Australian Government

Department of Agriculture, Fisheries and Forestry

ABARES

Global food production and prices to 2050

Scenario analysis under policy assumptions

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Research by the Australian Bureau of Agricultural and Resource Economics and Sciences

Conference paper 13.6

March 2013

Paper presented at the 43rd ABARES Outlook conference 5–6 March 2013, Canberra, ACT

Cataloguing data
Linehan, V, Thorpe, S, Gunning-Trant, C, Heyhoe, E, Harle, K, Hormis, M & Harris-Adams, K, *Global food production and prices to 2050: scenario analysis under policy assumptions*, ABARES conference paper 13.6, Canberra, March.

ISSN 1447-3666

ABARES project 43355

Internet

Global food production and prices to 2050 is available at daff.gov.au/abares/publications.

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Acknowledgements
The authors thank Neil Andrews and Jammie Penm for their insights during the project and for comments on the draft. We also acknowledge sponsorship from Amcor Australasia, ANZ Banking Group Ltd, Cargill Australia Ltd, Coles, Elders Ltd, Fisheries Research and Development Corporation, Grape and Wine Research and Development Corporation, Horticulture Australia, the Northern Territory Department of Business, Queensland Department of Agriculture, Fisheries and Forestry, Rural Industries Research and Development Corporation, Tasmanian Department of Economic Development, Tourism and the Arts, Tasmanian Department of Primary Industries, Parks, Water and Environment, Victorian Department of Primary Industries, the Western Australian Department of Agriculture and Food and the Australian Government Department of Agriculture, Fisheries and Forestry.

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Summary

With food security at the forefront of government policy agendas worldwide, much of the focus is on how the world will respond to a rise in food demand over the next 40 years. Many institutions, including the Food and Agriculture Organization of the United Nations (FAO), the International Food Policy Research Institute (IFPRI) and ABARES, have published projections of an increase in global food demand out to 2050.

This report uses three scenarios to investigate the possible response of world food prices, food production and trade to the projected increase in demand. This work builds on agrifood modelling in ABARES *Food demand to 2050: Opportunities for Australian agriculture* (Linehan et al. 2012a).

The uncertainties and dynamics surrounding factors such as climate change, international trade policy and biofuels policies add to the complexity of modelling global agrifood markets out to 2050. However, scenario analysis, which isolates each of these issues, allows for an assessment of indicative price and production responses over the projection period across different regions and agrifood commodities. A reference scenario is developed for this project using a set of assumptions drawn from the literature. The reference scenario serves as a starting point for the policy analysis and shows the sensitivity of the projections to changes in assumptions and parameter values.

This report uses an updated version of the ABARES agrifood model (Linehan et al. 2012b) that includes new assumptions about agricultural productivity growth, land availability and fisheries. Projections of global supply and price responses of agrifood products (food-based agricultural commodities and fish) are derived from a partial equilibrium model of agricultural markets that ABARES developed for this purpose. ABARES used the model to prepare projections that consistently account for the main economic forces linking demand and supply for various food commodities within a region and between regions over time.

In the reference scenario, the average price of world agrifood products in 2050 is projected to be 11.5 per cent higher than in 2007. However, it should be noted that prices have already risen considerably since 2007 and the price projections in this paper represent a marginal increase from 2012 average prices. The fish meal and oil, fish, meat, oilseed oils, and cereals commodity groups experience the largest price rise over the projection period. Associated with these price increases is a 75 per cent rise in the projected real value of world agrifood production and consumption over the same period. Most of the projected rise in food production occurs in Asia, where the real value of agrifood production is 84 per cent higher in 2050 than in 2007 (in 2007 US dollars). China accounts for over half the projected increase in the real value of Asian agrifood production, particularly from the meat, dairy products, fish, and vegetables and fruit commodity groups.

To compare the implications of alternative policy assumptions relating to food production, two additional scenarios are included in this report. The first policy scenario examines the response of world agrifood markets to more liberalised agrifood trade with trade liberalisation assumed to lead to additional productivity growth. Under this scenario, world agrifood prices rise 10.4 per cent between 2007 and 2050 (in 2007 US dollars). This projected price increase is not as strong as the reference scenario (when agricultural trade is protected) because of the assumed higher productivity growth induced by trade liberalisation. Liberalised trade also leads to a stronger rise in the real value of global agrifood exports between 2007 and 2050 compared

with the reference scenario (180 per cent rather than 149 per cent) as open markets allow an expansion of global trade.

The second scenario examines the response of world markets to a reduction in food grains in the production of biofuels in the United States and the European Union. When maize is completely removed from the production of US and rapeseed from the production of EU biofuels, the world price of maize falls in 2050 relative to 2007 as the competition for maize between the livestock, food and energy sectors is reduced. Rapeseed prices in 2050 are significantly higher than 2007 (in 2007 US dollars) reflecting the continued projected strength of demand for rapeseed for both food and feed use.

Projected increases in Australian agricultural production and exports reflect the commodities where Australia has a comparative advantage. Australia needs to remain competitive to meet the opportunities provided by higher global agrifood demand. Land and water constraints are inherent in Australian agriculture. If Australia is to remain responsive to changes in world agrifood markets and provide those foods most in demand in expanding markets, it will have to maintain productivity growth through ongoing investment in research and development.

Sensitivity analysis around some of the underlying assumptions, including land productivity, total factor productivity (TFP) and land availability, was undertaken to examine the robustness of the model and to gauge the response of global food price movements to the supply constraints. This analysis illustrated the significant impact of an increase in TFP growth in increasing food production and reducing upward pressure on global food prices. This result highlights the importance of improvements in productivity to meet the global food security challenge toward 2050.

Australia is well located to take advantage of the opportunities that higher food consumption will provide but there will be a need for a change to agricultural production in Australia to fully capture these opportunities. This will only be accomplished with a reversal of the recent slowing rate of growth in productivity and more targeting of consumer needs in the growth areas of the world—particularly Asia. At the industry level, this will require greater targeting of our products to more diversified markets and targeting different qualities of our products to market segments where there is greatest potential for value adding. Higher prices can lead to higher productivity by improving incentives for investment in research and development, through innovation and through adaptation of existing overseas technologies applied to an Australian environment. The government can also assist through a strong commitment to furthering global trade liberalisation and increasing access to a diverse range of overseas markets. Governments will need to continue to provide a sound economic environment, with appropriate fiscal policy settings that encourage economic and productivity growth—goals achievable only if regulation is limited to those areas where market failures exist and where the benefits of regulation clearly outweigh its costs.

1 Introduction

By 2050 world demand for agrifood products is projected to increase significantly because of a larger global population and growth in per person incomes, especially in developing countries. How agricultural production and trade will respond to this increase in demand over the next 40 years will depend on changes in economic, political, environmental and technological factors. Climate change, soil and water degradation, and land availability are some factors that agricultural producers will have to increasingly contend with if they are to maintain or improve levels of agricultural productivity.

In the report *Food demand to 2050: Opportunities for Australian agriculture* (Linehan et al. 2012a), ABARES projected the real value (in 2007 US dollars) of world agrifood demand to be 77 per cent higher in 2050 than in 2007 (Linehan et al. 2012a). This represents an annual average increase of 1.3 per cent over this period. Demand is projected to increase most strongly in Asia, doubling between 2007 and 2050. China is driving this demand, accounting for 43 per cent of the global agrifood increase, while India accounts for 13 per cent (Linehan et al. 2012a).

In this earlier report, the food products projected to be most sought after by 2050 were found to be the vegetables and fruit, meat, dairy products, cereals and fish commodity groups (Linehan et al. 2012a). China accounts for much of the projected increase in world import demand for these products, while the growth in demand from India was projected to be strongest for dairy products. These results are consistent with the expected change in diets toward high value products as consumer incomes rise.

The projected increase in global demand for agrifood products will affect global agricultural prices going forward. Several factors may influence production, consumption and prices over this period; for example, resource constraints are likely to affect productivity growth. Government policies, such as those relating to trade and biofuels, will also influence prices.

With food security at the forefront of many governments' policy agendas, the objective of this report is to highlight possible indicative price changes and production responses in 2050 compared with 2007 across a number of supply-side scenarios. These scenarios reflect possible constraints and challenges that producers of agrifood commodities around the world will likely face, including land availability, rainfall deficiency, and trade and biofuel policy changes.

Scenario analysis has been utilised in this report to examine the implications of alternative assumptions relating to food production. The procedure involves establishing a reference scenario with future prices, production, consumption and trade under a set of specified economic and environmental assumptions. The outcome of each scenario, in which some of the key underlying assumptions are altered, is then compared against the reference scenario.

The price projections toward 2050 presented in the reference scenario are conditional on the underlying assumptions. Those assumptions were sourced mainly from recent studies and should not be interpreted as ABARES long-term projections.

An updated version of the ABARES agrifood model (Linehan et al. 2012b) was used for this analysis. This model is an economic simulation model of global agricultural supply, demand and trade. The model was used to prepare annual projections between 2007 and 2050, and has been updated to include a set of supply-side assumptions relating to, for example productivity growth (Rosenzweig et al. 2012), availability of arable land (Alexandratos & Bruinsma 2012) and expectations about growth in global fisheries (FAO 2012). These projections are based on assumptions, data and projections from FAO and Agricultural Modelling Intercomparison and Improvement Project (AgMIP).

The projections are also conditional on parameter values used to represent the sensitivities of food demand and supply to economic forces. Changes to these assumptions and parameters have resulted in adjustments to the projections originally reported in Linehan and colleagues (2012a).

The commodity and regional coverage in the ABARES agrifood model provides projections for Australia and other major world agricultural exporters and importers. In addition, the best practice mixed complementarity framework (Rutherford 1995) is adopted to model key activities in production and policy, and impose key resource limits on land use, fish catch and yield growth (Linehan et al. 2012b).

2 Scenarios

The objective of using scenario analysis for this report is to examine the implications of alternative resource availability and policy assumptions relating to food production. Three scenarios are used:

- Scenario 1: Establishing the reference scenario
- Scenario 2: Trade liberalisation with stronger productivity
- Scenario 3: Biofuels changes.

The outcomes of scenarios 2 and 3, in which some key underlying assumptions are altered, are compared against the reference projection in Scenario 1.

Scenario 1 establishes a reference scenario. It is in this scenario that parameter values used in *Food demand to 2050: Opportunities for Australian agriculture* (Linehan et al. 2012a) are updated using the latest information from FAO and AgMIP (Appendix A). The scenario incorporates important assumptions about:

- projected land availability toward 2050, across all regions in the model
- land productivity growth rates
- rainfall deficiency (reflected in land productivity growth for crops)
- growth in global fisheries production.

The objective of this scenario is to provide a more comprehensive assessment of the response of agrifood markets to the projected increase in global demand reported in Linehan and colleagues (2012a).

Scenarios 2 and 3 build on the reference scenario by imposing stylised assumptions relating to trade liberalisation and biofuels developments on the model. The projections for world agrifood prices, production and trade emanating from these scenarios are indicative only, but are useful as a basis of comparison to understand the possible market adjustments that could take place under significant policy changes.

Scenario 2 considers trade liberalisation, where producer and consumer support, as measured by the OECD producer and consumer support estimates, are removed. At the same time, it is assumed that TFP (which is broadly defined as output divided by total inputs) will increase over some of the projection period as more liberalised trade allows, among other things, quicker technological catch-up of developing countries and greater investment in agriculture. The objective of this scenario is to better understand the nature of adjustment of global agrifood markets, relative to the reference scenario, when food products are allowed to flow more freely between countries and regions. The trade response of Australia is of specific interest given its geographic proximity to Asia, where a significant increase in agrifood demand is projected (Linehan et al. 2012a).

