




REPORT

Australian agricultural emissions projections

To 2050



*Prepared for
Department of Industry, Innovation, Climate Change, Science, Research and
Tertiary Education
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1 Introduction

This report

This report presents projections of agricultural emissions to 2050. The report is structured as follows:

- The remainder of this introduction sets out key features of the projections approach and methodology
- Chapter 2 sets out the headline features of the projections, putting them in the context of recent history and summarising the key features of the composition of the projections
- Chapter 3 sets out further details of the projections, looking closely at the sector and subsector level
- Chapter 4 sets out in detail the activity level results from the core economic models used as a basis for the projections
- Chapter 5 sets out the results of sensitivity analysis around some of the key assumptions underlying the central projections
- Appendix A summarises the key features of the models used in the analysis
- Appendix B provides details of the input assumptions to those models
- Appendix C provides additional information around the sensitivity analysis.

Core projections methodology

Emissions coverage

This report covers the five major sets of agricultural emissions as set out in Australia's inventory, namely:

- Enteric fermentation
- Manure management
- Rice cultivation
- Agricultural soils
- Field burning of agricultural residues.

Projections presented here do not include prescribed burning of savannah and do not cover emissions from the Land Use, Land Use Change and Forestry (LULUCF) sector. Within this report, 'total agricultural emissions' refers to the sum of the above emissions categories.

Overall methodology

The methodology for providing the emissions projections presented here contains two main elements.

- First, a number of economic models (see below) are used to project ‘activity levels’ for the agricultural activities that involve the generation of greenhouse gas emissions. These projections are produced at a highly disaggregated level and include livestock numbers, crop production, fertiliser use and so on.
- Second, these activity levels provide an input to a detailed emissions calculation spreadsheet developed by the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE). This spreadsheet converts activity levels to emissions projections for each of the emission sectors and subsectors.

Use of AR4 emissions coefficients

Emissions projections presented here are reported in carbon dioxide equivalents (CO₂-e), calculated from global warming potentials (GWPs) published in the Intergovernmental Panel on Climate Change’s (IPCC’s) 2007 Fourth Assessment Report (AR4). Past agricultural projections reports have used GWPs from the IPCC’s Second Assessment Report (AR2).

Base year for projections

The base year for the projections is 2011, which was the latest full year for inventory data at the time of the commencement of the projections project. Each of the economic models (see below) was calibrated to the 2011 starting point implied by DIICCSRTE’s emissions spreadsheet and projections were generated from 2012 onwards.

Towards the end of the projections project, actual emissions values for 2012 and 2013 became available¹. Tables 2.3 and 3.1 present actual results for 2012. Other charts and tables present the original projections. It is important to note that the differences between actual values and the projections are very small (of the order of 1 per cent or less for the main emissions categories) and so are not detectable in charts.

Conformance with ABARES short term projections

At the direction of DIICCSRTE, projections to 2017-18 were further calibrated around projections for the agricultural sector contained in recent ABARES publications — in particular *Agricultural Commodities June Quarter 2013*² and *Agricultural Commodities March Quarter 2013*³.

¹ Emissions values are updated quarterly by DIICCSRTE and are available, when published, at www.climatechange.gov.au.

² http://data.daff.gov.au/data/warehouse/agcomd9abcc004/agcomd9abcc004201306/AgCommodities2013.No2_Ver1.0.0.pdf

³ http://data.daff.gov.au/data/warehouse/agcomd9abcc004/agcomd9abcc004201303/AgCommodities2013.No1_Ver1.0.0.pdf

Central reference and sensitivity analyses

The main set of emissions projections are around a ‘central reference case’, which essentially involves a business as usual set of projections for the agricultural sector. While this central reference case includes the carbon pricing mechanism it does not analyse its direct impacts on agriculture (as agriculture is not directly covered by the mechanism), although indirect impacts are implicitly accounted for through effects on input costs. Further, the projections do not estimate abatement from the carbon farming initiative.

Note that the central reference case does not account for drought or other stochastic climatic influences on agricultural output. This is important to keep in mind when interpreting the longer-term projections relative to recent history.

The analysis includes sensitivity analysis around a number of key exogenous modelling assumptions — reflecting the fact that there is inevitable uncertainty around some of these assumptions.

