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South America's Contribution to World Food Markets: GTAP Projections to 2030

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Abstract

If rapid growth in the global economic importance of some emerging economies continues to be strongest in natural resource-poor Asian economies, so too will be the growth in that region's demand for imports of primary products, to the on-going benefit of natural resource-rich countries. This paper projects global trade patterns over the next two decades in the course of economic development and structural changes. The GTAP model and Version 8 of the GTAP database are used, together with supplementary data and growth forecasts from a range of sources. The baseline projection from 2007 to 2030 assumes trade-related policies do not change in each region but that agricultural land, extractable mineral resources, population, skilled and unskilled labour, capital and real GDP grow at exogenously-inserted rates. That core projection of the world economy is compared with a number of alternative scenarios. Implications for South American versus other natural resource-abundant economies are highlighted.

Keywords: Global economy-wide model projections; Asian economic growth and structural change; South-South trade; booming sector economics, food security

JEL codes: D58, F13, F15, F17, Q17

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South America's Contribution to World Food Markets: GTAP Projections to 2030

1. Introduction

Rapid economic growth in emerging economies is shifting the global economic and industrial centre of gravity away from the north Atlantic, and globalization is causing trade to grow much faster than output, especially in Asia. Together these forces are raising the importance of natural resource-poor Asian economies in world output and trade, and are increasing the demand for exports from natural resource-rich economies. This is a continuation of a process begun in Japan in the 1950s and followed by Hong Kong, Korea and Taiwan from the late 1960s, then by some Southeast Asian countries, but most recently by much more populous China and India. The earlier Northeast Asian group represents just 3 percent of the world's population and so its rapid industrial growth was accommodated by the rest of the world without much difficulty, including in markets for primary products. China and India, by contrast, account for more than two-fifths of humanity and so their rapid and persistent industrialization has far greater significance for primary product markets and thus for such things as food and energy security and greenhouse gas emissions globally. How markets and governments respond to these concerns could have non-trivial effects in both the emerging economies and those of their trading partners, including South American countries.

This paper focuses on the consequences for food and other primary product markets of the prospective continuation of this latest and by far largest emergence of Asian industrialization. Both development theory and historical experience provide guidance as to what to expect. Economic growth over the two previous generations in East Asia, plus the newest generation's first decades of rapid industrialization, have been quite consistent with trade and development theory. Section 2 of the paper briefly summarizes that theory and history, together with a set of forecasts, to assist anticipating likely trends over the next two decades. Those expectations are then put to the test using a global economy-wide model for projecting the world economy to 2030, described in Section 3. The results that emerge from a core business-as-usual projection are summarized in Section 4, and are compared in Section 5

with those generated using alternative assumptions about sectoral productivity growth rates, so as to be able to draw out implications for national and global food markets and trade.

The paper's core projection assumes current trade policies continue, and that endowment and productivity growth rates are sufficient to allow global export supplies of agricultural and mineral products to expand to almost keep pace with import demands. This ensures the prices of primary products relative to manufactures in international markets in 2030 are only modestly above 2007 levels. That core projection is compared with two alternative growth scenarios to 2030. One involves slower productivity growth in primary sectors globally, in which case the relative price of primary products will be somewhat higher by 2030. The other growth scenario assumes faster grain productivity growth in China and India, presumed to be due to expanded domestic agricultural R&D investments aimed at slowing the rise in their foodgrain import dependence that is projected in the core scenario to otherwise occur. Section 6 of the paper discusses several caveats before the final section concludes by drawing out key lessons and implications from the results for South America's natural resource-abundant economies.

2. What to expect from past experience

China and India, like Northeast Asia's earlier rapidly industrializing economies, are relatively natural resource-poor and densely populated. So too are some other Asian countries. They are therefore highly complementary with relatively lightly populated and slower-growing economies, well endowed with agricultural land and/or mineral resources in Latin America, Australasia, the Middle East and Africa, according to the workhorse theory of comparative advantage developed in the 20th century. That theory blends the Heckscher-Ohlin-Samuelson model, which assumes all factors of production are mobile between sectors, with the Ricardo-Viner model which assumes some factors are sector-specific. Such a blend is provided by Krueger (1977) and explored further by Deardorff (1984). They consider two tradable sectors each using intersectorally mobile labour plus one sector-specific factor (natural-resource capital or produced capital). Assuming that labour exhibits diminishing marginal product in each sector, and that there are no services or nontradables and no policy distortions, then at a given set of international prices the real wage in each economy is determined by the aggregate per worker endowment of natural-resource and produced capital. The commodity composition of a country's trade – that is, the extent to which a country is a net exporter of

primary or industrial products – is determined by its endowment of natural relative to industrial capital compared with that ratio for the rest of the world.

Leamer (1987) develops this model further and relates it to paths of economic development. If the stock of natural resources is unchanged, rapid growth by one or more economies relative to others in their availability of produced capital (physical plus human skills and technological knowledge) per unit of available labour time would tend to cause those economies to strengthen their comparative advantage in non-primary products. By contrast, a discovery of minerals or energy raw materials would strengthen that country's comparative advantage in mining and weaken its comparative advantage in agricultural and other tradable products, *ceteris paribus*. It would also boost national income and hence the demand for nontradables, which would cause mobile resources to move into the production of nontradable goods and services, further reducing farm and industrial production (Corden 1984).

Domestic or foreign savings can be invested to enhance the stock and/or improve the quality not only of a country's produced capital but also of its economically exploitable stock of natural resources. Any such increase in the net stock of produced capital per worker will put upward pressure on real wages. That will encourage, in all sectors, the use of more labour-saving techniques and the development and/or importation of better technologies that are less labour intensive. Whether it boosts industrialization more than agriculture or other primary production will depend on the relative speed of sector-specific productivity growth that such R&D investments yield. Which types of investment would expand fastest in a free-market setting depends on their expected rates of return. The more densely populated, natural resource-poor an open economy is, the greater the likelihood that the highest payoff would be in expanding stocks of capital (including technological knowledge) for non-primary sectors. That gives rise to the Rybczynski effect, of pulling mobile resources (most notably labour) out of agriculture. If there is also relatively rapid productivity growth in primary sectors (as Martin and Mitra (2001) have found to be the case historically), and especially if that productivity growth is labour-saving, this also pushes labour into non-primary sectors (Martin and Warr 1993).

At early stages of development of a country with a relatively small stock of natural resources per worker, wages would be low and the country would have a comparative cost advantage in unskilled labour-intensive, standard-technology manufactures. Then as the stock of industrial capital grows, there would be a gradual move toward exporting manufactures that are relatively intensive in their use of physical capital, skills and knowledge. Natural

resource-abundant economies, however, would invest more in capital specific to primary production and so would not develop a comparative advantage in manufacturing until a later stage of development, at which time their industrial exports would be relatively capital intensive.