Scenario 3 considers a reduction in the amount of maize and rapeseed used in the production of biofuels in the United States and European Union, respectively. The objective of the scenario is to understand the sensitivity of world cereal markets to a progressive decline in the supply of maize and rapeseed for biofuel production. Given the substitutability of grains in feed use, the impact on the production and export of wheat and canola in Australia is of particular interest.

Scenario 1: Establishing the reference scenario

Productivity growth assumptions

Productivity growth is an important determinant of long-run agricultural production. However, determining future rates of productivity growth is challenging given the uncertain nature of future technological advancement and the potential influence of changes in the natural resource base arising from climate change and other factors. The reference scenario simulated in this analysis assumes present climate conditions are maintained to 2050 and productivity is driven by technological changes alone. For comparative purposes, a rainfall deficiency scenario is also presented which incorporates analysis of the effects of rainfall deficiency on the land productivity of cropping.

The rate of technological progress has been a key driver of productivity growth in the past. One example of a technological progress is the development of crop varieties with higher yields. By contrast, technical efficiency reflects, for example, the adoption of existing technologies in order to catch up. Improvements in technical efficiency are potentially important determinants of productivity growth rates in developing countries.

The capacity of the natural resource base to accommodate increasing agricultural production is the subject of ongoing debate. Water availability, diminishing soil quality and desertification have been identified as potential causes of declining productivity growth rates into the future (Appendix B). At the same time, climate change is projected to increasingly influence agricultural productivity; however, depending on the region, the effects for individual regions and commodities could be for better or for worse (IPCC 2007).

The two types of productivity improvements in the ABARES agrifood model are land productivity and TFP improvements. Improvements in land productivity reflect a reduction in the input of land per unit of output of cropping or livestock product. This is a partial measure of productivity, where a single factor, land, experiences technological advancement. TFP is a measure of the value of total output relative to the value of total inputs.

Crop land productivity growth estimates for this study stem from the AgMIP model comparison exercise (Table 1). Land productivity growth assumptions out to 2050 are driven by technology improvements, including crop management research, conventional plant breeding and other more advanced breeding techniques. Other sources of land productivity growth incorporated in the estimates include private sector agricultural research and development, agricultural extension and education, the development of markets, improved infrastructure, availability of irrigation, and access to water.

Livestock land productivity estimates used in the model are derived from the ABARES Global Trade and Environment model (GTEM), a multisector, multiregion dynamic global computable general equilibrium model of the world economy (ABARE 2007).

In general, productivity growth is projected to be higher for livestock-based industries than for cropping (Table 1) and highest for livestock products in China and India.

Table 1 Reference scenario—annual average land productivity growth rates, by region and commodity group, from 2007 to 2050

Food group	World (%)	Australia[a] (%)	China (%)	India (%)	Rest of Asia (%)	Rest of world (%)
Meat	1.6	1.3	2.3	3.0	1.6	1.6
Dairy products	1.6	1.3	2.3	3.0	1.6	1.6
Cereals	1.3	1.2	1.1	1.2	1.3	1.4
Other food	1.0	0.8	1.2	1.1	0.9	1.0
Vegetables and fruit	0.8	0.7	0.6	0.9	0.6	0.9

a Australia is also part of the Rest of world region.

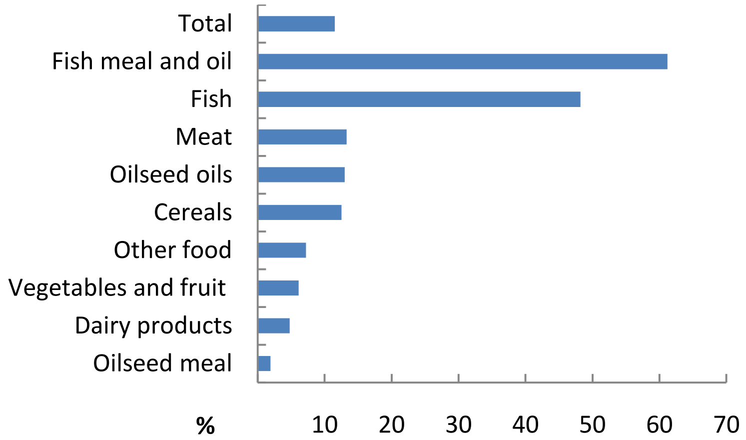
Data sources: Agricultural Modelling Intercomparison and Improvement Project; ABARES Global Trade and Environment model

Productivity projections used in this study are broadly consistent with OECD/FAO (2012) 2001-40 projections. The OECD/FAO (2012) project the world average TFP to be 1.38 per cent a year from 2001 to 2040, with ABARES world average TFP projection approximately 1 per cent a year from 2007 to 2050.

Results from the reference scenario

Given the productivity assumptions set out above, the real value of world agrifood production and consumption in 2050 (in 2007 US dollars) is projected to be 75 per cent higher than in 2007, with real prices (in 2007 US dollars) projected to increase, on average, by 11.5 per cent over this period (Figure 1). By comparison, the FAO real food price index rose by 10.8 per cent between 2007 and 2012 due mainly to droughts in some major producing countries (FAO 2013). Using recent movements in food prices as a guide, the simulation results indicate that food prices (in real terms) by 2050 are projected to be only marginally higher than their average in 2012.

Figure 1 Reference scenario—world real price, change from 2007 to 2050



Data source: ABARES model output

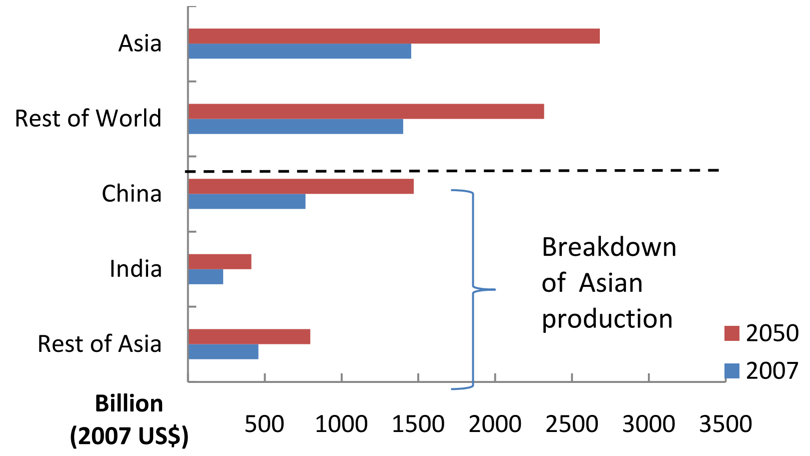
The projected increase in real agrifood prices toward 2050 is driven by significant increases in the prices of the fish meal and oil and the fish commodity groups. The rise in the price of the fish group (which includes high-value and low-value capture fish and seafood, and aquaculture fish and seafood) reflects the effect of fixed quotas on capture fisheries. The only source of growth in fish production is from aquaculture, which is also dependent on fish meal and oil from the capture fishery as its feed input. With no growth projected for the capture fishery, feed inputs for aquaculture are constrained and hence growth in aquaculture is limited. As a result, the prices of all types of fish rise significantly toward 2050. Appendix B provides background on world fisheries.

The next largest price increases over the projection period are in the meat (13.3 per cent), oilseed oils (13.0 per cent) and cereals (12.5 per cent) commodity groups.

It is projected that developing countries will be the main source of global agrifood production growth to 2050, as they have a greater potential to increase agricultural land and improve productivity. By 2050 developing countries' share of global agrifood production is projected to increase to 74.3 per cent from 70.3 per cent in 2007.

Asia, and in particular China, drives the projected rise in the real value of production to 2050 (Figure 2). In 2050 the real value of agrifood production in Asia (in 2007 US dollars) is projected to be 84 per cent higher than 2007. In China, the rise in the real value of production (in 2007 US dollars) over the projection period is projected to be 92 per cent, driven by higher real value of production for meat, dairy products, fish, and vegetables and fruit.

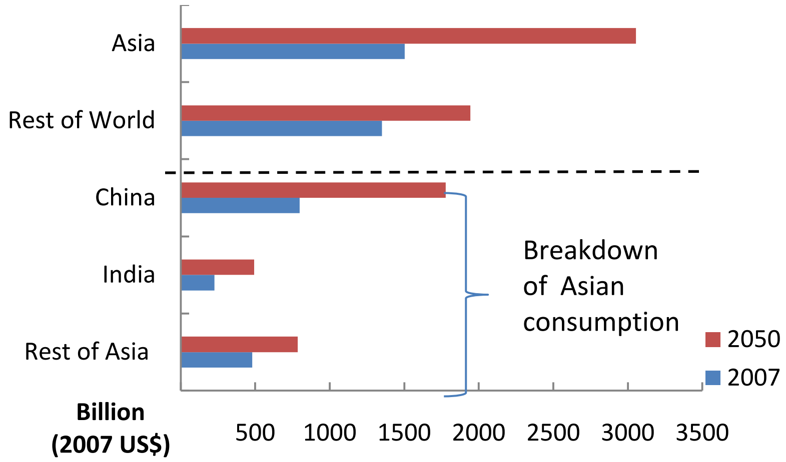
Figure 2 Reference scenario—real value of world agrifood production, by region, 2007 and 2050



Data source: ABARES model output

Asia is also driving the rise in real value of world agrifood consumption in 2050 (Figure 3), accounting for 72 per cent of the projected global increase between 2007 and 2050. China alone accounts for almost half (46 per cent) the projected increase in world consumption.

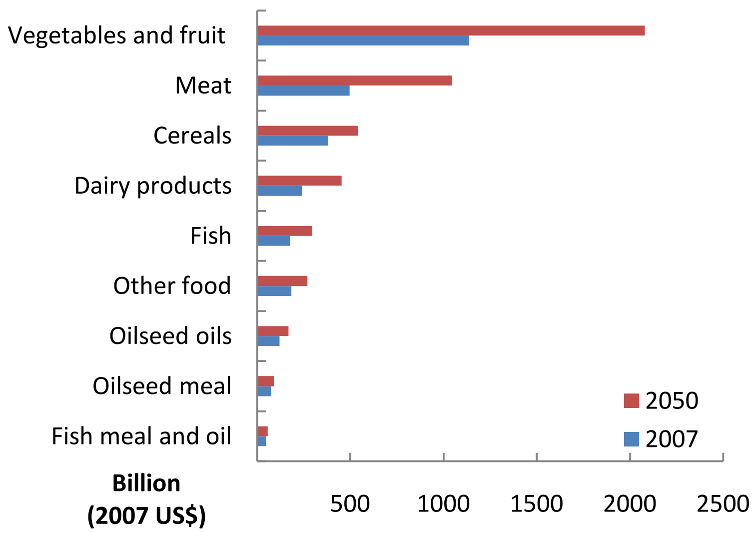
Figure 3 Reference scenario—real value of world agrifood consumption, by region, 2007 and 2050



Data source: ABARES model output

In terms of commodity groups, the largest increases in the real value of global agrifood production (in US 2007 dollars) in the reference scenario are for vegetables and fruit and meat (Figure 4). The vegetables and fruit group accounts for 44 per cent of the projected rise in the real value of agrifood production (in US 2007 dollars), while meat accounts for 26 per cent. In terms of annual average growth, the groups that are expected to grow fastest between 2007 and 2050 are meat (1.7 per cent a year), dairy products (1.5 per cent) and fish (1.2 per cent).