The models

Key models

The central reference case projections and the sensitivity analyses were developed using a suite of agricultural commodity models developed and maintained by the CIE. These models are:

- The Global Meat Industry (GMI) model of 10 meat products in 22 countries and regions;
- The Dairy model of the production and use of milk and dairy products in Australian states and territories as well as in Australia’s key competitor countries/regions; and
- The Grains model of wheat, barley, oilseeds, pulses and other coarse grain production and consumption in Australian states and territories as well as in Australia’s key markets and competitors.

In addition, spreadsheet models are used as supplementary tools for some agricultural products not formally included in the above models, including rice, cotton and sugarcane.

Input assumptions

Developing the projections with these economic models requires assumptions about a number of key model drivers. Details of these assumptions are set out in Appendix B. These assumptions are all based on plausible future outcomes within the agricultural sector.

While the central reference case has input assumptions based partly on history (which includes the average effects of drought) it does not incorporate assumptions based on extreme values. Thus, the future is an average expectation that does not account for the possibilities of extreme events.

In addition, for parts of the analysis, input assumptions were provided from the economy wide general equilibrium modelling produced by the Commonwealth Treasury. This was to ensure consistency in macroeconomic assumptions between the agricultural projections and projections for other sectors.

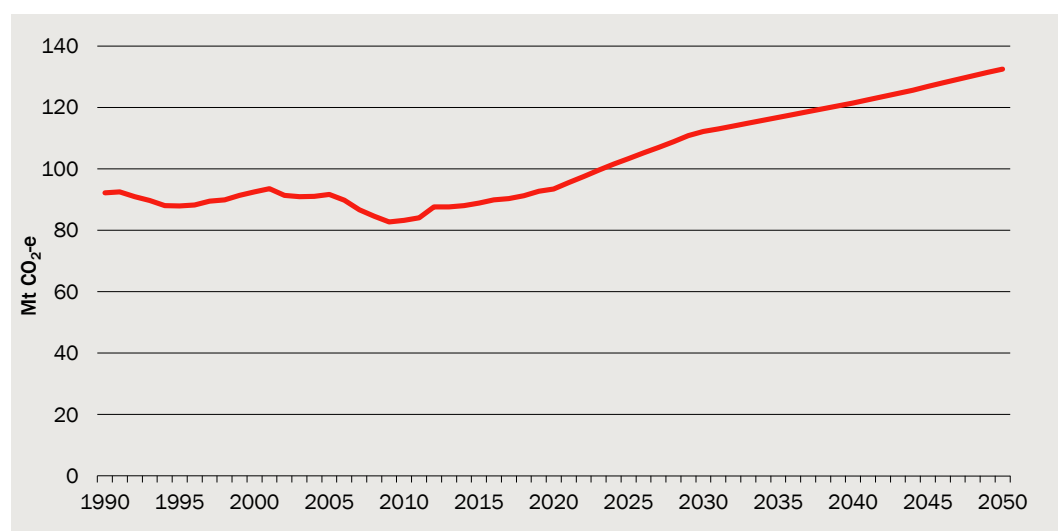
2 Key projection results

This chapter summarises the agricultural emissions projections at an aggregate level, noting the ways in which the projections vary from the historical record. It also summarises recent developments in agriculture, which helps explain the pattern of historical emissions and expected differences in the future.

Emissions projections in the context of history

Chart 2.1 shows total agricultural emissions from 1990 to 2050. Emissions from 1990 to 2011 are based on actual values, while emissions from 2011 to 2050 are projections.

2.1 Total agricultural emissions (excluding prescribed burning of savannas): 1990 to 2050



Note: All emissions are calculated using AR4 global warming potentials. Average emissions reported. While actual values for 2012 and 2013 are available, they are not used in this chart. The difference at the aggregate level is around 1 per cent and is not visually detectable

Data source: DIICSRTE emissions template, CIE projections

Historically, total agricultural emissions have not grown strongly. Between 1990 and 2011 they fell at an average rate of around 0.3 per cent a year. This was largely due to a decline in sheep numbers and drought conditions (see the discussion below).

