economic welfare as % of Income
USA	86	912	-265	732	0.00
Canada	114	43	-97	61	0.00
EU27 and EFTA	804	505	-1639	-330	0.00
Russia	183	-186	-65	-67	-0.01
Rest of Europe/C. Asia	612	84	194	889	0.07
Australia	8	341	-30	319	0.03
New Zealand	17	49	1	68	0.04
Japan	189	-94	-265	-171	0.00
Korea	857	115	-909	63	0.00
HongKong/Sing/Taiwan	33	46	-5	75	0.01
China	-7656	-1805	-175	-9636	-0.21
Indonesia	-280	-5	13	-272	-0.05
Malaysia	-62	-34	20	-76	-0.02
Thailand	-354	180	-99	-274	-0.08
Rest of East Asia	-418	-38	-1	-456	-0.12
India	-5894	-294	425	-5764	-0.34
Rest of South Asia	-946	-167	93	-1021	-0.24
Argentina	-173	200	-132	-106	-0.04
Brazil	-304	226	17	-61	-0.01
Rest of Latin America	-952	18	221	-713	-0.03
Middle East/Nth Africa	201	-282	22	-59	0.00
South Africa	-84	116	-12	20	0.01
Rest Sub-Saharan Africa	-1468	74	25	-1370	-0.21
<b>High-income countries</b>	2013	1654	-2166	1501	0.00
<b>Developing countries</b>	-17500	-1652	-497	-19649	-0.11
<b>World</b>	-15487	2	-2663	-18148	-0.03

Table 4 (continued): Effects on national economic welfare of crop productivity losses, 2030 and 2050

(2004 US\$ million, deviation from baseline in projected year)

(d) 2050

	Due to changes in:				
	Factor productivity	Terms of trade	Resource use efficiency	Total economic welfare	Total economic welfare as % of Income
USA	-4838	9300	1125	5587	0.03
Canada	434	800	-552	682	0.04
EU27 and EFTA	1723	5146	-8512	-1643	-0.01
Russia	239	-1110	-184	-1055	-0.08
Rest of Europe/C. Asia	2104	885	1302	4292	0.24
Australia	226	2961	-75	3112	0.19
New Zealand	66	455	21	543	0.24
Japan	199	-588	-1116	-1505	-0.03
Korea	2170	590	-2577	183	0.01
HongKong/Sing/Taiwan	-129	344	-65	150	0.01
China	-39341	-16630	-569	-56540	-0.68
Indonesia	6143	172	-464	5851	0.56
Malaysia	-226	32	149	-45	-0.01
Thailand	-1417	663	-379	-1133	-0.19
Rest of East Asia	-1445	-417	-28	-1890	-0.28
India	-23668	-2305	1309	-24664	-0.82
Rest of South Asia	-3487	-973	467	-3993	-0.53
Argentina	-716	1186	-454	17	0.00
Brazil	-1346	1929	1	585	0.04
Rest of Latin America	-5424	-1213	612	-6026	-0.15
Middle East/Nth Africa	841	-2010	219	-951	-0.03
South Africa	-624	1248	-74	551	0.11
Rest Sub-Saharan Africa	-7854	-431	207	-8078	-0.75
<b>High-income countries</b>	153	17849	-7990	10012	0.02
<b>Developing countries</b>	-76523	-17815	-1647	-95986	-0.32
<b>World</b>	-76370	34	-9638	-85974	-0.11

Source: authors' simulations

Table 5: Effects on agricultural production, consumption and trade of crop productivity losses and decreases in unskilled labour productivity, 2030 and 2050

(percent deviation from baseline in projected year)