The above theory of changing comparative advantages – which can also be used to explain shocks to that pattern from discovery-driven mining booms or major terms of trade changes imposed from the rest of the world – has been used successfully to explain the evolving trade patterns of Asia's resource-poor first- and second-generation industrializing economies and their resource-rich trading partners (see, e.g., Anderson and Smith 1981). It has also explained the 20th century evolution, for early- and later-industrializing countries, of the flying geese pattern of comparative advantage and then disadvantage in unskilled labour-intensive manufactures as some rapidly growing economies expand their endowments of industrial capital per worker relative to the rest of the world – the classic example being clothing and textiles (Anderson 1992; Ozawa 2009).

The evolving pattern of a country's production and trade specialization depends on its changes not only in its comparative advantages but also in its sectoral and trade policies. If a developing economy that had been protecting its manufacturers from import competition chose to lower those barriers, there would be two sets of consequences. One is that the country would be better able to specialize in those manufacturing activities in which it had its strongest comparative advantages and to nimbly alter its product mix as those advantages evolved. The other is that its real exchange rate would depreciate, allowing other tradable sectors such as agriculture to expand production and net exports. If the economy had been taxing exports of primary products, a lowering of them also would allow production of those goods to grow. And if a dual or multiple exchange rate system was replaced by a market-driven system, that reform would effectively remove that implicit form of trade taxation (Dervis, de Melo and Robinson 1981) and thus amplify the above effects.

According to a recent multi-country empirical study, precisely those types of policy reforms have taken place in many developing countries over the past three decades. More specifically, policy-induced distortions to the domestic prices of agricultural goods relative to other tradable product prices had discriminated heavily against many developing country farmers prior to the 1980s, but they have since been greatly reduced (Anderson 2009). This is

particularly so in Asia, but also in Latin America.¹ That new evidence sheds light on something that has perplexed agricultural trade analysts for some time (see, e.g., Anderson and Peng 1998): why self-sufficiency in farm products in China, India and some other densely populated emerging Asian economies has fallen so little, despite very strong growth in production and exports of manufactures (and of certain tradable services in the case of India). The fact that the previous anti-agricultural bias of national policies in Asia's emerging economies has been gradually phased out raises the question: will it be replaced by agricultural protection growth, as happened first in Japan and then in Korea and Taiwan? If not, then will expectations from theory now be realized in the form of declining self-sufficiency in farm products as industrialization proceeds further?

3. Modeling methodology and database

Given the interdependence between sectors of growing economies, an economy-wide model of the world's national markets is needed to project future trends in agricultural trade and food markets. In this study we employ the GTAP model of the global economy (Hertel 1997) and the new Version 8 of the GTAP database which is calibrated to 2007 levels of production, consumption, trade and protection (Narayanan, Aguiar and McDougall 2012). The standard GTAP model is perhaps the most widely used CGE model for economy-wide global market analysis, in part due to its robust and explicit assumptions; and its base period of 2007 is ideal because it immediately precedes the recent period of temporary spikes in food and fuel prices and the global financial crisis and recession.

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 intermediate inputs substitute for value-added at the next CES level in fixed proportions. Land is specific to agriculture in the GTAP database, and is mobile amongst alternative agricultural uses over this projection period, according to a Constant Elasticity of Transformation (CET) which, through a revenue function, transforms land from one use to another. In the modified version of the GTAP model we use, natural resources, including

¹ For more details on the Asian and Latin American policy experiences, see Anderson and Martin (2009), Anderson and Valdés (2008) and Valdés and Foster (2012).

coal, oil, gas and other minerals, are specific to the sector in which they are mined. Aggregate national employment of each productive factor is fixed in the standard macro-economic closure, although we use exogenous projections to model changes in factor availability over time. Labour and produced capital are assumed to be mobile across all uses within a country, but immobile internationally, in the long-run model closure adopted.

On the demand side there is a national representative household whose expenditure is governed by a Cobb-Douglas aggregate utility function which allocates net national expenditures across private, government, and saving activities. The greatest advantage of this household representation is the unambiguous indicator of economic welfare dictated by the national utility function.² 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, calibrated to replicate a vector of own-price and income elasticities of demand (Hertel et al. 2008). ~~In projecting to 2030 we modify these elasticities for developing country crops and animal products for rapidly growing economies so they more closely match the income elasticities for these products in currently higher income countries (following Yu et al. 2004). We do so by econometrically estimating the relationship between per capita incomes and changes in income elasticities of demand for agricultural and food products, as reflected in the full GTAP database for 2007. In projecting to 2030 we follow Yu et al. (2004) in modifying these elasticities. We do so by econometrically estimating the relationship between per capita incomes and changes in income elasticities of demand for agricultural and food products, as reflected in the full GTAP database.~~³ These estimates are then used to modify the elasticities for each region by 2030, given our projections of per capita income for each region.⁴

Bilateral international trade flows are handled through the Armington (1969) specification by which products are differentiated by country of origin. These Armington

² 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.

³ We are grateful to Papu Siameja for his careful research assistance with econometrically estimating these projected income elasticities.

⁴ As a form of sensitivity analysis, we also tested the impact of driving the income elasticities close to zero for grains in China. It turns out that dropping them from the already fairly low adjusted estimate of 0.2 has little further effect on overall food self-sufficiency. This is in part because elasticities for other products, including other types of foods, have to rise slightly so their weighted average is still unity. Even for grains there is little change in self-sufficiency, with intermediate usage of grains by firms increasing a little, dampening the impact of lower household direct demand for grains.

elasticities are the same across countries 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 long-term changes, we follow the typical modelling practise of doubling the short-to-medium term Armington elasticities. The national balance of trade is determined by the relationship between national investment and savings and investment can be allocated either in response to rates of return, with capital markets kept in equilibrium, or in fixed shares across countries so that it moves in line with global savings. For present purposes we allow savings and investment to respond to changes in rates of return.

The GTAP version 8 database divides the world into 129 countries/country groups, and divides each economy into 57 sectors: 20 for agriculture, food, beverages and tobacco, 6 for other primary goods, 16 for manufactures and 15 for services. For most modelling tasks, including this one, it is necessary for the sake of both computational speed and digestion of model outputs to restrict the number of regions and sectors. In the present study we initially aggregate to 35 countries/country groups and to 26 sector/product groups. We then further aggregate to 15 regions and just 4 sectors for some tables.

4. Core projection of the database to 2030

We project the GTAP database's 2007 baseline for the world economy to provide a new core baseline for 2030 by assuming the 2007 trade-related policies of each country do not change.