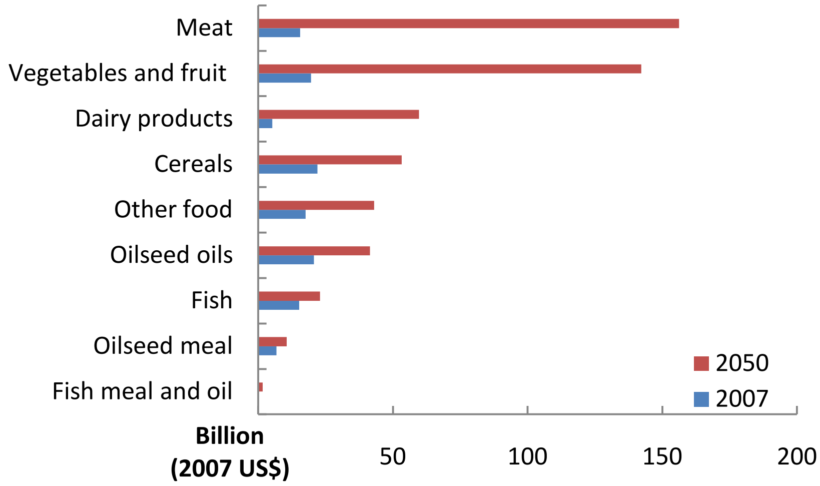
Figure 4 Reference scenario—real value of world agrifood production, by commodity group, 2007 and 2050



Data source: ABARES model output

The real value of world agrifood imports is projected to increase from US$278 billion in 2007 to US$694 in 2050 (in 2007 US dollars), a rise of 149 per cent (or 2.1 per cent annually). Asia accounts for the bulk of the growth in agrifood imports, with China driving most of this rise. Asia’s import position is driven by substantial increases in imports of meat and vegetables and fruit (Figure 5).

Figure 5 Reference scenario—real value of Asian agrifood imports, by commodity group, 2007 and 2050



Data source: ABARES model output

Sensitivity analysis around some of the underlying assumptions was undertaken to examine the robustness of the model and to gauge the response of the model to the supply constraints, specifically their impact on prices. This analysis found that prices and production are highly responsive to changes in TFP. When TFP growth in the reference scenario is assumed to be 12 per cent higher each year over the projection period (for example, increasing world TFP from 1 per cent a year to 1.12 per cent a year), food prices by 2050 are projected to be largely equal to those in 2007. This compares with the reference scenario, which has a projected average price increase of 11.5 per cent. Further detail on the sensitivity analysis can be found in Appendix C.

Comparison with higher rainfall deficiency

In the reference scenario, a present climate scenario is assumed. However, for comparative purposes, it is worth considering a potentially different set of market outcomes under a rainfall deficiency scenario.

Climate change is projected to exacerbate the current stresses on water posed by population growth, and economic and land-use changes. As climate change becomes more severe, analysis indicates the availability of fresh water is likely to be reduced by changes in rainfall patterns, melting of glaciers and ice caps, and a reduction in mountain snow cover. Higher temperatures will increase evaporation rates, further reducing surface water availability. Higher temperatures are also likely to affect agricultural production through heat stress (IPCC 2007). Although some benefits may be derived from crop growth through higher carbon dioxide levels, these will be largely negated in the longer term by the combined effects of reduced rainfall and increased temperatures. Additionally, such crop growth gains have been found to have a negative effect on crop quality (Chapman et al. 2012; Lin et al. 2005; Tausz 2012).

The latest data show that current greenhouse gas emissions are tracking at the higher end of international projection scenarios. This could lead to a projected temperature rise of 4 to 6 degrees Celsius by 2100 (Peters et al. 2012). Agricultural systems under such a scenario are likely to be severely negatively affected by reduced water availability and increased temperatures. Additionally, a significant projected rise in sea level would inundate low-lying coastal areas, while warming and acidification of the Earth's oceans would likely have a significant negative effect on global fisheries (Parry et al. 2007).

To compare the effect of a severe, climate-induced reduction to land productivity with the reference scenario results, a second set of crop productivity assumptions from the AgMIP climate scenario set was used in the agrifood model. Under this scenario, projected land productivity growth rates are modified to reflect the highest greenhouse gas emissions scenario modelled by the Intergovernmental Panel on Climate Change (IPCC) (Rosenzweig et al. 2012). The crop productivity implications of these concentration levels were modelled using a global climate (IPSL-CM5A-LR) and crop model (DSSAT) combination. The climate model projects changes in temperature and rainfall arising from increased greenhouse gas concentrations, and the crop model translates these changes in climate into changes in crop productivity.

Livestock productivity estimates remain unchanged from the reference scenario. However, livestock commodities will be impacted by this scenario due to higher feed costs resulting from lower productivity of crops. Fish productivity estimates are also unchanged, and climate change is assumed to have little impact on fish under this scenario.

Higher rainfall deficiency is characterised by significantly lower crop land productivity growth than in the reference scenario (Table 2). For example, the annual average growth rate for world cereals productivity over the projection period falls from 1.3 per cent in the reference scenario to 0.8 per cent given higher rainfall deficiency. However, despite lower productivity growth, world agrifood production is 71 per cent higher in 2050 than 2007, only 4 percentage points lower than in the reference scenario. Of note is the significant increase in the average agrifood price, which is 22.9 per cent higher in 2050 compared with 2007, nearly double the 11.5 per cent increase projected under the reference scenario (Figure 6). Driving the projected rise in global agrifood prices is the cereals commodity group, whose increase is more than four times the reference scenario result. Prices also rise significantly for the oilseed meals, oilseed oils, and the other food (which includes sugar, eggs and oilseeds) commodity groups.

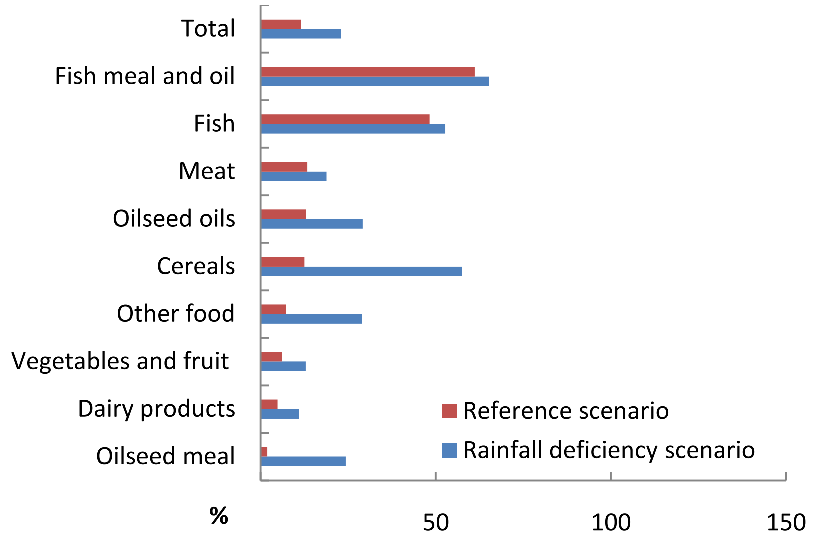
Table 2 Higher rainfall deficiency—annual average land productivity growth, by region and commodity group, from 2007 to 2050

Food group	World (%)	Australia[a] (%)	China (%)	India (%)	Rest of Asia (%)	Rest of world (%)
Meat[b]	1.6	1.3	2.3	3.0	1.6	1.6
Dairy products	1.6	1.3	2.3	3.0	1.6	1.6
Cereals	0.8	0.8	0.6	0.2	0.6	0.9
Other food	0.6	0.3	1.0	0.6	0.5	0.7
Vegetables and fruit	0.5	0.4	0.6	0.6	0.4	0.7

a Australia is also part of the Rest of world region. b Land productivity growth projections for livestock are identical to the reference scenario.

Data sources: Agricultural Modelling Intercomparison and Improvement Project; ABARES Global Trade and Environment model

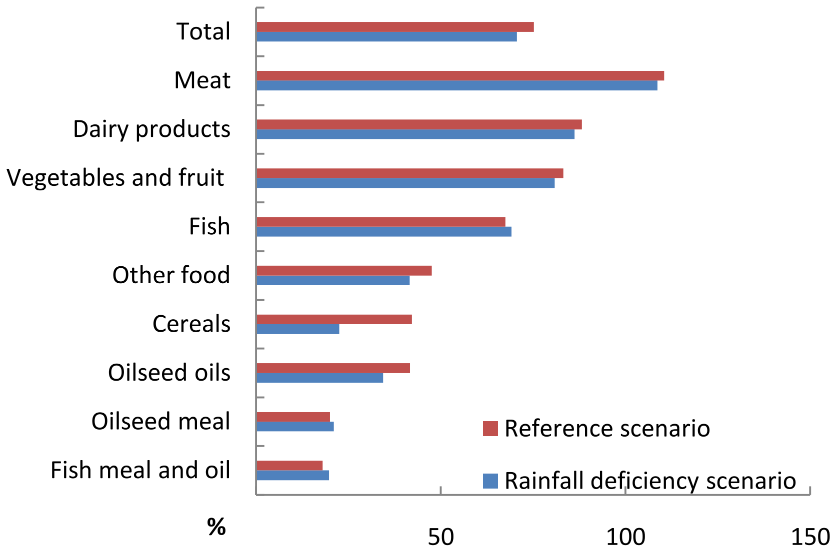
Figure 6 Higher rainfall deficiency—world real food price, change from 2007 to 2050



Data source: ABARES model output

The real value of production (in 2007 US dollars) of most commodity groups is lower compared with results from the reference scenario, particularly cereals, which are approximately 20 per cent lower (Figure 7).

Figure 7 Higher rainfall deficiency—real value of world production, increase from 2007 to 2050



Data source: ABARES model output

Scenario 2: Trade liberalisation with stronger productivity

International trade allows food to get to where it is needed most. As the issue of food security continues to dominate the global food policy agenda, the importance of liberalising international trade rules will remain at the forefront. Trade liberalisation, including reform of agricultural support regimes, improves the allocation of resources in the economy and can lead to productivity improvements in agriculture (Moir & Morris 2011).

Over the past four decades there have been significant developments in agricultural trade and in the policies and institutions surrounding it (Josling 2008). In recent years there has been a shift toward regional and bilateral trade agreements, while multilateral negotiations have stalled. Continued integration through these regional and bilateral agreements and continued support for the World Trade Organization (WTO) will affect trade liberalisation in coming years.

The short-term outlook for trade liberalisation is uncertain and is dependent on many factors, including global economic growth, growth in agricultural output and investment and continued policy reform in developed and developing countries (Josling 2008; Sarris 2009). Price volatility and absolute price levels may also affect the direction of agricultural trade policy. An example of this type of response occurred as recently as 2008 when high and volatile food prices led some countries to impose restrictions on exports.

Trade liberalisation with stronger productivity scenario

While it is not possible to accurately predict the path of trade liberalisation out to 2050, it is worth examining the effects of one possible trade liberalisation scenario and its price implications. This scenario utilises heavily stylised policy settings and assumptions with the aim of providing an indication of the world agrifood price response.