(c) 2030: average difference in world agric prices = 0.44%

	Farmer price	Agricultural production volume	Agricultural consumption volume	Agricultural value added	Agricultural value of exports	Agricultural value of imports
USA	0.4	0.4	0.0	-1.2	2.4	-0.7
Canada	0.3	1.0	0.2	-1.8	3.4	0.7
EU27 and EFTA	-0.1	1.1	0.3	-0.7	3.5	-0.6
Russia	0.0	0.6	0.1	-0.7	9.0	-1.6
Rest of Europe/C. Asia	-0.4	1.4	0.3	-0.8	10.9	-1.7
Australia	0.6	0.9	-0.1	-2.0	2.7	0.9
New Zealand	0.4	1.2	0.3	-1.8	2.4	-0.1
Japan	-0.3	0.7	0.3	-0.1	13.6	-0.8
Korea	-3.0	3.5	0.8	0.3	41.7	-5.9
HongKong/Sing/Taiwan	0.6	0.2	-0.2	-1.5	9.3	0.5
China	4.8	-2.8	-1.7	-4.0	-23.2	6.1
Indonesia	1.3	-1.2	-1.0	0.0	8.4	0.7
Malaysia	1.0	-1.6	-0.3	0.6	0.2	0.7
Thailand	2.5	-1.5	-0.7	-2.0	-1.6	4.0
Rest of East Asia	1.9	-2.0	-1.2	-0.3	-3.1	3.0
India	3.3	-2.3	-1.5	-1.5	-8.7	10.3
Rest of South Asia	1.4	-1.7	-1.0	0.1	-2.8	2.7
Argentina	1.1	-1.8	-0.5	0.3	-4.3	1.6
Brazil	0.7	-1.2	-1.1	0.5	-1.6	-0.1
Rest of Latin America	1.2	-1.7	-1.0	0.1	-5.4	2.1
Middle East/Nth Africa	0.4	-0.6	-0.5	0.0	2.5	0.2
South Africa	1.1	-1.2	-0.5	-1.3	-3.1	1.5
Rest Sub-Saharan Africa	3.0	-2.9	-1.5	-0.6	-8.7	2.9
<b>High-income countries</b>	<b>0.1</b>	<b>0.8</b>	<b>0.4</b>	<b>-0.9</b>	<b>1.6</b>	<b>-0.7</b>
<b>Developing countries</b>	<b>2.6</b>	<b>-1.9</b>	<b>-1.2</b>	<b>-1.6</b>	<b>-3.5</b>	<b>3.0</b>
<b>World</b>	<b>1.4</b>	<b>-0.6</b>	<b>-0.5</b>	<b>-1.4</b>	<b>0.6</b>	<b>1.4</b>



Table 5 (continued): Effects of on agricultural production, consumption and trade of crop productivity losses and decreases in unskilled labour productivity, 2030 and 2050

(percent deviation from baseline in projected year)

(d) 2050: average difference in world agric prices = 1.90%

Regions	Farmer price	Agricultural production volume	Agricultural consumption volume	Agricultural value added	Agricultural value of exports	Agricultural value of imports
USA	3.1	-0.6	-1.3	-5.1	2.5	2.9
Canada	1.7	3.0	0.2	-6.8	9.2	2.8
EU27 and EFTA	0.2	4.5	1.0	-4.9	13.5	-0.3
Russia	0.6	1.9	0.3	-3.7	29.9	-1.5
Rest of Europe/C. Asia	0.4	4.5	0.3	-5.3	27.0	-0.4
Australia	1.8	3.8	0.2	-6.8	9.0	2.9
New Zealand	1.4	3.8	0.5	-6.4	7.3	1.6
Japan	-0.1	2.5	1.2	-2.9	28.1	0.5
Korea	-3.9	8.6	3.0	-5.5	98.8	-4.9
HongKong/Sing/Taiwan	1.7	-0.5	0.9	-2.3	0.9	3.1
China	13.5	-7.1	-3.5	-9.8	-43.6	16.5
Indonesia	-5.3	6.0	1.0	0.1	117.0	-16.1
Malaysia	2.2	-2.8	0.2	0.7	2.6	2.1
Thailand	5.3	-2.9	-0.9	-3.6	2.5	10.4
Rest of East Asia	4.4	-4.2	-2.1	-1.0	-4.1	7.1
India	6.1	-4.9	-2.7	-1.8	-10.1	12.1
Rest of South Asia	3.2	-3.4	-1.8	0.0	-6.1	4.0
Argentina	3.7	-4.1	-2.2	-1.2	-7.0	5.0
Brazil	2.3	-2.4	-2.6	-0.5	-2.0	0.8
Rest of Latin America	5.7	-4.9	-2.5	-3.6	-12.3	10.1
Middle East/Nth Africa	1.2	-0.5	-0.8	-1.6	7.3	0.3
South Africa	5.1	-5.5	-3.0	-8.4	-9.2	5.4
Rest Sub-Saharan Africa	9.2	-6.8	-3.2	-3.9	-19.3	9.5
<b>High-income countries</b>	<b>1.3</b>	<b>2.5</b>	<b>0.6</b>	<b>-5.1</b>	<b>6.4</b>	<b>0.3</b>
<b>Developing countries</b>	<b>7.0</b>	<b>-4.3</b>	<b>-2.3</b>	<b>-4.6</b>	<b>-4.8</b>	<b>7.9</b>
<b>World</b>	<b>4.7</b>	<b>-1.6</b>	<b>-1.4</b>	<b>-4.7</b>	<b>4.1</b>	<b>5.8</b>