However, over the 263-year period we assume that national real GDP, population, unskilled and skilled labour, capital, agricultural land, and extractable mineral resources (oil, gas, coal and other minerals) grow at exogenously set rates, summarized in Appendix Table A.1. The exogenous growth rates for GDP, growth in the capital stock and population are based on estimates from the World Bank and CEPII (Fouré et al. 2012).⁵ For projections of skilled and unskilled labour growth rates, we draw on Chappuis and Walmsley (2011). We estimate historic trends in agricultural land from FAOSTAT (summarized in Deininger and Byerlee 2011) and in mineral and energy raw material reserves from BP (2010) and the US Geological Survey (2010) and assume that past annual rates of change in fossil fuel reserves

⁵ Some compiled using tools from Chappuis and Walmsley (2011).

since 1990 continue for each country over the next two decades.⁶ For other minerals, in the absence of country-specific data, the unweighed average of the annual rate of growth of global reserves for iron ore, copper, lead, nickel and zinc between 1995 and 2009 for all countries is used (from the US Geological Survey 2010). These rates of change in natural resources are summarized in the last five columns of Appendix Table A.1.

Given those exogenous growth rates, the model is able to derive implied rates of total factor productivity and GDP per capita growth. For any one country the rate of total factor productivity growth is assumed to be the same in each of its manufacturing sectors, somewhat higher in most primary sectors and somewhat lower in services (see Appendix Table A.2 for full details). Higher productivity growth rates for primary activities were characteristic of the latter half of the 20th century (Martin and Mitra 2001), and are necessary in this projection if real international prices of primary products (relative to the aggregate change for all products) are to rise only modestly. This is consistent with the World Bank projections over the next four decades (see van der Mensbrugghe and Roson 2010). An alternative projection in which prices rise by even more is considered below. We do not consider one in which agricultural prices fall, as occurred in the latter half of the 20th century (Pfaffenzeller, Newbolt and Rayner 2007) and as projected in GTAP-based projection studies in the late 20th century (see, e.g., Anderson et al. 1997), because that seems too unlikely a scenario over the next two decades, given the slowdown in agricultural R&D investment since 1990 and its consequent delayed slowing of farm productivity growth (Alston, Babcock and Pardey 2010). It is even less likely for farm products if fossil fuel prices and biofuel mandates in the US, EU and elsewhere are maintained over the next decade.⁷

The implied TFP growth rates for all sectors are shown in the first column of Appendix Table A.2,⁸ and the international price consequences for the core simulation are depicted in Appendix Table A.3. It should be noted that the extent to which productivity growth rates are higher in each primary sector than in other sectors is the same for high-

⁶ Past reserves data are from BP (2010). For coal, however, production data are used since reserves data are not available. For Vietnam's coal, oil and gas, along with Indonesia's coal, data for only one decade of exceptionally high growth were available, which provided implausibly high projections for the future, so these were modified downward. The growth rates for Vietnam's oil and gas, along with Indonesian and Thai coal, provided implausibly high projections for the future, so they were modified downward.

⁷ Timilsina et al. (2010) project that by 2020 international prices will be higher in the presence versus the absence of those biofuel mandates for sugar (10 percent), corn (4 percent), oilseeds (3 percent), and wheat and coarse grains (2.2 percent), while petroleum product prices will be 1.4 percent lower.

⁸ In the initial baseline, these TFP estimates are endogenously determined. However, in the subsequent simulations, the TFP estimates are exogenous while GDP is endogenous.

income and developing countries,⁹ and is the same for all crop and livestock industries within each country's farm sector. Since overall TFP growth is higher for developing than high-income countries in Appendix Table A.2, this means we are assuming agricultural TFP growth is higher for developing than high-income countries on average. That is consistent with recent (if not earlier) experience: Ludena et al. (2007, Table 2) estimate that agricultural TFP annual growth during 1981-2000 averaged 1.3 percent globally and only 0.9 percent for high-income countries (but during 1961-80 those rates were 0.6 and 1.4 percent, respectively).

4.1 Consequences for size and sectoral and regional compositions of GDP and trade

The differences across regions in rates of growth of factor endowments and total factor productivity, and the fact that sectors differ in their relative factor intensities and their share of GDP, ensure that the structures of production, consumption and trade across sectors within countries, and also between countries, is going to be different in 2030 than in 2007.

In particular, the faster-growing developing economies (especially those of Asia) will account for considerably larger shares of the projected global economy over the next two decades. Their aggregate share of world GDP (measured in 2007 US\$, not PPP dollars in which developing country shares are much larger) is projected to rise from 27 percent in 2007 to 46 percent in 2030, and for just Developing Asia from 14.5 to 32 percent. Western Europe's share, meanwhile, is projected to fall from one-third to just above one-fifth. Population shares change much less, with the developing countries' share rising from 81 to 83 percent but Developing Asia's component remaining steady between 2007 and 2030. Thus per capita incomes converge considerably, with the ratio of the high-income to developing country average halving between 2007 and 2030. In particular, the per capita income of Developing Asia is projected to rise from 27 to 60 percent of the global average over the projection period (bottom rows of Appendix Table A.4).

When global value added (based on producer expenditure) is broken down by sector, the changes are more striking. This is especially so for China: by 2030 it is projected to return to its supremacy as the world's top producing country not only of primary products but also of manufactures. This is a ranking China has not held since the mid-19th century when first the UK and then (from 1895) the US was the top-ranked country for industrial production –

⁹ With the exception of agriculture in China and India.

see Allen (2011, Figure 2) and also Bairoch (1982) and Crafts and Venables (2003). The manufacturing share of South and Central America (denoted SCA near the bottom of the tables) remains at 4 percent, while the region's share of overall GDP rises from 5.1 to 5.9 percent. In this core scenario the SCA share of global agricultural value added slips slightly because of the huge growth in Asia – and despite the high-income countries' share falling from one-half to one-third (Table 1).

[insert Table 1 about here]

The Asian developing country share of global exports of all products nearly doubles, rising from 22 to 39 percent between 2007 and 2030. China's share alone grows from 8 to 21 percent. Note, however, that the growth of China's export share is entirely at the expense of high-income countries, as the export shares for the other developing-country regions in Table 2 also grow. The developing country share of primary products in world exports rises slightly (SCA's doubles), and its share of manufactures in world exports rises dramatically over the projection period, almost doubling. Asia's import shares also rise, although not quite so dramatically: the increase for Developing Asia is from 19 to 32 percent for all products, but the rise is much sharper for China's primary product imports (Table 3).

[insert Tables 2 and 3 about here]

The projected increase in Developing Asia's share in total world imports of more than half, and of nearly half even in manufactures, would be considerably larger if the GTAP model accommodated the on-going fragmentation of global production of manufactured goods, whereby the supply chain has many components whose production is footloose (Baldwin 2012). We understate that phenomenon because of the high degree of aggregation of manufacturing industries in the version of the GTAP model we use here. It would be even larger had we accommodated endogenous foreign direct investment flows, since they tend to reinforce trade flows in manufactures within Asia (Petri 2012).

As for the sectoral shares of national trade, the consequences of continuing Asian industrialization are again evident: primary products are less important in developing country exports and considerably more important in their imports, and conversely for non-primary products, with the changes being largest in Developing Asia. The opposite is true for SCA and for high-income countries (Tables 4 and 5). It may seem surprising that high-income countries' comparative advantage in primary products strengthens, but recall that (a) what one part of the world imports the remaining part of the world must export to maintain global equilibrium, (b) the high-income country grouping includes Australia, Canada and New Zealand (and the US in terms of food exports) and (c) we have not allowed for possible

agricultural protection growth in emerging Asia in this core scenario. Note also from Table 4 that services exports are far more important for India than for China or ASEAN, and that difference is projected to increase substantially by 2030.