In the model a price wedge approach is used to take into account the difference between domestic producer and consumer prices and the world price, where the producer price is defined as the domestic market price inflated by the exogenous ad valorem producer support estimate (PSE), while the consumer price is the domestic price deflated by the exogenous ad valorem consumer support estimate (CSE). This price wedge approach is frequently used in trade liberalisation modelling; for example, by IFPRI, using the IMPACT model, and by ABARES. For further information on PSEs and CSEs see the OECD Producer and Consumer Support Estimates database (OECD 2013).

Economic theory suggests that, in response to trade liberalisation, resources should be reallocated toward more efficient industries and regions, which would then lead to productivity improvements. The ABARES agrifood model cannot fully capture these effects as it does not allow for adjustments to productivity endogenously within the model. Therefore, for brevity, a constant annual productivity improvement is imposed on every commodity for which PSEs and CSEs are available, across every region. This reflects assumed changes to total factor productivity, which captures technical improvement across all aspects of production. Because it was not possible to include PSEs and CSEs for fish in the model database, no productivity improvement is imposed on this sector. It is assumed that regions that do not have PSEs and CSEs will still achieve a productivity improvement as a result of factors such as technological catch-up and knowledge transfer.

In the reference scenario it is assumed that PSEs and CSEs remain unchanged from base year levels over the projection period. For the trade liberalisation scenario, it is assumed that PSEs and CSEs remain unchanged between 2007 and 2020. Between 2020 and 2040, the PSEs and CSEs are reduced in a linear fashion to be fully removed by 2040. As a result the price wedge between domestic and world prices is removed. In response to this liberalisation, the annual rate of TFP growth is assumed, for brevity, to be 5 per cent higher across all regions and commodities. This is compared with the growth rate in the reference scenario, from 2030 onward; that is, world TFP growth grows at approximately 1 per cent each year in the reference scenario. Under the trade liberalisation scenario this rate of growth would be 1.05 per cent. These periods have been chosen in order to examine the full effects of trade liberalisation and the resulting productivity improvements on global food markets.

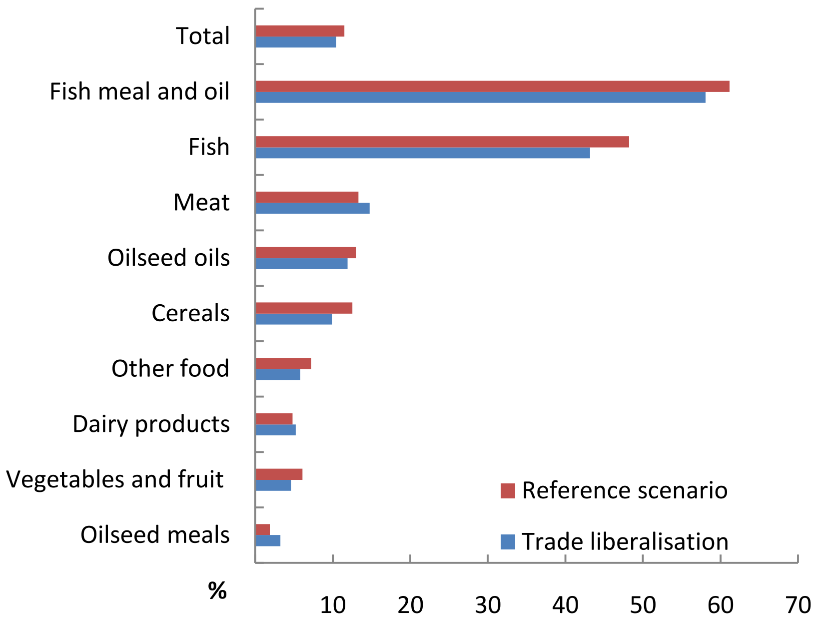
Results

In the model, PSEs effectively act as production subsidies and CSEs effectively act as consumption tax equivalents. When the PSEs are fully removed in 2040, global agrifood production falls, assuming other factors remain unchanged, while the removal of CSEs (expressed as a tax on consumption) over the same period results in higher demand and consumption. The consequence of these combined policy changes is an increase in excess demand that puts upward pressure on world prices (assuming other factors remain unchanged).

Following the assumed improvement in TFP between 2030 and 2050 across all regions and commodities, agrifood production is projected to gradually increase toward 2050, leading to downward pressure on food prices and an increase in food demand. Interactions between the assumption of total trade liberalisation and TFP growth drive the overall results of this scenario.

In 2050 the real value of global agrifood production (in 2007 US dollars) is projected to be 86 per cent higher than in 2007, a result greater than the reference scenario projection of 75 per cent. At the same time, agrifood prices are projected to be 10.4 per cent higher than in 2007, a result that is slightly lower (1.1 percentage points) than the reference scenario, due to relatively higher production putting more downward pressure on prices (Figure 8). Despite the relatively smaller price rise overall, the price rise by 2050 is higher relative to the reference scenario for meat, dairy products, and oilseed meals. This rise is driven by higher consumer demand resulting from trade liberalisation (removal of import tariffs). Higher global food production than in the reference scenario is projected to continue beyond 2050, placing more downward pressure on real world food prices than in the reference scenario.

Figure 8 Trade liberalisation scenario—world real food price, change from 2007 to 2050

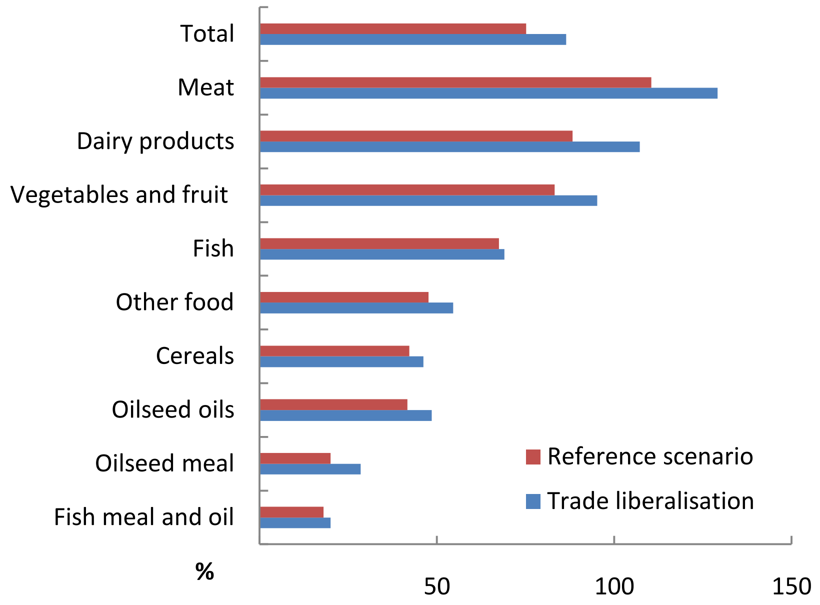


Data source: ABARES model output

Production and consumption

The projected rise in the real value of global agrifood production following trade liberalisation and higher productivity is being driven by the higher real production values of the meat, dairy products, and vegetables and fruit commodity groups (in 2007 US dollars) (Figure 9).

Figure 9 Trade liberalisation scenario—world real value of production, change from 2007 to 2050



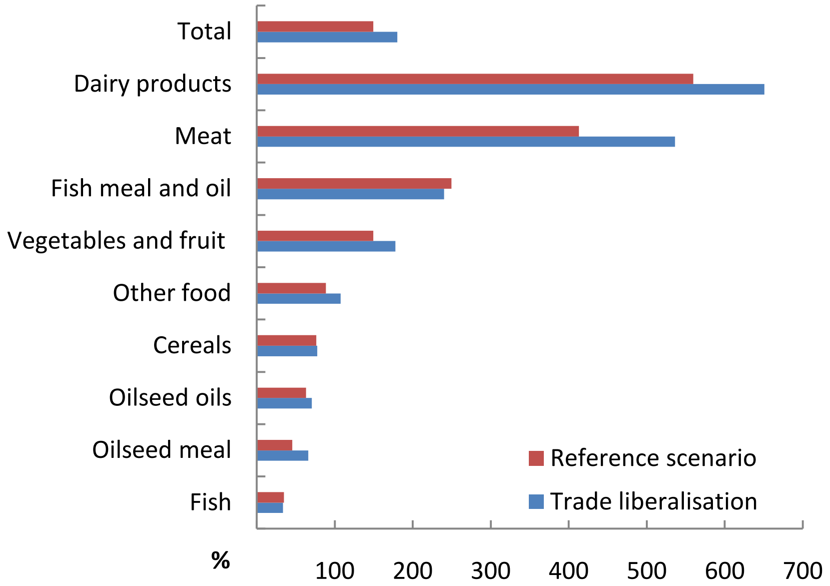
Data source: ABARES model output

Asia is projected to drive the higher consumption of agrifood products, accounting for 72 per cent of the projected rise in the real value of consumption in 2050 compared with the reference scenario. Under the trade liberalisation scenario, Asian demand for all commodity groups is greater than under the reference scenario, with the real value of consumption (in 2007 US dollars) significantly higher for the meat and dairy products commodity groups. The Rest of the world region is also projected to increase the real value of consumption (in 2007 US dollars) for all commodity groups, and also experience a strong rise in demand for meat and dairy products.

Exports

In 2050 the real value of global agrifood exports is projected to be 180 per cent higher than in 2007 under trade liberalisation (Figure 10). This is higher than the projected increase under the reference scenario of 149 per cent. The rise in the real values of exports of the commodity groups meat, vegetables and fruit, and dairy products drives this result.

Figure 10 Trade liberalisation scenario—world real value of exports, change from 2007 to 2050



Data source: ABARES model output

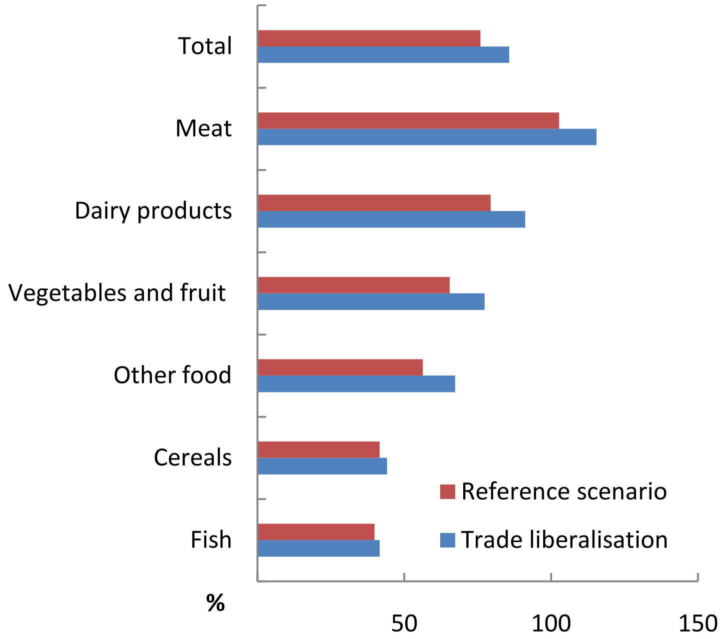
Implications for Australia

Production and exports

The projected increase in the real value of Australian agrifood production by 2050 compared with 2007 over the projection period is around 10 percentage points higher under the trade liberalisation scenario (incorporating additional productivity growth) than the reference scenario (86 per cent compared to 76 per cent) (Figure 11).