In contrast, projected emissions are expected to grow at around 1.2 per cent a year to 2050. The reasons for these differences between the historical record and the projections trend can be understood by looking in more detail at the composition of agricultural emissions.

The broad composition of agricultural emissions

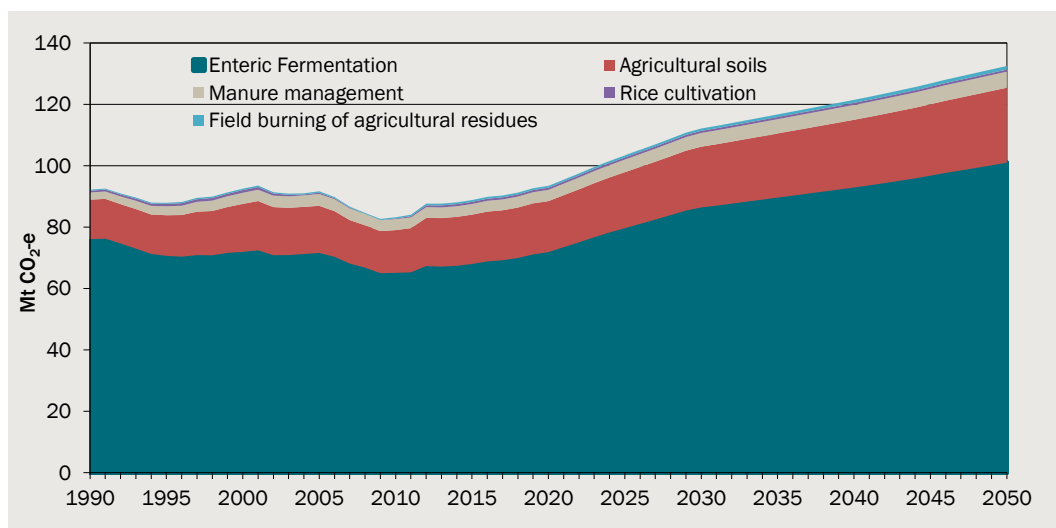
The agricultural emissions projected here consist of five broad components:

- Enteric fermentation — the emission of methane as a by-product of the digestive processes of cattle, sheep, pigs and other animals.
- Manure management — the emission of methane (and in some cases nitrous oxide) from the decomposition of organic matter in animal manure.
- Rice cultivation — methane generated during rice growing from the decomposition of residues and organic carbon in the soil as a consequence of flooding of the rice crop.
- Agricultural soils — the emission of nitrous oxide from soils as a result of microbial and chemical transformations, due in part to the application of nitrogen fertilisers.
- Field burning of agricultural residues — emission of a range of greenhouse gases largely as a result of stubble burning (for crops such as wheat) or burning of a sugar cane crop before harvest.

Emissions by broad sector

Chart 2.2 reports emissions for each of these sources from 1990 to 2050. Table 2.3 presents key values for the projections. This shows clearly that the main reason for the decline in total emissions to 2011 was the decline in emissions from enteric fermentation.

2.2 Emissions by broad sector 1990 to 2050



Note: All emissions are calculated using AR4 global warming potentials. Average emissions reported.

Data source: DIICSRTE emissions template, CIE projections

2.3 Emissions by broad sector

	1990	2012	2020	2030	2050
	Mt CO ₂ -e	Mt CO ₂ -e	Mt CO ₂ -e	Mt CO ₂ -e	Mt CO ₂ -e
Enteric fermentation	76.09	66.77	71.85	86.41	101.00
Manure management	2.34	3.47	3.67	4.49	5.22
Rice cultivation	0.58	0.60	0.70	0.70	0.70
Agricultural soils	12.86	14.84	16.63	19.80	24.43
Field burning of agricultural residues	0.32	0.50	0.60	0.74	1.16
Total	92.20	86.18	93.46	112.15	132.51

Note: All emissions are calculated using AR4 global warming potentials. Average emission reported. Results for 2012 are actual emissions.

Data source: DIICSRTE emissions template, CIE projections

Key outcomes and drivers

Table 2.4 summarises the key drivers — in terms of activity levels and in terms of economic drivers — for each of these categories of emissions.