[insert Tables 4 and 5 about here]

SCA's export composition strengthens a little in farm products but greatly in other primary products – at the expense of manufactures and services, which suffer the Dutch disease problem associated with the strengthening of primary sector prices resulting from Asia's rapid industrialization. The share of non-farm primary products in SCA exports almost doubles, from 20 to 39 percent (Table 4) – a change that is bigger than for any other developing country group. That is, while SCA's comparative advantage strengthens somewhat in farming, it strengthens even more in mining as it weakens in non-primary goods and services. (Only in Australia are such changes in comparative advantage slightly more pronounced.) Even so, the SCA region's share of global exports of agricultural products is projected to rise 2.5 percentage points between 2007 and 2030, as the region out-competes others in supplying the huge growth in imports of farm products by China (Table 6).

[insert Table 6 about here]

4.2 Consequences for food self-sufficiency and consumption of agricultural products

These changes mean that food self-sufficiency in developing countries is projected in this core scenario to fall considerably by 2030, but the source of that change is mainly China and to a smaller extent India (columns 1 and 2 of Table 7). It is possible that these populous countries will seek to prevent such a growth in food import dependence in practice, by erecting protectionist barriers at least for food staples, but that is not modelled here (however, see Anderson and Nelgen 2011 and Anderson and Strutt 2012).

[insert Table 7 about here]

Self sufficiency is a poor indicator of food security, however (Warr 2011). A more meaningful indicator is real per capita private consumption of agricultural and processed food products by households. Table 8 reports those results. It shows that between 2007 and 2030 real per capita food consumption would double for developing countries (a 97 percent rise). It would increase even more for China and South Asia, and even in relatively well-fed SCA the increase over the projection period is 57 percent. These are major improvements in food consumption per capita. Even if income distribution were to worsen in emerging economies

over the next two decades, virtually all developing country regions could expect to be much better fed by 2030 according to this baseline scenario.

[insert Table 8 about here]

The rise in grain consumption is especially great in China because of their expanding demand for livestock products, most of which continue to be produced domestically in this core scenario. So even though China's share of the world's direct grain consumption by households grows little, its share of grain consumed indirectly grows from 8 to 26.5 percent of the global total. That promises to provide on-going growth in the market for grain (and soybean) exports from South America.

4.3 Consequences for bilateral trade

The projected increase in global exports of farm products of 2.5 percentage points in the shares of SCA and 5 percentage points for other natural resource-rich countries between 2007 and 2030 is mostly due to China, whose share of SCA exports rises more than five-fold (Table 9(a), (b)).

[insert Table 9 about here]

Of course SCA is not the only natural resource-rich region benefitting from this huge growth in China's imports of primary products. According to our projections, if current resistances to trade continue (distance, language, etc.), SCA's index of primary product export intensity to China will drop a little (where that index is defined as the share of SCA exports going to China divided by China's share of global imports). That outcome is uncertain though, and probably will depend to some extent on the intensity of Chinese investment in natural resource sectors over next two decades in SCA, Sub-Saharan Africa, Australia, and elsewhere.

5. Alternative TFP growth projections to 2030

The above core projection is but one of myriad possibilities, so in this section we explore others and compare their economic consequences with those just summarized for 2030. Specifically, the following two alternative growth scenarios are considered:

- ***Slower total factor productivity (TFP) growth in primary sectors in all countries***, so that real international prices for agricultural, mineral and energy products by 2030 are

much more above 2007 levels than in the core projection and thus closer to 2012 prices, and more consistent with the projections of some international agencies that specialize in those markets instead of with the World Bank's projections; and

- ***Faster total factor productivity (TFP) growth in grain cropping in China and India,*** so grain output is higher in those Asian countries.

5.1 Slower TFP growth in primary sectors in all countries

The core projection sets higher TFP growth rates for some primary product sectors than for other sectors such that average real international prices for agricultural, mineral and energy products by 2030 are only marginally above 2007 levels (column 1 of Appendix Table A.4). That prospect is quite different from what was experienced in the 20th century, when real primary product prices traced a long-run downward trend (Pfaffenzeller, Newbolt and Rayner 2007). In the past decade, however, those prices have been rising, and price projections of several international agencies suggest they will be well above 2007 levels in the next decade or two (FAO/OECD 2012, Nelson et al. 2010, Conforti 2011, IEA 2011). Hence in this alternative scenario we assume the TFP growth rate assumed per year for primary products is reduced by 1 percentage point in all regions. This amendment leads to real international prices for farm products in 2030 to be 15 instead of 3.6 percent above those in 2007, and those for other primary products to be 42 instead of 1.4 percent above 2007 levels (see columns 1 and 2 of Appendix Table A.3 for details by product).

This reduces the shares of SCA and other natural resource-rich countries in global trade in farm products (Table 6). It also reduces their food self-sufficiency (Table 7), and their real household food consumption (Table 8).

5.2 Faster total factor productivity (TFP) growth in grain cropping in China and India

In this next alternative scenario, the annual TFP growth rates for rice, wheat and coarse grains are set an extra 1 percent higher for just China and India. This could come about by boosting agricultural R&D in those countries, marginal returns from which are likely to be so high as to not need to worry about modelling their up-front cost (Alston et al. 2000, 2009).

Such a boost does not make a discernible difference to overall agricultural self-sufficiency rates for these countries, however. This is because the higher incomes associated with their accelerated grain productivity growth causes domestic consumers there to consume

more of most things, including food. Nonetheless, it does raise self-sufficiency in grains by about 2 percentage points for China and India. It also brings down the international price of grains a little (by 4 to 6 percent, see first three rows of Appendix Table A.3). This higher grain productivity also slightly increases the share of China and South Asia in global agricultural and food exports, while reducing their share of global agricultural and food imports (Table 6). For SCA, the region's share of farm trade with China falls slightly (Tables 6 and 9).

6. Caveats

As with the results from all other economy-wide projections modelling, it is necessary to keep in mind numerous qualifications. One is that for the core projection we have assumed trade costs in the form of transport and communications costs do not change, even though they have been falling steadily during the current wave of globalization (Arvis et al. 2012).

A second assumption is that we have aggregated the model into just 26 sectors or product groups. This leads to gross underestimation of the extent to which firms can take advantage of intra-industry trade through exploiting the increasing opportunities to lower costs through fragmenting the production process into ever-more pieces whose location is footloose (Feenstra 1998, Baldwin 2012).

Third, we have assumed constant returns to scale and perfect competition rather than allowing firms to enjoy increasing returns and some degree of monopoly power for their differentiated products. This too leads to underestimates of the changes associated with production and trade growth (Krugman 2009).