The projected rise in the real value of exports (in 2007 US dollars) is also significant, 166 per cent in the trade liberalisation scenario compared with 142 per cent in the reference scenario. While the real value of production and exports of all commodity groups increase under the trade liberalisation scenario, the responsiveness of the meat, dairy products, vegetables and fruit, and other food commodity groups demonstrates the potential opportunities for growth in these sectors in a more liberalised global trading environment. Vegetables and fruit in particular benefit under this scenario with growth in the real value of Australian exports by 2050 double that of the reference scenario. This is a result of stronger demand for vegetables and fruit from Asian countries as a result of trade liberalisation. Asian countries have comparatively high PSEs and CSEs on these commodities.

Figure 11 Trade liberalisation scenario—Australian real value of production, change from 2007 to 2050



Data source: ABARES model output

Scenario 3: Biofuels changes

Biofuels are touted as an important renewable energy source, 'that can decrease the dependence on fossil fuels, increase farm revenues, and improve the environmental sustainability of the world industrial and transportation sectors' (IFPRI 2012a). By contrast, the use of food crops for fuel is often criticised in light of the increasing importance of food security around the world (Global Issues in Context 2013; IFPRI 2012b; Oxfam 2012).

Biofuels markets are likely to continue to be dominated by the United States, Brazil and, to a lesser extent, the European Union until at least 2021 (OECD/FAO 2012). Currently biofuels are produced almost entirely from food-based feedstock, such as maize, rapeseed and sugar cane. These biofuels are known as first-generation biofuels. The OECD/FAO (2012) report that 40 per cent of US maize, 50 per cent of Brazilian sugar cane and 65 per cent of EU vegetable oil production are used as feedstock for biofuel production (OECD/FAO 2012).

Alternative, non-food based feedstock (known as cellulosic feedstock), such as switchgrass, crop and wood residues, and industrial and other wastes, can be used to produce second-generation biofuels. Despite the commitment by the European Union and the United States to significantly increase production of second-generation biofuels, until very recently commercial production of these biofuels has been limited by the high cost of extracting the sugars from cellulosic feedstock for conversion to ethanol. However, considerable investment into research and development in this area over the past decade is slowly yielding results and the production of second-generation biofuels, particularly in the United States, is expected to increase markedly (EPA 2013).

Biofuel scenario

Recent proposed updates to the US Renewable Fuel Standard (RFS) and the EU Renewable Energy Directive (RED), policies that mandate the levels of production and use of biofuels in these countries, demonstrate the ongoing commitment of the United States and the European Union to the use of renewable fuels in their energy sectors. Targets set by the RFS and RED extend only to 2022 and 2020, respectively. In this biofuels scenario, four simulations were developed that reflect a continuing and significant shift by the United States and European Union away from using food-based feedstock in the production of biofuels. The assumptions behind these simulations are imposed on top of those already reported in the reference scenario.

Given the importance of the United States as the world's largest producer and exporter of maize, the first three simulations model the impact on world agrifood prices of an incrementally larger cut in the proportion of US-produced maize used in the production of ethanol. Starting in 2015, the share of maize used in US ethanol production is reduced by 50 per cent (from a 40 per cent share of US maize production to a 20 per cent share), followed by 75 per cent and finally 100 per cent (complete removal). The fourth simulation examines the impact on world prices of completely removing food-based inputs (maize and oilseed oils) from US ethanol and EU biofuel production. These four simulations reflect two possibilities: cuts to the US and EU mandates for biofuels use, and/or an increase in the production of second-generation biofuels in lieu of first generation biofuels.

The simulations within this biofuels scenario are not meant to reflect any ongoing developments within the United States or the European Union. Of interest is the relative change of world cereal and oilseed prices from the reference scenario under heavily stylised settings.

Although Brazil is the second largest ethanol producer and a significant exporter of ethanol, results from simulations that cut the amount of sugar used in Brazilian ethanol production are not reported as part of this scenario. This is because competition for sugar cane on the world market is predominantly between the food and energy sectors, not the food and livestock sectors (as are maize and rapeseed), although there could be some substitution between sugar cane and beef production in Brazil. Brazil has a comparative advantage in using sugar to produce ethanol. While it is acknowledged that any significant change to sugar cane use in Brazil would likely have implications on the world trade of ethanol and sugar, the objective of this scenario is to focus on the implications to global cereal markets. As a result, this report only considers adjustments to the use of cereal crops for US and European biofuels production.

The production share of maize, sugar, wheat and oilseed oils in the production of biofuels was updated for each of the years from 2007 to 2012 in the ABARES agrifood model to accurately reflect the progressive increase in the volume of biofuels produced globally (IGC 2012; OECD/FAO 2012; USDA 2012). The agrifood model captures the demand for the biofuels feedstock through its equation for total demand.

Results

World price and production of maize and rapeseed

Under the reference scenario, the world price of maize in 2050 is 12.5 per cent higher (in 2007 US dollars) compared with 2007 (Table 3). With a 50 per cent reduction in the share of US-grown maize used for ethanol production, the world price of maize in 2050 (in 2007 US dollars) is virtually unchanged (0.6 per cent) compared with 2007. This result reflects lower maize consumption by the US energy sector. Because of continued growth in demand for maize by the food and livestock sectors over the projection period, the value of US maize production (which includes maize for all final uses) in 2050 is projected to be 14 per cent higher in this first simulation, a slightly lower rise compared with the reference scenario at 16 per cent. This projected increase is sufficient to virtually eliminate any price increase.

Table 3 Biofuel simulations: real world prices for maize and rapeseed, change from 2007 to 2050

Simulation	Simulation description	Maize (%)	Rapeseed (%)
	Reference scenario	12.5	27.9
1	US maize (50% reduction)	0.6	24.6
2	US maize (75% reduction)	–3.3	23.7
3	US maize (complete removal)	–6.3	22.9
4	US maize and EU rapeseed (complete removal)	–6.4	22.8

Data source: ABARES model output

In simulations 2 and 3, more significant cuts to the share of US maize in ethanol production (75 per cent followed by 100 per cent) result in the real world price of maize in 2050 (in 2007 US dollars) falling below the 2007 price, by 3.3 per cent and 6.3 per cent, respectively. This price decline occurs because of the relative absence of demand from the energy sector, which in these two simulations is consuming only 10 per cent of US maize production and no maize at all. Thus almost the entirety of the US maize crop is used as food and feed. Despite the decline in real world prices, relatively strong growth in global demand for maize in the food and livestock sectors between 2007 and 2050 is still projected to result in a rise of about 13 per cent in the total US value of maize production, a result only slightly below the reference scenario.

The world price of rapeseed in the reference scenario is nearly 28 per cent higher in 2050 (in 2007 US dollars) compared with 2007. In each of the first three simulations where the share of US maize is reduced in biofuels production, world rapeseed prices continue to be significantly higher in 2050 (in 2007 US dollars) compared with 2007. However, world rapeseed prices are between 3.5 and 5 percentage points lower than in the reference scenario (Table 3). This result reflects the substitutability in demand between the cereals and oilseed meals commodity groups for feed. As a result, while the real value of EU rapeseed exports (in 2007 US dollars) continues to increase over the projection period in each of the first three simulations, the increase is always slightly lower than in the reference scenario.

When both US maize and EU rapeseed are completely removed from the production of biofuels (Simulation 4), the results are largely unchanged from Simulation 3, when only US maize is removed from biofuels production. Under this last simulation, the world price of rapeseed in 2050 is 22.8 per cent higher than in 2007 (in 2007 US dollars), 5.1 percentage points less than in the reference scenario. This significant increase, as in each of the first three simulations, reflects the strength of demand for rapeseed for food and feed use. Indeed, the magnitude of the projected increase in real rapeseed prices in each simulation suggests that world rapeseed prices are not influenced as strongly by demand from the European biofuels industry as maize is by demand from the US biofuels industry.

Implications for Australia

Despite adjustments in the world grains market that will result following a significant reduction to first-generation biofuel production in the United States and the European Union, total Australian exports of cereals are not projected to be significantly lower than in the reference scenario.

Although Australia does not export maize, changes in the world price of maize have an effect on the world wheat market because of the substitutability of wheat for maize in feed. Australia is a significant exporter of wheat. In the reference scenario, the world wheat price is projected to be 8.5 per cent higher in 2050 relative to 2007. In the four simulations discussed here, as the world price of maize ceases to increase over the projection period, the projected rise in the world price of wheat is lower than in the reference scenario. When both US maize and EU rapeseed are completely removed from the production of biofuels (Simulation 4), the world price of wheat is 6.6 per cent higher in 2050 relative to 2007, nearly 2 percentage points lower than in the reference scenario. This occurs as a result of weakening demand for feed wheat in lieu of maize, which has an impact on Australian wheat exports. Although the value of Australian wheat exports (in 2007 US dollars) in each of the scenarios is projected to be higher in 2050 relative to 2007 (between 62 per cent and 63 per cent higher), this increase is still marginally lower than in the reference scenario (64.6 per cent).

For rapeseed (canola), Australia competes directly with the European Union on the world market for both rapeseed oil and meal. The projected changes in real world rapeseed prices in 2050 relative to 2007 (in 2007 US dollars) in each of the four biofuels simulations is projected to have an effect on the real value of Australian rapeseed production and exports, although the response will be lower than in the reference scenario. In the reference scenario, the increase in the value of Australian rapeseed exports is 105 per cent in 2050 relative to 2007. Over the four simulations, increases in Australian rapeseed exports are between 96 per cent and 99 per cent.

3 Conclusions

Under the assumptions established in the reference scenario model simulation, world agrifood prices are projected to be 11.5 per cent higher in 2050 compared with 2007 (in 2007 US dollars). This increase is driven by stronger global demand stemming from increasing incomes and population and resource constraints that are likely to affect productivity increases. The price increase is projected to be lower than in the reference scenario when agrifood trade is liberalised with additional increases in productivity growth rates. When the production of first-generation biofuels in the United States and European Union is reduced, the simulation results indicate a significant impact on world cereal prices.

In the reference scenario, the real value of world agrifood production (in 2007 US dollars) is projected to be 75 per cent higher in 2050 compared with 2007. However, when trade is more liberalised, the rise in the real value of world agrifood production by 2050 is projected to be higher than the reference scenario, at 86 per cent. One model limitation for this study is that no adjustments to productivity growth between periods are assumed—adjustments that might come from innovation. If these adjustments could be incorporated in the model, as was done in the trade liberalisation scenario, the production response to higher prices in the reference scenario might be different. The results for each of the scenarios presented in this report are merely indicative of one potential set of responses to a given set of assumptions.

These scenarios highlight the effect policy can have on agricultural prices, and the market response to the removal of distortions. The policy environment will be instrumental in meeting the demand for agrifood to 2050 in a sustainable manner, particularly given resource constraints. To ensure food goes where it is needed, the policy agenda must include the limitation and removal of trade restrictions, as well as the utilisation of resources by the most efficient regions and sectors.

The simulations discussed in this report emphasise the significance of improvements in productivity to meet higher food consumption and reduce price pressures. As was seen in the sensitivity analysis, a small improvement in total factor productivity above a reference scenario can lead to significantly lower global price rises over the longer term. In order to attain higher productivity growth greater investment in research, development and extension and infrastructure development is required.