For the majority of emissions (particularly enteric fermentation and manure management) the main activity driver is the number of livestock (head of cattle, sheep and so on) in either the meat industry or the dairy industry. Our economic modelling of these industries suggests that export demand will be a major determinant of future growth in livestock numbers. This is in turn mostly due to projected population and income growth in Asian economies.

2.4 Summary of emissions and key drivers

Emission type, growth and composition	Agricultural activity drivers	Economic driver
Enteric fermentation		
<p>77 per cent of agricultural emissions in 2020</p> <p>Emissions projected increase by 50 per cent between 2012 and 2050</p>	<p>Number of animals eg head of cattle, sheep etc. This is modelled within the CIE's GMI and Dairy models</p>	<p>Exports are a major focus of meat and dairy markets so population and income growth in trading partners are major drivers of meat and dairy product demand. Strong growth in this demand (particularly in Asia) is projected.</p> <p>Growth in cattle numbers is also determined by growth in the slaughter weight (for beef cattle) and milk yields for dairy cattle. These are projected to increase at historical rates.</p>
Manure management		
<p>4 per cent of agricultural emissions in 2020</p> <p>Expected to increase by 49 per cent between 2012 and 2050</p>	<p>Number of animals. Number of animals are projected using the CIEs GMI and Dairy models</p>	<p>Similar economic drivers to enteric fermentation — strongly growing export demand leading to increased meat and dairy production and therefore increases stock numbers.</p>
Rice cultivation		
<p>Less than 1 per cent of agricultural emissions in 2020</p> <p>Expected to increase by 17 per cent between 2012 and 2050</p>	<p>Area of rice planted. This is estimated using historical information and expectations about future water constraints</p>	<p>Largely driven by production constraints. Well established export markets but constraints on water availability limit overall production</p>
Agricultural soils		
<p>18 per cent of agricultural emissions in 2020</p> <p>Expected to increase by 56 per cent between 2012 and 2050</p>	<p>Fertiliser use in pastures and crops. This is modelled within the GMI, Dairy and Grains model and estimated for rice and sugar</p>	<p>Fertiliser use is directly related to total production which in turn is largely driven by export demand, which in turn depends on income and population growth among trading partners. Continued export growth is projected</p>
Field burning of agricultural residues		
<p>Less than 1 per cent of agricultural emissions</p> <p>Projected to increase by 113 per cent between 2012 and 2050</p>	<p>Production of grain, sugar, rice and other crops. Modelled within the Grains model, and estimated for rice and sugar.</p>	<p>Mostly driven by export demand which in turn depends on income and population growth among trading partners. Continued export growth is projected</p>

Source: CIE projections

Key point from the high level results

Several points emerge from these results.

- The decline in emissions to 2012 was largely a consequence of a decline in enteric fermentation emissions. As will be discussed in chapter 3, this was consequence of declines in sheep numbers. The reasons for this decline are described in more detail below.
- Emissions in other agricultural sectors have been constrained by a range of climatic outcomes, as described further below.
- These projections indicate that total agricultural emissions (excluding prescribed burning of savannas) will reach 93.46 Mt CO₂-e in 2020, 112.15 Mt CO₂-e in 2030 and 132.51 Mt CO₂-e in 2050. This is a growth rate of about 1.2 per cent a year for the projections period.
- The majority of emissions are from enteric fermentation, accounting for just over three quarters of emissions in most years.
- Enteric fermentation emissions are projected to grow at 1.16 per cent a year for the forecast period. Other emissions (with the exception of rice cultivation) are projected to grow slightly faster (just over 1.2 per cent for manure management and agricultural soils, and around 2.2 per cent for burning of agricultural residues).

Comparison with previous emissions projections

Because the current projections use AR4 global warming factors, it is impossible to compare current emission projections directly with the 2010 projections round (which used the AR2 factors). However, we can compare *growth rates* in emissions between the two rounds for 2012 to 2030 (see table 2.5).

The emissions growth rates in the current projections are slightly higher than previously. This is mainly due to a slightly higher growth rate in enteric fermentation emissions—in turn due to slightly higher growth rate in beef cattle and sheep numbers. This is itself due to slightly lower growth in slaughtering weights, and higher growth in sheepmeat demand.