Fourth, where consumers (including firms importing intermediate inputs) value a greater variety of goods, or a greater range of qualities, intra-industry trade can grow as a result of both economic growth and trade policy reform (Rutherford and Tarr 2002), but that too is not taken into account in the above analysis.

Fifth, our model has not included the new biofuel policies that have been put in place in many countries recently. The new US and EU biofuel mandates and subsidies have had a non-trivial effect of increasing both the mean and the variance of international food prices, and are expected to become even more important over the next decade if those countries' mandates continue to increase to 2020-21 (see Hertel and Beckman 2011, Hertel and Diffenbaugh 2011, and the references therein). Whether these policies will still be in place in

2030 is a moot point. If the expected dramatic expansion in unconventional gas production materializes (see IEA 2012), and if biofuel mandates were removed, this omission from our modelling may be inconsequential.

Finally, the standard GTAP model used here is comparative static. It therefore does not measure the additional dynamic consequences of economic growth and trade reform. Dynamic effects arise in numerous ways. One of the more important is through encouragement of the more-efficient firms to take over from the less efficient in each country (Melitz 2003, Bernard et al. 2007, Melitz and Ottaviano 2008). Another way is through multinational firms sharing technologies and knowledge across countries within the firm (Markusen 2002). Offshoring is yet another mechanism through which heterogeneous firms are affected, including via re-locating from small to larger nations (Baldwin and Okuba 2011). It may also alter the political economy of protection, providing stronger opposition from new exporters and thus leading to more opening up of economies (Baldwin 2012).

7. Policy implications and conclusions

Should relatively rapid economic growth in Asia and to a lesser extent in other developing countries continue to characterize world economic development as suggested above, developing Asia's share of global GDP and trade will continue to rise steeply over the next two decades. Their share of global agricultural GDP is projected to almost double also, but that is not fast enough to keep pace with their growing consumption of food. By 2030, developing Asia is projected to consume nearly around half of the world's grain and fossil fuels (or even more if carbon taxes are introduced in high-income countries but not emerging economies), and three-quarters of the world's other minerals. This is possible because their shares of the world's imports of primary products are projected to double between 2007 and 2030 in the core scenario.

Since developing Asia in total accounts for around one-thirds of all agricultural and food output and consumption currently, and that global share will be three-fifths by 2030, its food security is likely to be greatest when markets for farm products are always open, and not only regionally but globally. This is because greater openness ensures international markets are 'thicker' and thus more stable and predictable, and hence are more likely to reduce poverty through encouraging investment and boosting employment prospects and economic growth.

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This basic truth seems anathema to those governments who perceive food security as a production issue rather than a consumption issue, and who thus focus on food self-sufficiency rather than on the spending capability of the poor. Such a view is understandable, though, in a world where other countries protect and insulate their domestic producers. Throughout the post-World War II era many governments, in Asia as elsewhere, have been reluctant to open their agricultural markets. True, taxes on farm trade have fallen in many countries since the 1980s, but not in Northeast Asia where government assistance to farmers remains extremely high, having risen inexorably since the 1950s – which is partly why farm policies are still by far the most welfare-reducing of the restrictions to global merchandise trade (Anderson 2009). Were China and India to follow those Northeast Asian countries in raising their assistance to farmers as their per capita incomes grew – as they have been doing already in recent decades – the contribution of farm policies to the global cost of goods trade barriers would become even higher. Clearly such a policy development would be harmful for SCA's farm trade interests, given the huge growth in agricultural exports to China that is predicted for them (Table 9). It increases the stake South America has in the resumption and successful conclusion of the WTO's Doha Development Agenda as it relates to agricultural trade in particular.

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Table 1: Regional shares of global value added by sector, 2007 and 2030 core (percent)

(a) 2007 Base

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	0.8	0.6	0.3	0.4	0.4
Brazil	3.6	1.7	2.2	2.5	2.5
Chile	0.4	0.7	0.3	0.3	0.3
Rest SCA	4.2	4.5	1.4	1.6	1.9
China	13.6	9.2	11.2	4.2	6.2
East Asia	6.5	6.9	7.5	4.8	5.4
South Asia	8.5	2.6	2.1	2.4	2.7
HICs^a	50.8	34.8	69.2	78.3	73.2
Developing	49.2	65.2	30.8	21.7	26.8
of which SCA	9.0	7.5	4.2	4.8	5.1
World	100.0	100.0	100.0	100.0	100.0

(b) 2030 core

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	0.8	0.4	0.3	0.5	0.5
Brazil	3.0	1.5	2.2	3.2	2.9
Chile	0.3	0.5	0.3	0.3	0.3
Rest SCA	3.1	5.0	1.4	2.0	2.1
China	31.7	23.8	28.9	11.1	16.2
East Asia	6.4	7.2	9.3	6.2	6.8
South Asia	11.4	5.3	4.4	6.0	6.1
HICs^a	32.1	23.3	45.9	63.9	56.4
Developing	67.9	76.7	54.1	36.1	43.6
of which SCA	7.2	7.5	4.3	6.0	5.9
World	100.0	100.0	100.0	100.0	100.0

^a High-income countries (including Eastern Europe)

Source: Derived from the authors' GTAP Model results

Table 2: Regional and sectoral shares of global exports, 2007 and 2030 core (percent)

(a) 2007

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	0.2	0.0	0.2	0.1	0.4
Brazil	0.3	0.2	0.6	0.1	1.2
Chile	0.1	0.1	0.2	0.0	0.5
Rest SCA	0.2	0.5	0.7	0.3	1.7
China	0.2	0.1	7.4	0.6	8.3
East Asia	0.5	0.5	8.5	2.1	11.6
South Asia	0.1	0.1	1.1	0.5	1.8
HICs	4.0	3.1	43.3	13.2	63.6
Developing	2.1	6.7	22.6	5.0	36.4
of which SCA	0.8	0.8	1.7	0.6	3.8
World	6.1	9.8	65.8	18.2	100.0

(b) 2030 core

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	0.2	0.0	0.1	0.1	0.5
Brazil	0.5	0.5	0.3	0.1	1.3
Chile	0.1	0.1	0.3	0.0	0.5
Rest SCA	0.2	1.0	0.5	0.2	1.9
China	0.0	0.1	18.6	2.0	20.8
East Asia	0.7	0.7	10.8	2.2	14.4
South Asia	0.1	0.2	2.5	1.1	4.0
HICs	3.9	4.6	24.9	1.0	43.4
Developing	2.4	8.1	38.4	7.7	56.6
of which SCA	1.0	1.7	1.2	0.4	4.2
World	6.3	12.7	63.3	17.7	100.0

Source: Derived from the authors' GTAP Model results

Table 3: Regional sectoral shares of global imports, 2007 and 2030 (percent)