Australia is well located to take advantage of the opportunities that higher food consumption will provide but there will be a need for a change to agricultural production in Australia to fully capture these opportunities. This will only be accomplished with a reversal of the recent slowing rate of growth in productivity and more targeting of consumer needs in the growth areas of the world—particularly Asia.

At the industry level, this will require targeting of our products to more diversified markets and targeting different qualities of our products to market segments where there is greatest potential for value adding. Such qualities could include, for example, safe, low pest, environmentally sound, animal friendly products; products with a low carbon footprint or any combination thereof. The relationship between prices and production is dynamic. Global agrifood production adjusts to the incentives and opportunities inherent in market price movements. Higher prices can lead to higher productivity by improving incentives for investment in research and development, through innovation and through adaptation of existing overseas technologies applied to an Australian environment. In so doing, producers will be able to better cope with climatic challenges and land and water constraints.

The government can also assist through a strong commitment to furthering global trade liberalisation and increasing access to a diverse range of overseas markets. The government has a role in providing information to support sound decision-making and to correct information imbalances in the marketplace. It also has a role in education and training to ensure skills are available. Governments will need to continue to provide a sound economic environment, with appropriate fiscal policy settings that encourage economic and productivity growth—goals achievable only if regulation is limited to those areas where market failures exist and where the benefits of regulation clearly outweigh its costs.

Appendix A: ABARES agrifood model

For this analysis, ABARES used the agrifood model developed for *Food demand to 2050: Opportunities for Australian agriculture* (Linehan et al. 2012a & 2012b). The model is an economic simulation model of global agricultural supply, demand and trade. As in earlier analysis, the model was used to prepare annual projections for 2007 to 2050. Annual regional demand and supply curves are specified for each agrifood commodity. World prices, expressed in real terms, balance global demand and supply for each commodity.

In the model, agrifood is defined as agricultural and fishery output that is used for food. This includes food for human consumption, animal feed and food crops used as feedstock for other purposes, such as biofuels. It does not include non-food agricultural outputs such as cotton or wool.

Consumer demand for each commodity changes over time in the agrifood model, given assumptions relating to real per person income and population. Commodities are linked through substitution responses to relative price changes, which are themselves derived in the model. The production of commodities increase with assumed rates of technical advancement. Crop production is linked through competing land use. Livestock feed use competes with human consumption and industrial feedstock use, and also with crop production for land for pasture. The supply of land for agriculture, either for cropping or grazing, is price responsive, although the availability of total arable land is limited. Low-value and high-value fish products are incorporated in the model to account for possible protein options as well as to link with the feed sector.

Key results from the model are expressed as real values to allow different commodities to be aggregated. Real values are obtained by multiplying quantities in the projection years by world prices in 2007, the model base year. For a single commodity, a given percentage change in real value is equivalent to a pure volume change of the same percentage, assuming prices are unchanged.

The two types of productivity improvements incorporated in the model are land productivity and total factor productivity (TFP) improvements. Improvements in land productivity reflect a reduction in the input of land per unit of output of cropping or livestock product. This is a partial measure of productivity, where a single factor, land, experiences technological advancement (or land productivity). TFP is a measure of total output relative to total inputs. In the modelling framework, improvements in TFP are incorporated by applying changes in technological improvement to every input, including land, feed conversion and an aggregate measure of other inputs.

The model-based projections presented in the report are conditional on a set of assumptions, most notably about the macro-economic environment and changes in agricultural technology and productivity. Projections are also conditional on parameter values used to represent the sensitivities of demand and supply curves to economic forces. Changes to these assumptions and parameters result in changes to the projections.

New information and data has been incorporated into the model for this study. In particular, the productivity growth assumptions for this study were sourced from a model comparison exercise, the Agricultural Modelling Intercomparison and Improvement Project (AgMIP), undertaken by ABARES and other research institutions (Rosenzweig et al. 2012), and are treated as exogenous to the model. The land productivity assumptions for crops were derived from the

International Food Policy Research Institute's IMPACT model (Rosegrant et al. 2012). Land productivity estimates for the livestock sectors were derived from the ABARES Global Trade and Environment model (GTEM), and are capped at 3 per cent in any region. No technology catch-up is reflected or imposed on these numbers.

With the exception of Australia, global maximum land availability figures for cropping and pasture land are sourced from Alexandratos and Bruinsma (2012), and are mapped to the regions in the agrifood model. For Australia, ABARES assumptions are used.

In the ABARES agrifood model a capture fishery is constrained to produce within, or on, an exogenously set quota, depending on the most profitable option. Given the biophysical constraints to expansion of global capture fisheries, quotas have been set equal to the base year level of production for both high-value and low-value capture fisheries. One limitation of the fisheries component of the model is the use of the fish meal and oil commodity group as the only feed input in aquaculture production. In reality, aquafeed also includes animal protein meals and fats as well as plant nutrients, such as cereals, oilseed meals and oilseed oils.

Information on the share of US maize, EU rapeseed, and Chinese wheat and maize used for biofuels production was sourced from the International Grains Council (IGC 2012). The share of Brazilian sugar used in ethanol production was sourced from OECD/FAO (2012).

A more detailed description of the model can be found in Linehan and colleagues (2012a and 2012b).

The model-based projections presented in this report are conditional on a set of assumptions. Assumptions about the annual average growth rate in real incomes for each region in the model are presented in Table A3.

Table A1 Commodities in the ABARES agrifood model

Commodity	Aggregate food groups	Commodity	Aggregate food groups
Beef **a b**	Meat	Soybean oil	Oilseed oils
Pig meat	Meat	Rapeseed	Other food
Sheep meat **a c**	Meat	Rapeseed meal	Oilseed meals
Poultry	Meat	Rapeseed oil	Oilseed oils
Eggs	Other food	Sunflower seed	Other food
Dairy products **d**	Dairy products	Sunflower meal	Oilseed meals
Wheat **e**	Cereals	Sunflower oil	Oilseed oils
Rice **f**	Cereals	Other oilseed meals	Oilseed meals
Maize	Cereals	Other oilseed oils	Oilseed oils
Other cereals **g**	Cereals	Vegetables	Vegetables and fruit
Potatoes	Vegetables and fruit	Fruit **i**	Vegetables and fruit
Sweet potatoes **h**	Vegetables and fruit	Sugar **j**	Other food
Other roots	Vegetables and fruit	Fish low value **k**	Fish
Soybeans	Other food	Fish high value **k**	Fish
Soybean meal	Oilseed meals	Fish meal and oil concentrate	Fish meal and oil concentrate

Note: Commodities in the ABARES agrifood model are based on commodity definitions used in the Food and Agriculture Organization food balance sheets (FAO 2011). **a** Includes meat equivalent of live animal trade. **b** All bovine meat, including buffalo. **c** Includes goat meat. **d** Milk and milk equivalent of dairy products. **e** Includes wheat equivalent of flour and bakery products. **f** Milled equivalent. **g** Includes barley equivalent of malt, excludes beer. **h** Includes yams. **i** Excludes wine. **j** Raw sugar equivalent. **k** Includes seafood products.

Table A2 Regions in the ABARES agrifood model

United States	Central Asia **b**	Thailand	Rest of Oceania **j**
Canada	India	Vietnam	Egypt
Mexico	Pakistan	Rest of South East Asia **d**	Rest of North Africa
Brazil	Bangladesh	West Asia **e**	Nigeria
Argentina	Sri Lanka	Turkey	Rest of Middle and Western Africa
Rest of America	Rest of South Asia **c**	European Union 15 **f**	Republic of South Africa
Japan	Indonesia	Eastern Europe **g**	Rest of Southern and Eastern Africa
Republic of Korea	Malaysia	Southern Europe **h**	
China	Myanmar	Rest of Europe **i**	
Rest of East Asia **a**	Philippines	Australia	

Note: Regions used in the ABARES agrifood model are based on United Nations geographical regions (United Nations 2011). **a** China (Hong Kong) Special Administrative Region, China (Macao) Special Administrative Region, Democratic People's Republic of Korea and Mongolia. **b** Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. **c** Afghanistan, Bhutan, Islamic Republic of Iran, Maldives and Nepal. **d** Brunei Darussalam, Cambodia, Lao People's Democratic Republic, Singapore and Timor-Leste. **e** Armenia, Azerbaijan, Bahrain, Cyprus, Georgia, Iraq, Israel, Jordan, Kuwait, Lebanon, Occupied Palestinian Territory, Oman, Saudi Arabia, Syrian Arab Republic and United Arab Emirates. **f** Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. **g** Belarus, Bulgaria, Czech Republic, Hungary, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia and Ukraine. **h** Albania, Andorra, Bosnia and Herzegovina, Croatia, Gibraltar, Holy See, Malta, Montenegro, San Marino, Serbia, Slovenia, and the Former Yugoslav Republic of Macedonia. **i** Åland Islands, Channel Islands, Estonia, Faeroe Islands, Guernsey, Iceland, Isle of Man, Jersey, Latvia, Lithuania, Norway, Sark, Svalbard and Jan Mayen islands, Lichtenstein, Monaco and Switzerland. **j** Predominantly New Zealand.

Table A3 Average annual real income growth, 2007 to 2050

Country or region	Annual real income growth (%)	Country or region	Annual real income growth (%)
United States	2.3	Philippines	3.8
Canada	1.9	Thailand	2.7
Mexico	2.4	Vietnam	4.3
Brazil	3.0	Rest of South East Asia	2.7
Argentina	3.3	West Asia	3.6
Rest of America	3.0	Turkey	2.6
Japan	1.1	European Union 15	1.4
Republic of Korea	2.2	Eastern Europe	2.4
China	5.5	Southern Europe	1.6
Rest of East Asia	3.0	Rest of Europe	1.7
Central Asia	3.9	Australia	2.6
India	5.4	Rest of Europe	2.5
Pakistan	3.5	Egypt	3.2
Bangladesh	4.3	Rest of North Africa	3.2
Sri Lanka	4.3	Nigeria	5.5
Rest of South Asia	4.9	Rest of Middle and Western Africa	4.6
Indonesia	4.2	Republic of South Africa	3.0
Malaysia	3.6	Rest of Southern and Eastern Africa	5.3
Myanmar	4.3		

Agricultural land expansion assumptions

Global estimates

With the exception of Australia, maximum land availability for cropping and pasture land globally is sourced from Alexandratos and Bruinsma (2012), who project arable land use for crops in 2050 based on production and yield estimates (Table A4)

Table A4 Arable land projected change, 2005–07 to 2050

Country or region	Per cent change
World (excluding Australia)	4.3
Developed countries (excluding Australia)	–7.1
Developing countries	11.0
Asia	1.6
China	–4.8
India	3.6
Argentina	40.9
Brazil	28.4
Rest of America	20.3
Rest of Middle and Western Africa	24.1
Rest of Southern and Eastern Africa	28.8

Data source: Alexandratos and Bruinsma 2012

Australian estimates

To estimate an upper limit for agricultural land area in Australia, potentially available land that could be used for agriculture was spatially modelled to find where it coincided with land under a suitable climate and terrain. This provided an estimate of the area of potential additional agricultural land. This estimate was then compared to the current area of agricultural land to calculate the proportionate potential increase. The current area of agricultural land was taken from the 2005–06 National Land Use Map, which is based on ABS agricultural census data (ABARE–BRS 2010). Using this method the potential for further land to be available for cropping was estimated to be 0.62 per cent and for pasture 0.04 per cent.