2.5 Projected annual growth rate of agricultural emissions between 2012 and 2030

	Current round	the 2010 round
	%	%
Total agriculture	1.37	1.25
Enteric Fermentation	1.39	1.21
Manure Management	1.42	1.42
Rice Cultivation	0.75	0.40
Agricultural Soils	1.34	1.32
Field burning of agricultural residues	1.37	2.72

Source: DIICSRTE emissions template, CIE projections

Projections in the context of recent history

Projection drivers

In the long history of Australian agriculture is a strong ongoing tendency for increased production and yields. Essentially, as long as there are growing markets, agricultural supply has been able to respond to supply these markets. Historically, yields (and productivity more generally) have increased for a variety of reasons. We expect that this will generally remain true in the future. Most of our economic models focus on export markets, and the projects of population, incomes, trade barriers, production in competitor countries, when put through our models strongly suggest increasing agricultural output.

However, this feature of the projections appears at odds with recent history where emissions have declined in some years. This is due to the strong dependence of output on short term variations in climate — the discussion below points this out for a number of notable cases. Our projections, however, do not include forecasts for the next drought or other difficult conditions (such as floods). Rather, they present an average ‘business as usual’ outcome. The sensitivity analysis presented in chapter 5 provides some account of how variations in growth factors may influence total emissions.

Agriculture and weather

Changeable weather conditions are the primary driver of variations in agricultural output over time. Australia’s climate is very variable with great swings between drought and floods. Over the past 15 years significant areas of the country have suffered from one or both of these.

Millennium drought

Between 1997 and 2009 a long period of very dry conditions, now referred to as the Millennium Drought, was experienced across south-eastern Australia. Annual rainfall over this period was consistently well below average. 2003 and 2006 were particularly bad years. The drought eased at slightly different times for various areas of the south east of Australia at slightly different times. In Victoria, South Australia and Tasmania the dry conditions lasted into 2009 but areas of Queensland and New South Wales had rainfall closer to normal levels from 2007. Drought persisted in Western Australia through to 2010.

As a result of the drought, agricultural production over this period declined, especially for irrigated production. The poor conditions led to lower levels of production for crops, especially in 2003 and 2006, a decline in milk production from 2002 and slowing growth in cattle numbers and declines in cattle numbers in 2003. Over the period there was some adaptation as farmers sought ways to cope with the reduced water availability. For example, dairy farmers substituted bought in feed for irrigated pastures. Due to the adaptation during drought years, the use of water since the lifting of the drought has been

much lower than before the drought⁴. The industries most affected by the drought were rice (production fell by 99 per cent between 2001 and 2007) cotton (production declined by 23 per cent between 2001 and 2006) and dairy (declined 14 per cent between 2001 and 2006)⁵.

Flooding

In 2010-11 a particularly strong La Niña occurred and resulted in widespread increases in rainfall across Australia, and flooding in areas. Heavy rainfall and flooding in December 2010 and January 2011 in eastern Queensland, Western New South Wales and Victoria delayed harvests, lowered the quality of grains and led to crop losses and disease. Despite this, total winter crop production in 2010-11 was higher than 2009-10. Soil moisture and irrigation water supplies allowed for increased summer crop (sorghum, cotton and rice) planting and increased livestock numbers.

Flooding again occurred in late summer of 2011-12 in southern Queensland and northern New South Wales. The direct damage of the floods to summer crops, however, was very localised and generally the region benefited from the high rainfall.

Flooding affected areas in Queensland and New South Wales after Tropical Cyclone Oswald in early 2013. These areas account for large proportions of Australia's production of cattle, fruit and vegetables and sugar cane. The flooding directly and negatively affected a number of producers, however, operators in other areas of the states benefited from above average rainfall.

Sheep

Australia's sheep flock fell from 170 million head in 1990 to less than 77 million in 2008⁶. Rather than being driven by weather impacts, the changes in the sheep flock was due to market forces. Previously, most of the value in the sheep industry was realised through the sale of wool.

World demand for wool declined 20 per cent between 1995 and 2007⁷. Analysis suggests that this is due to:

- declining per capita incomes in countries facing recession (eg US and Europe)
- decline in the share of wool in key apparel categories

⁴ Kirby et al. 2012, *The economic impact of water reductions during the Millennium Drought in the Murray-Darling Basin*, Contributed paper prepared for presentation at the 56th AARES annual conference, Fremantle, Western Australia, February 7-10, 2012.