(a) 2007

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	0.0	0.0	0.2	0.1	0.3
Brazil	0.0	0.1	0.7	0.2	1.0
Chile	0.0	0.0	0.2	0.0	0.3
Rest SCA	0.2	0.1	1.3	0.2	1.8
China	0.3	1.0	4.5	0.7	6.5
East Asia	0.5	1.3	6.5	1.7	10.0
South Asia	0.1	0.6	1.3	0.4	2.4
HICs	4.3	6.7	45.1	12.6	68.8
Developing	2.0	3.5	20.7	4.9	31.2
of which SCA	0.3	0.3	2.4	0.6	3.5
World	6.4	10.2	65.9	17.6	100.0

(b) 2030 core

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	0.0	0.0	0.3	0.1	0.4
Brazil	0.0	0.0	0.9	0.4	1.4
Chile	0.0	0.0	0.2	0.1	0.3
Rest SCA	0.2	0.1	1.4	0.3	1.9
China	1.7	5.1	7.6	1.0	15.5
East Asia	0.6	1.5	7.9	2.1	12.1
South Asia	0.3	1.7	2.2	0.7	4.9
HICs	2.9	4.1	35.5	10.4	52.8
Developing	3.6	9.2	27.8	6.5	47.2
of which SCA	0.2	0.2	2.8	0.8	4.1
World	6.6	13.2	63.3	16.9	100.0

Source: Derived from the authors' GTAP Model results

Table 4: Sectoral shares of national exports, 2007 and 2030 core (percent)

(a) 2007

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	44.1	5.5	35.8	14.6	100.0
Brazil	23.5	14.6	49.7	12.1	100.0
Chile	15.1	25.4	51.0	8.6	100.0
Rest SCA	14.1	26.8	40.7	18.4	100.0
China	2.9	0.6	89.8	6.7	100.0
East Asia	4.1	4.3	73.3	18.3	100.0
South Asia	7.9	4.2	60.0	27.8	100.0
HICs	6.3	4.8	68.1	20.8	100.0
Developing	5.9	18.5	62.0	13.7	100.0
of which SCA	20.6	20.3	44.3	14.8	100.0
World	6.1	9.8	65.8	18.2	100.0

(b) 2030 core

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	48.2	8.9	30.9	11.9	100.0
Brazil	34.6	37.0	22.5	5.9	100.0
Chile	12.0	29.0	53.6	5.3	100.0
Rest SCA	11.4	51.8	26.7	10.2	100.0
China	0.2	0.3	89.7	9.8	100.0
East Asia	4.6	5.0	74.8	15.6	100.0
South Asia	2.9	5.8	63.1	28.2	100.0
HICs	9.0	10.6	57.4	23.0	100.0
Developing	4.3	14.2	67.9	13.6	100.0
of which SCA	23.1	39.4	29.0	8.4	100.0
World	6.3	12.7	63.3	17.7	100.0

Source: Derived from the authors' GTAP Model results

Table 5: Sectoral shares of national imports, 2007 and 2030 (percent)

(a) 2007

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	3.5	1.9	77.0	17.6	100.0
Brazil	4.1	8.8	64.6	22.5	100.0
Chile	6.3	13.8	64.8	15.1	100.0
Rest SCA	10.6	6.2	70.2	13.0	100.0
China	4.3	15.6	69.9	10.2	100.0
East Asia	5.4	13.2	64.8	16.7	100.0
South Asia	5.6	25.8	52.3	16.3	100.0
HICs	6.3	9.7	65.6	18.4	100.0
Developing	6.5	11.4	66.4	15.7	100.0
of which SCA	7.6	7.3	68.6	16.4	100.0
World	6.4	10.2	65.9	17.6	100.0

(b) 2030 core

	Agric. & Food	Other Primary	Manufactures	Services	Total
Argentina	3.4	3.0	76.0	17.6	100.0
Brazil	2.3	3.1	67.4	27.2	100.0
Chile	5.5	14.8	62.1	17.6	100.0
Rest SCA	8.7	4.8	70.2	16.3	100.0
China	11.2	33.1	49.3	6.4	100.0
Other East Asia	4.8	12.8	65.4	17.0	100.0
South Asia	5.3	34.5	45.8	14.4	100.0
HICs	5.5	7.7	67.2	19.6	100.0
Developing	7.7	19.4	59.0	13.8	100.0
of which SCA	5.8	4.9	69.1	20.2	100.0
World	6.6	13.2	63.3	16.9	100.0

Source: Derived from the authors' GTAP Model results

Table 6: Regional shares of world trade in agricultural and food products, 2007 base, 2030 core and 2030 alternative growth scenarios
(percent)

	Exports				Imports			
	2007	2030 Core baseline	2030 Slower Primary TFP	2030 Faster China & India grain TFP	2007	2030 Core baseline	2030 Slower Primary TFP	2030 Faster China & India grain TFP
Argentina	3.1	3.7	3.5	3.7	0.2	0.2	0.2	0.2
Brazil	4.7	7.4	6.6	7.4	0.6	0.5	0.5	0.5
Chile	1.2	1.0	0.8	1.0	0.3	0.3	0.3	0.3
Rest SCA	3.9	3.4	3.0	3.4	3.0	2.6	2.9	2.7
China	3.9	0.6	0.2	0.7	4.3	26.6	27.2	25.4
East Asia	7.8	10.5	9.6	10.4	8.5	8.8	9.1	8.9
South Asia	2.4	1.8	1.7	2.1	2.1	3.9	4.4	3.9
SSAfrica	3.1	3.8	3.9	3.8	3.2	4.4	5.6	4.5
Totals								
HICs	65.2	61.8	63.8	61.5	68.0	44.4	41.7	45.1
Developing	34.8	38.2	36.2	38.5	32.0	55.6	58.3	54.9
of which SCA	12.9	15.4	14.0	15.4	4.1	3.6	3.9	3.7
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Derived from the authors' GTAP Model results

Table 7: Agricultural self-sufficiency ratio,^a 2007 base, 2030 core and 2030 alternative growth scenarios

(percent)

	2007	2030 Core baseline	2030 Slower primary TFP	2030 Faster China & India grain TFP
Argentina	170	178	176	178
Brazil	119	138	136	138
Chile	117	114	116	114
Rest SCA	103	102	100	102
China	98	89	88	89
East Asia	98	103	101	103
South Asia	100	97	96	97
SSAfrica	101	102	100	101
Totals				
HICs	100	108	110	108
Developing	100	96	96	96
of which SCA	116	125	123	125
World	100	100	100	100

^a Agricultural self-sufficiency ratio excludes ‘other (processed) food products’

Source: Derived from the authors’ GTAP Model results

Table 8: Changes in real household consumption per capita of agricultural and food products from 2007 base, core and alternative growth scenarios in 2030

(percent)

	2030 core	2030 Lower primary productivity growth	2030 higher China and India grain productivity growth
Argentina	69	61	69
Brazil	61	55	61
Chile	53	46	53
Rest SCA	52	45	52
China	163	126	165
East Asia	71	56	71
South Asia	131	108	132
SSAfrica	100	90	100
HICs	37	28	37
Developing	97	80	98
of which SCA	57	51	57