Appendix B: Factors affecting future food production

Land availability

While studies suggest plenty of arable land is available globally, much of this land is located in Latin America and sub-Saharan Africa, and may be inaccessible, lack agricultural infrastructure or be diseased. Land constraints at the country or regional level can be significant, with a number of countries having reached, or about to reach the limits of their available land for agriculture. At the same time, competition exists for this land for urbanisation, industrial, environmental and recreational uses (OECD/FAO 2012).

The continuing decline of agricultural land availability is often cited as an indicator of difficulties in meeting future food demand. However, Alexandratos and Bruinsma (2012) suggest that changes in land use will be the result of countervailing forces—population, demand growth and increasing crop yields—and the outcome will differ between countries.

Alexandratos and Bruinsma (2012) project that between 2005–07 and 2050 the area of arable land suitable for cropping use will increase by 70 million hectares (4.3 per cent). Developing countries are projected to increase arable land by almost 110 million hectares, while the arable land area for developed countries is projected to fall by about 40 million hectares. The bulk of the projected expansion is expected to take place in sub-Saharan Africa (51 million hectares) and Latin America (49 million hectares), with almost no land expansion in South Asia, and a constant area in the Middle East, North Africa and East Asia.

Productivity

A number of factors are expected to affect agricultural productivity include land degradation, limitations in water availability and climate change.

Land degradation

Land degradation is the long-term decline in ecosystem function (Bai et al. 2008). It is an ongoing global issue that affects soils, biomass, water, biodiversity and socio-economic services derived from ecosystems (Nachtergaele et al. 2011). Land degradation processes include vegetation degradation, loss in quantity and quality of water resources, and soil degradation, such as erosion, salinisation, loss of nutrients, acidification, and physical and biological degradation (FAO 1999). The OECD/FAO (2012) estimate that approximately 25 per cent of the world's agricultural land area is highly degraded.

Soil degradation in drylands is a significant contributor to the reduction of soil fertility and, in turn, agricultural productivity. Based on available data in 2010, the United Nations Convention to Combat Desertification found that 44 per cent of global food production takes place in the world's drylands, and that 52 per cent of the land used for agriculture is moderately or severely affected by land degradation (UNCCD 2010).

Water quality and availability

Water availability is a constraint on agriculture and agricultural expansion, especially in the dryland regions. Competing uses, such as urbanisation and industrial activity, can and do exacerbate water shortages. Irrigation has been widely adopted as one way to ensure constancy of water supply. It has been estimated that between 2005 and 2007 around 15 per cent of arable land globally was irrigated, accounting for 42 per cent of crop production (Nachtergaele et al. 2011). However, increased use of irrigation can and has lead to increased incidence of salinisation.

Climate variability and change

Climate variability, in particular drought, can lead to short-term water shortages, and in turn, exacerbate land degradation. Climate change is expected to further affect water availability, with many regions of the world projected to have reduced rainfall with consequent impacts on both surface and groundwater availability.

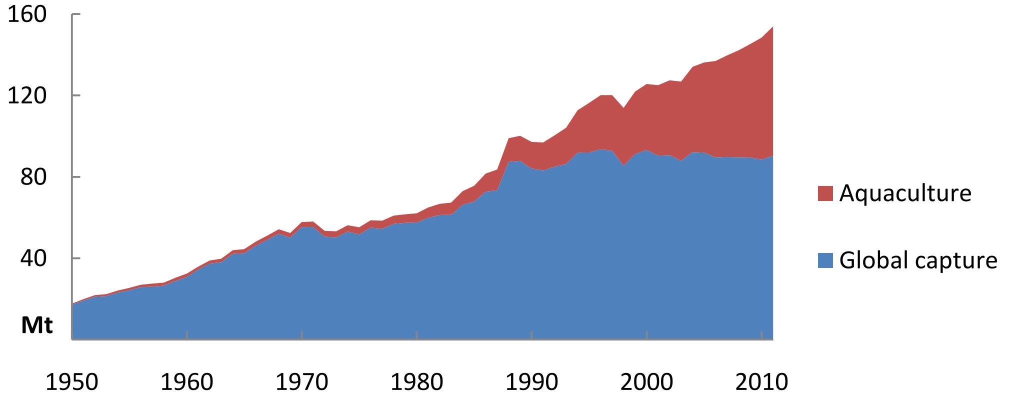
The effects of these factors on food production toward 2050 are incorporated in the model simulations through the assumptions about land productivity and total factor productivity (Chapter 2).

Global fishery product supply

Growth in global fishery product supply is expected to be supported mainly by the aquaculture sector; this is because global capture fisheries are thought to be operating at or above biologically sustainable levels. This is consistent with fishery production trends since the early 1990s: production within capture fisheries has plateaued, while aquaculture production has continued to grow.

In 2011 total fishery product supply is estimated to have reached 154 million tonnes, of which 87 per cent (131 million tonnes) was destined for human consumption (FAO 2012). In 2011 capture production accounted for around 59 per cent (90 million tonnes) of total fishery product supply, down from 87 per cent in 1990. Global capture fisheries production continues to remain stable at around 90 million tonnes.

Figure B1 Global capture and aquaculture fisheries production, 1950–2010



Data source: FAO 2012

Capture fisheries

In 2011 world capture production is estimated to have reached 90.4 million tonnes, of which around three-quarters was destined for human consumption. Prospects for growth in output from capture fisheries are limited. Many key stocks worldwide are fully exploited, overexploited or from depleted or recovering stocks (FAO 2012). The two main avenues for potential increases in capture production are from underexploited fisheries and from stocks that are recovering under a sound management strategy. Little production growth from fully exploited, overexploited or depleted fisheries is expected up to 2050.

Underexploited fisheries represent a relatively small proportion of fishery resources (FAO 2005). They are underexploited primarily because, with current technology, it is not economically viable to harvest at higher levels. However, under appropriate management, and with more efficient fishing technology and/or the development of new seafood markets, these fisheries could increase production and improve their economic viability.

Recovering fisheries could increase production up to 2050, provided stocks are rebuilt to a point where higher sustainable harvests are possible. However, increased production in these fisheries relies on sound management strategies to ensure recovery and environmental factors conducive to stock recovery. The ability of many management regimes to facilitate stock recovery remains unproven.

Aquaculture

Most of the growth in global seafood production up to 2050 is expected to be sourced from aquaculture. Over the past three decades, global seafood production of aquaculture grew at an average annual rate of 8.8 per cent. In 2010 global edible aquaculture production reached a peak of 60 million tonnes.

To meet future demand for food from aquaculture, production will largely depend on the availability of quality feeds. Growth of the aquaculture sector may also be limited by natural factors. For example, growth in the production of the non-fed sector, that is species that do not rely on fish feed, but only natural food sources, may be limited by the availability of suitable sites. Similarly, growth in the fed sector (species that rely on fish feed) may be limited by the availability of fish meal and fish oil from capture species, which are major ingredients in aquaculture fish feed. Aquaculture production is also vulnerable to the adverse effects of disease and environmental conditions.

Appendix C: Sensitivity analysis

In order to improve understanding of the relationships between the assumptions used in the simulations and the model projections, sensitivity analysis around some of the assumptions was applied. Sensitivity analysis was also undertaken to gauge the responsiveness of the model to the new supply constraints, specifically their effect on prices. For these reasons, land productivity, total factor productivity (TFP) and land availability assumption were each increased and decreased by 10 per cent compared with the reference scenario (from 2013 onward). The respective effects of these simulations on the projection results compared with the reference scenario are examined in Table C1.

Table C1 Sensitivity analysis, change from 2007 to 2050

Simulation description	Price change (%)	Real value of production change (%)
Reference scenario	11.5	75
Land productivity (10% lower)	15.0	73
Land productivity (10% higher)	8.8	77
TFP (10% lower)	22.7	68
TFP (10% higher)	1.1	83
Land availability (10% less)	15.3	73
Land availability (10% more)	9.2	77

TFP = total factor productivity

Data source: ABARES model output

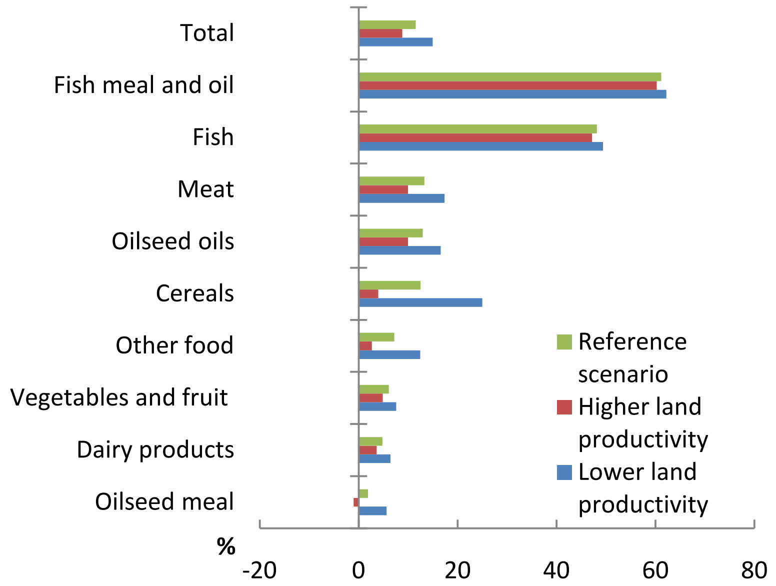
Results are not symmetric around the reference scenario, with prices and the real value of production generally more responsive to lower land productivity, lower TFP and lower land availability.

Land productivity assumptions

Under the simulation of lower livestock and cropping land productivity growth, the real increase in global agrifood production (in 2007 US dollars) over the projection period (73 per cent) is lower than the reference scenario (75 per cent), while it is higher under the scenario of higher land productivity growth (77 per cent). Consistent with this, the increase in the aggregate price index is higher under the lower productivity scenario and lower under the higher productivity scenario compared with the reference scenario (Figure C1).

Prices and the real value of production are generally more responsive to the lower land productivity simulation. The change in the prices between 2007 and 2050 resulting from these changes in land productivity is greater than 10 per cent for all commodity groups, except for fish and fish meal and oil. Lower growth rates of cropping land productivity have a significant effect on cereals prices with the rise in the price of cereals over the projection period doubling that of the reference scenario.

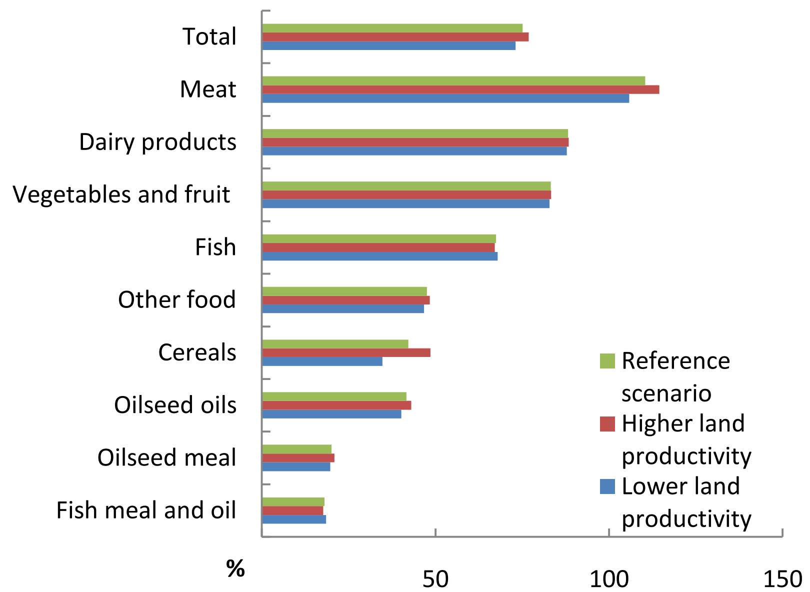
Figure C1 Land productivity sensitivity—world real food, change from 2007 to 2050



Data source: ABARES model output

The real value of cereals production is sensitive to the change in land productivity (Figure C2). In the lower land productivity simulation, the real value of cereals production (in 2007 US dollars) in 2050 is 34.8 per cent higher than 2007, while under the reference scenario it is 42.2 per cent higher, and under the higher land productivity simulation it is 48.5 per cent higher. As a result of lower land productivity for livestock and higher feed input costs, the real value of meat production in 2050 is projected to be 106 per cent higher than in 2007 in the lower land productivity simulation, lower than the rise in the reference scenario (110 per cent) and in the higher land productivity simulation (115 per cent).