Source: authors' simulations

Table 6: Effects on national economic welfare of crop productivity losses **and** decreases in unskilled labour productivity, 2030 and 2050

(2004 US\$ million, deviation from baseline in projected year)

(c) 2030

	Factor productivity	Terms of trade	Resource use efficiency	Total economic welfare	Total economic welfare as % of Income
USA	87	-163	-858	-933	-0.01
Canada	114	-246	-215	-347	-0.03
EU27 and EFTA	803	-386	-4143	-3726	-0.02
Russia	183	-1826	-627	-2270	-0.23
Rest of Europe/C. Asia	609	-477	98	230	0.02
Australia	8	-1067	-167	-1225	-0.11
New Zealand	17	57	-12	62	0.04
Japan	189	193	-430	-48	0.00
Korea	-10309	1297	-2758	-11771	-0.79
HongKong/Sing/Taiwan	-8852	1161	-490	-8180	-0.69
China	-42711	3822	-7855	-46745	-1.03
Indonesia	-4841	-299	-196	-5335	-0.91
Malaysia	-2853	165	-109	-2797	-0.92
Thailand	-354	448	-79	15	0.00
Rest of East Asia	-3172	-66	-387	-3624	-0.92
India	-18420	1628	-814	-17606	-1.05
Rest of South Asia	-4511	262	-213	-4462	-1.04
Argentina	-173	112	-135	-196	-0.08
Brazil	-9290	201	-1163	-10253	-0.97
Rest of Latin America	-15267	-507	-6941	-22716	-0.89
Middle East/Nth Africa	-9935	-3227	-1148	-14310	-0.73
South Africa	-84	-233	-60	-377	-0.11
Rest Sub-Saharan Africa	-6260	-858	-430	-7547	-1.16
<b>High-income countries</b>	2010	-3914	-6353	-8257	-0.02
<b>Developing countries</b>	-137031	3907	-22779	-155903	-0.88
<b>World</b>	-135022	-7	-29131	-164160	-0.28

Source: authors' simulations

Table 6 (continued): Effects on national economic welfare of crop productivity losses and decreases in unskilled labour productivity, 2030 and 2050

(2004 US\$ million, deviation from baseline in projected year)

(d) 2050

	Factor productivity	Terms of trade	Resource use efficiency	Total economic welfare	Total economic welfare as % of Income
USA	-4766	-149	-659	-5574	-0.03
Canada	429	-1644	-930	-2146	-0.12
EU27 and EFTA	1684	-4303	-15320	-17938	-0.10
Russia	237	-8213	-1594	-9570	-0.71
Rest of Europe/C. Asia	2068	-1561	879	1387	0.08
Australia	223	-4234	-650	-4662	-0.28
New Zealand	65	389	-31	423	0.19
Japan	197	-898	-1549	-2250	-0.04
Korea	2162	4066	-2849	3378	0.13
HongKong/Sing/Taiwan	-128	1992	49	1913	0.10
China	-149143	18491	-23808	-154460	-1.85
Indonesia	-8367	-540	-1082	-9989	-0.96
Malaysia	-9413	1160	-297	-8549	-1.58
Thailand	-1410	1959	-329	220	0.04
Rest of East Asia	-9992	-320	-1182	-11495	-1.71
India	-61146	7837	-1189	-54499	-1.82
Rest of South Asia	-14699	1269	-485	-13915	-1.85
Argentina	-708	756	-487	-438	-0.12
Brazil	-26800	952	-3164	-29013	-1.83
Rest of Latin America	-46611	-3455	-20528	-70594	-1.81
Middle East/Nth Africa	-29479	-9842	-3349	-42670	-1.34
South Africa	-609	-632	-269	-1510	-0.30
Rest Sub-Saharan Africa	-21666	-3144	-1232	-26042	-2.43
<b>High-income countries</b>	138	-20613	-19855	-40329	-0.08
<b>Developing countries</b>	-378011	20548	-60200	-417663	-1.38
<b>World</b>	-377873	-64	-80055	-457992	-0.57

Source: authors' simulations