Source: Derived from the authors' GTAP Model results

Table 9: Shares of bilateral trade in agricultural and food products, 2007 base, 2030 core and 2030 alternative growth scenarios

(percent)

(a) 2007 base

Importer: Exporter:	SCA	Other NRRich	US&Europe	China	Other Asia	Total
SCA	2.04	2.83	5.72	1.16	1.16	12.91
Other NRRich	0.47	6.20	8.92	1.36	4.12	21.07
US&Europe	1.42	9.87	39.46	1.22	4.11	56.08
China	0.06	0.91	1.22	0.00	1.67	3.86
Other Asia	0.05	2.11	1.71	0.42	1.80	6.09
Total	4.03	21.91	57.03	4.16	12.87	100.00

(b) 2030 core baseline

Importer: Exporter:	SCA	Other NRRich	US&Europe	China	Other Asia	Total
SCA	1.77	2.87	3.45	6.00	1.33	15.41
Other NRRich	0.47	6.56	6.34	8.00	4.85	26.22
US&Europe	1.28	9.55	26.30	10.03	4.30	51.47
China	0.01	0.15	0.17	0.00	0.26	0.59
Other Asia	0.04	1.73	0.92	2.02	1.61	6.31
Total	3.56	20.87	37.17	26.04	12.36	100.00

(c) 2030 with slower primary TFP growth

Importer: Exporter:	SCA	Other NRRich	US&Europe	China	Other Asia	Total
SCA	1.72	2.55	3.10	5.46	1.15	13.97
Other NRRich	0.55	6.85	5.84	7.51	4.91	25.66
US&Europe	1.55	11.03	24.93	11.61	4.84	53.95
China	0.00	0.08	0.05	0.00	0.11	0.25
Other Asia	0.03	1.82	0.57	2.23	1.52	6.16
Total	3.84	22.33	34.49	26.81	12.53	100.00

(d) 2030 with faster China and India grain TFP growth

Importer: Exporter:	SCA	Other NRRich	US&Europe	China	Other Asia	Total
SCA	1.79	2.90	3.51	5.88	1.33	15.42
Other NRRich	0.48	6.65	6.46	7.73	4.82	26.13
US&Europe	1.30	9.60	26.65	9.48	4.28	51.31
China	0.01	0.17	0.18	0.00	0.30	0.67
Other Asia	0.04	1.94	1.00	1.81	1.68	6.48
Total	3.62	21.27	37.81	24.89	12.40	100.00

Source: Derived from the authors' GTAP Model results

Appendix Table A.1: Average annual GDP and endowment growth rates, percent per year, 2007 to 2030

	GDP growth	Population growth	Unskilled labour	Skilled labour	Produced capital	Oil	Gas	Coal	Other minerals	Agric. Land
Mexico	2.89	0.71	0.75	3.01	2.66	-7.49	-7.34	2.52	2.07	-0.07
Argentina	3.80	0.75	0.00	3.32	3.38	2.52	-2.94	0.00	2.07	0.23
Brazil	3.48	0.58	0.44	2.85	3.18	5.66	6.29	0.50	2.07	0.50
Chile	3.14	0.76	0.69	2.96	3.37	0.00	0.00	0.00	2.07	-0.06
Rest LAmerica	3.41	1.10	0.98	3.73	3.14	5.45	2.17	5.53	2.07	0.22
China	7.95	0.42	-0.06	2.75	7.32	-0.40	4.85	5.62	2.07	-0.36
East Asia	3.94	0.84	-0.18	2.48	4.04	1.31	1.46	0.88	2.07	-0.03
South Asia	7.06	1.16	1.39	4.08	5.37	0.23	-1.18	4.84	2.07	-0.05
MENA	4.06	1.37	0.58	3.86	3.78	0.71	3.73	0.96	2.07	0.00
SSAfrica	5.34	2.11	1.78	4.52	4.16	4.16	2.74	1.89	2.07	0.09
WEurope	1.29	0.11	-1.25	1.34	1.08	2.81	0.77	-2.51	2.07	-0.28
EEurope	2.94	-0.07	-0.74	1.25	3.17	2.67	0.35	-1.97	2.07	-0.23
USC	1.96	0.80	0.09	1.56	1.39	1.11	-0.70	0.17	2.07	-0.20
ANZ	2.30	1.07	0.32	1.89	2.18	1.40	6.07	3.55	2.07	-0.56
Japan	0.89	-0.21	-1.53	0.77	0.70	0.00	0.00	-9.35	2.07	-1.14
HICs	1.61	0.26	-0.64	1.40	1.31	2.12	0.25	-0.28	2.07	-0.30
Developing	5.13	1.03	0.42	3.12	4.57	1.51	2.53	4.33	2.07	-0.09
of which SCA	3.47	0.84	0.61	3.19	3.19	5.19	1.91	5.31	2.07	0.30
World	2.55	0.88	-0.37	1.67	2.36	1.70	1.44	2.09	2.07	-0.15

Source: Authors' assumptions (see text for details)

Appendix Table A.2: Implied annual growth in total factor productivity for the various sectors,^a 2007 to 2030

(percent per year, using 2007 national GDP values as weights)

	Core baseline				2030 Lower primary productivity growth				2030 Faster China & India grain productivity				
	A & E	B	C	D	A & C	B	D	E	A & E	B	C	D	F
WEurope	1.2	2.3	2.3	0.7	1.2	1.2	0.7	0.2	1.2	2.3	2.3	0.7	2.3
EEurope	1.5	2.5	2.5	1.0	1.5	1.5	1.0	0.5	1.5	2.5	2.5	1.0	2.5
USC	1.4	2.4	2.4	0.9	1.4	1.4	0.9	0.4	1.4	2.4	2.4	0.9	2.4
ANZ	1.1	2.1	2.1	0.6	1.1	1.1	0.6	0.1	1.1	2.1	2.1	0.6	2.1
Japan	1.4	2.4	2.4	0.8	1.4	1.4	0.8	0.4	1.4	2.4	2.4	0.8	2.4
China	4.4	4.4	5.4	3.8	4.4	3.4	3.8	3.4	4.4	4.4	5.4	3.8	5.4
EastAsia	1.8	2.9	2.9	1.3	1.8	1.8	1.3	0.8	1.8	2.9	2.9	1.3	2.9
SouthAsia	3.8	4.0	4.9	3.3	3.8	3.0	3.3	2.8	3.8	4.0	4.9	3.3	4.9
Mexico	1.1	2.1	2.1	0.6	1.1	1.1	0.6	0.1	1.1	2.1	2.1	0.6	2.1
Argentina	2.0	3.0	3.0	1.5	2.0	2.0	1.5	1.0	2.0	3.0	3.0	1.5	3.0
Brazil	1.7	2.7	2.7	1.2	1.7	1.7	1.2	0.7	1.7	2.7	2.7	1.2	2.7
Chile	0.9	1.9	1.9	0.4	0.9	0.9	0.4	-0.1	0.9	1.9	1.9	0.4	1.9
RestLA	1.2	2.2	2.2	0.7	1.2	1.2	0.7	0.2	1.2	2.2	2.2	0.7	2.2
MENA	1.5	2.5	2.5	1.0	1.5	1.5	1.0	0.5	1.5	2.5	2.5	1.0	2.5
SubSAfrica	2.1	3.2	3.2	1.6	2.1	2.1	1.6	1.1	2.1	3.2	3.2	1.6	3.2
TOTAL	1.7	2.6	2.7	1.2	1.7	1.6	1.2	0.7	1.7	2.6	2.7	1.2	2.7