Figure C2 Land productivity sensitivity—world real value of production under high and low land productivity growth, change from 2007 to 2050



Data source: ABARES model output

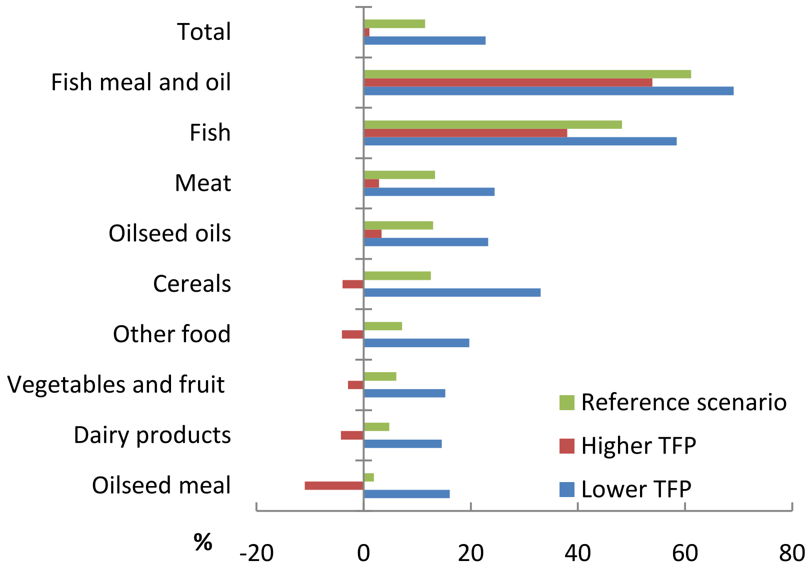
Total factor productivity assumptions

Sensitivity analysis around the productivity (technical change) assumptions is applied by increasing and decreasing the growth rate of total factor productivity (TFP) in the reference scenario by 10 per cent, from 2013 onward, holding everything else constant.

The impact of the TFP shock is projected to be larger than the land productivity shock (Figure C3 and Figure C4), with the real value of production (in 2007 US dollars) and prices of all commodity groups being significantly affected. In response to higher TFP, in 2050 agrifood prices are projected to be only 1.1 per cent higher than in 2007, significantly lower than projected under the reference scenario (11.5 per cent) and the lower TFP simulation (22.7 per cent). All commodity prices are projected to be higher under the lower TFP simulation compared with the reference scenario, and lower under the higher TFP simulation.

In the 10 per cent higher TFP simulation, prices are projected to decline for oilseed meal, dairy products, vegetables and fruit, other food and cereals between 2007 and 2050 (Figure C3). Similarly, in the lower TFP simulation, compared with the reference scenario these commodities are projected to experience significantly large price rises. For each commodity group the rise in prices is projected to be greater than the fall experienced under the higher TFP simulation. The change in price from the reference scenario is significantly greater than 10 per cent for all commodities for both the higher and lower TFP simulations.

Figure C3 Total factor productivity sensitivity—world real price, change from 2007 to 2050

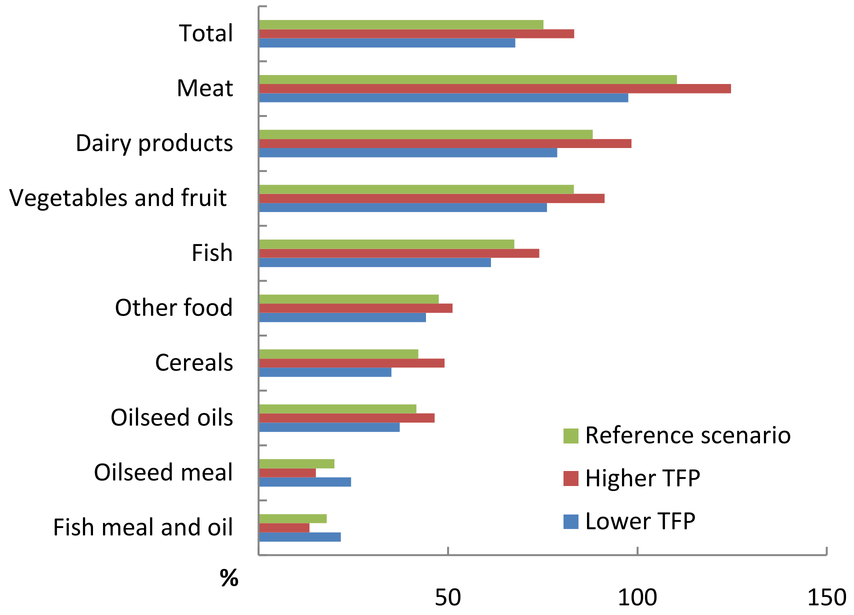


TFP = total factor productivity

Data source: ABARES model output

As a result of higher TFP, the real value of global agrifood production in 2050 (in 2007 US dollars) is projected to be 83 per cent higher than in 2007, a result higher than the projected rise of 75 per cent in the reference scenario. With a lower growth in TFP, the real value of global agrifood production is 68 per cent (Figure C4). In the higher TFP simulation, the real value of production of all commodity groups is projected to increase by a lesser amount compared with the reference scenario over the projection period with the exception of fish meal and oil, and oilseed meal. Cereals, meat, vegetables and fruit, and oilseed oils are most affected by these simulations.

Figure C4 Total factor productivity sensitivity—world real value, change from 2007 to 2050



TFP = total factor productivity

Data source: ABARES model output

Due to lower TFP, the real value of fish production (in 2007 US dollars) falls. However, at the same time, the input of fish meal and oil per unit output of aquaculture production increases (due to the higher productivity assumption). This results in higher demand for fish meal and oil and larger rises in the price and the real value of production compared with the reference scenario. The opposite occurs under the higher TFP simulation.

Similarly, for oilseed meal, under the lower TFP simulation, larger price rises are projected for oilseed oils and meal. At the same time the input of oilseed meal required for feed per unit output of meat rises, increasing demand for oilseed meal and leading to higher real value of production (in 2007 US dollars) of oilseed meal.

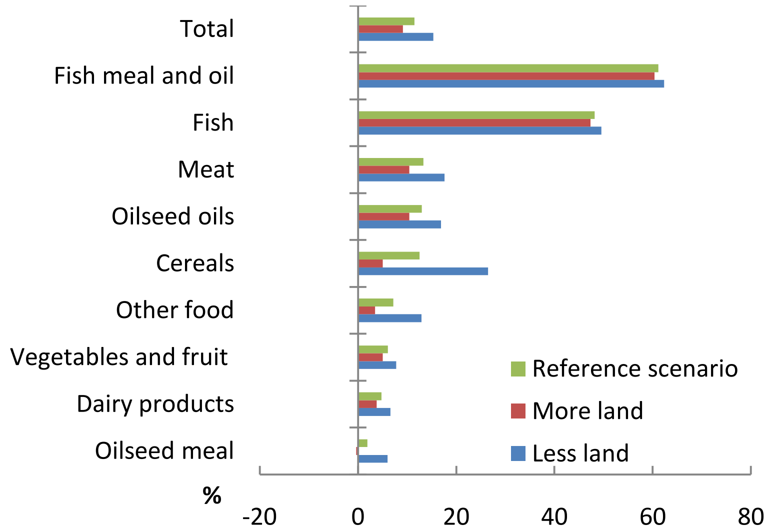
Land availability assumptions

Sensitivity around the land availability for cropping and pasture is considered by analysing the impact of 10 per cent more and less maximum land available for each region on prices, while leaving everything else in the model as specified in the reference scenario. Not every region is using up to this limit in the reference scenario. In these regions, an expansion in land availability will have no impact on the results, as no extra land will be utilised, while a reduction in land availability will only have an impact if the new limit is binding for that region.

In response to less land being available, the price of all commodity groups is higher than in the reference scenario. The real food price index in 2050 is 15.3 per cent higher than in 2007, higher than the reference scenario increase of 11.5 per cent (Figure C5). In response to less land available the real value of production of all commodity groups is lower than in the reference scenario, with the exception of fish and fish meal and oil concentrate, whose growth in the real value of production is slightly higher than the reference level. In 2050 the real value of agricultural production is 73 per cent higher than in 2007, lower than the rise in the reference scenario of 75 per cent (Figure C6).

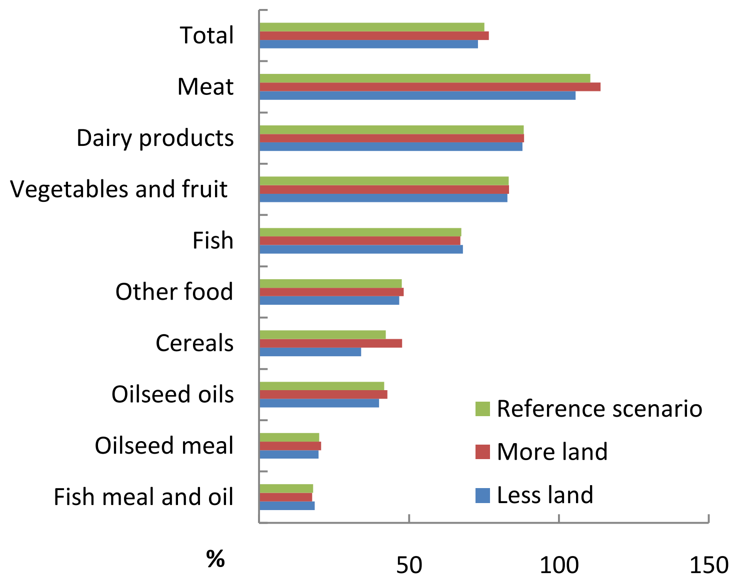
As a result of more land being available, the price of all commodity groups falls below the reference scenario, while oilseed meal prices fall slightly from the 2007 level, in real terms. The real food price index in 2050 is 9.2 per cent higher than in 2007, lower than the reference scenario rise of 11.5 per cent. In 2050 the real value of agricultural production (in 2007 US dollars) is approximately 77 per cent higher than in 2007, higher than the rise of 75 per cent in the reference scenario. Compared with the simulation of less land available, the magnitude of change in prices and real value of production is lower for all commodity groups, and for the total agrifood price.

Figure C5 Land availability sensitivity—world real price, change from 2007 to 2050



Data source: ABARES model output

Figure C6 Land availability sensitivity—world real value of production under higher and lower land availability, change from 2007 from 2050



Data source: ABARES model output

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