^a The above TFP growth rates are those implied for the non-primary sectors by the GDP and factor growth rates in Appendix Table A.1, including the following assumptions about primary sector TFP growth. Primary sector annual TFP growth rates other than for fossil fuels were exogenously set 1 percentage point higher than those for the non-primary sectors in the core projection for all countries except for Agriculture in China and India (where rates are already well above those for all other countries), with the aim of ensuring little or no growth between 2007 and 2030 in international relative prices for those primary products (shown in Appendix Table A.3). As well, the Services sector annual TFP growth rates were exogenously set 0.5 percentage points lower than those for the non-primary sectors in the core projection for all countries, consistent with historical experience. In the slower primary TFP growth scenario, the increment for all primary sectors is assumed to be 1 percentage point lower than in the core baseline. For the higher China and India grain productivity scenario, the increment is increased in rice, wheat and coarse grains by 1 percent for China and India. Column heading letters refer to:

- A Manufactures
- B Agriculture and lightly processed food
- C Forestry, fishing and other minerals
- D Services
- E Fossil fuels (coal, oil and gas)
- F Rice, wheat and coarse grains (faster China & India grain scenario)

Source: Derived from the GTAP Model, based on authors' assumptions (see text for details)

Appendix Table A.3: Cumulative changes in world prices, 2007 to 2030
(price relative to global average output price change across all sectors, percent)

	2030 core	2030 Lower primary productivity growth	2030 higher China/India grain productivity growth
Rice	4.4	18.7	-2.1
Wheat	3.3	20.7	-0.8
CoarseGrains	3.1	23.5	-0.7
Fruit_Veg	15.8	40.8	15.4
Oilseeds	0.2	11.7	-0.1
Sugar	-4.7	3.7	-4.8
Cotton	6.7	26.9	6.4
OtherCrops	-1.3	19.3	-1.6
Beef_Sheep	-1.3	8.7	-1.5
Pork_Chicken	9.7	22.2	8.9
Dairy	-2.4	7.2	-2.6
OtherFood	2.8	9.7	2.6
Forest_Fish	48.9	198.7	49.6
Coal	-11.4	2.0	-11.2
Oil	-2.6	27.7	-2.5
Gas	-13.4	-1.0	-13.3
OthMinerals	-7.0	11.1	-7.0
Text_App_Lea	-0.7	-2.6	-0.8
MotorVehicle	-2.1	-4.7	-2.0
Electronics	-5.6	-10.4	-5.4
OtherLtMan	-2.1	-1.1	-2.1
HeavyManuf	-4.7	-2.6	-4.7
Utiliti_Cons	1.9	-0.3	2.0
Elect_Gas	-4.8	-6.2	-4.7
Trade_transp	1.6	-1.5	1.6
Other services	1.4	-3.0	1.5
Aggregate Prices:			
Agriculture_Food	3.6	15.3	2.9
OtherPrimary	1.4	41.7	1.6
Manufactures	-3.7	-3.1	-3.7
Services	1.3	-2.4	1.3

Source: Derived from the authors' GTAP Model results

Appendix Table A.4: Regional shares of world real GDP and population, and GDP per capita relative to world average, 2007 and the core projection for 2030,^a percent

	World GDP share		World population share		GDP per capita relative to world average	
	2007	2030	2007	2030	2007	2030
WEurope	32.0	21.6	7.7	6.4	415.9	338.4
Russia	2.3	2.2	2.1	1.6	108.5	134.2
RestEEurope	1.8	1.8	2.3	2.0	76.7	88.6
USA	25.2	19.8	4.6	4.4	553.4	449.5
Canada	2.6	2.0	0.5	0.5	512.1	405.1
Australia	1.5	1.3	0.3	0.3	482.1	397.0
NewZealand	0.2	0.2	0.1	0.1	387.9	309.2
Japan	7.8	4.8	1.9	1.5	406.3	325.0
China	6.3	18.3	19.9	17.7	31.4	103.2
Singapore	0.3	0.3	0.1	0.1	456.8	448.6
Indonesia	0.8	1.4	3.4	3.3	22.8	42.4
Malaysia	0.3	0.5	0.4	0.4	83.3	105.0
Philippines	0.3	0.4	1.3	1.5	19.3	23.5
Thailand	0.4	0.6	1.0	0.9	43.7	67.3
Vietnam	0.1	0.2	1.3	1.3	9.5	16.1
RestSEAsia	0.1	0.1	1.1	1.1	6.9	10.0
PacificIslan	0.1	0.1	0.1	0.2	40.0	40.7
HongKong	0.4	0.4	0.1	0.1	354.5	357.1
SouthKorea	1.9	1.8	0.7	0.6	256.8	304.1
Taiwan	0.7	1.0	0.3	0.3	204.1	320.5
RestNEAsia	0.1	0.1	0.4	0.4	16.3	25.9
India	2.2	5.5	17.0	17.5	13.0	31.7
Pakistan	0.3	0.5	2.5	3.0	10.4	16.1
Bangladesh	0.1	0.3	2.4	2.5	5.1	10.5
RestSthAsia	0.1	0.2	1.2	1.2	8.4	16.2
CentralAsia	0.4	0.4	1.1	0.8	31.5	49.8
Mexico	1.8	1.8	1.6	1.5	115.5	117.5
Argentina	0.5	0.6	0.6	0.6	78.3	96.6
Brazil	2.4	2.7	2.9	2.7	85.2	101.9
Chile	0.3	0.3	0.3	0.2	117.1	124.8
Peru	0.2	0.3	0.4	0.4	44.7	59.6
RestLamerica	1.7	1.8	2.8	2.9	58.9	59.9
ME_NthAfrica	3.4	4.2	5.5	6.0	61.7	70.1
SouthAfrica	0.5	0.5	0.7	0.7	70.9	78.6
RestSSAfrica	1.1	2.3	11.4	15.2	9.3	14.8
High-income	73.5	53.7	19.5	16.8	376.1	319.5
Developing	26.5	46.3	80.5	83.2	33.0	55.7
of which Asia:	14.37	32.0	534.23	52.9	27.04	60.4
World	100	100	100	100	100	100

^a 2007 prices.

Source: Authors' assumptions (see text for details)