⁵ See Kirby et al. 2012.

⁶ Curtis 2009, *Recent changes in the Australian sheep industry (the disappearing flock)*, Department of Agriculture and Food, Western Australia, available at: <http://www.sheepcrc.org.au/information/publications/australias-declining-sheep-flock.php>

⁷ Poimena Analysis 2009, *Situation, outlook and opportunities for the supply and demand of apparel wool*, Report Prepared for the Cooperative Research Centre for Sheep Industry Innovation, available at: <http://www.sheepcrc.org.au/information/publications/australias-declining-sheep-flock.php>

- increased competition from other fibres in the apparel market.

In line with the decline in demand, global supply of wool has declined since 1991 – driven by lower wool prices and more attractive opportunities in other farming enterprises.

In the past few years, much more value has been derived from the sale of sheep meat. While some of the value of sheep meat has been realised through sustainable production, the remainder through depletion of the national flock. The number of producers with sheep also declined significantly after 1990.

Increased demand for sheep meat has been one driver of this shift. The number of lambs slaughtered has increased and the flock is now dominated by ewes as the focus shifts from wool production to sheep meat. The proportion of wethers in the flock has declined as they are turned off as either lambs or for live export. The share of sheep being sold for live export increased slightly between 2006 and 2008 (although the total number of sheep sold has not changed much).

3 *Sector and subsector emissions projections*

This chapter provides a further breakdown of agricultural emissions by sector and subsector focusing on the relative importance of different emission sources and differences between historical and projected growth rates in emissions.

Overview of emissions by sector and subsector

Table 3.1 summarises the emissions projections for each emissions sector and subsector of the Australian emissions inventory.

Several points emerge from this table.

- As already noted, enteric fermentation is the major source of emissions. Within this, most emissions come from grazing beef cattle (66 per cent in 2020, for example) followed by sheep (20 per cent in 2020, for example).
- Within manure management (which is around 4 per cent of total emissions), just over a third of emissions come from pigs, followed by grain fed cattle, poultry and dairy cattle.
- Agricultural soil emissions are 18 per cent of total agricultural emissions. Within this, indirect soil emissions are the largest component (accounting for 40 per cent in 2020). This is closely followed by direct soil emissions, and animal production related soil emissions.
- Rice cultivation accounts for less than 1 per cent of total agricultural emissions.
- The burning of agricultural residues account for less than 1 per cent of total agricultural emissions, with wheat accounting for over half of these.

3.1 Agricultural emissions by sector and subsector

	1990	2012	2020	2030	2050
	Mt CO ₂ -e	Mt CO ₂ -e	Mt CO ₂ -e	Mt CO ₂ -e	Mt CO ₂ -e
Enteric Fermentation	76.09	66.77	71.85	86.41	101.00
Cattle	46.45	53.87	57.08	69.84	83.06
Dairy Cattle	6.89	7.53	7.60	8.11	8.86
Grazing beef cattle	39.12	44.03	47.26	59.09	71.40
Grain fed cattle	0.44	2.30	2.21	2.63	2.80
Sheep	29.28	12.57	14.43	16.14	17.41
Swine	0.08	0.08	0.08	0.11	0.13
Other	0.28	0.25	0.26	0.33	0.39
Manure Management	2.34	3.47	3.67	4.49	5.22
Cattle	0.73	1.56	1.59	1.82	1.96
Dairy Cattle	0.51	0.56	0.58	0.62	0.68
Grazing beef cattle	0.02	0.02	0.03	0.03	0.04
Grain fed cattle	0.19	0.98	0.98	1.16	1.24
Sheep	0.01	0.00	0.00	0.00	0.00
Swine	1.27	1.30	1.35	1.75	2.07
Poultry	0.33	0.60	0.73	0.92	1.19
Other	0.00	0.00	0.00	0.00	0.00
Rice Cultivation	0.58	0.60	0.70	0.70	0.70
Agricultural Soils	12.86	14.84	16.63	19.80	24.43
Animal Production	4.69	3.60	4.05	4.80	5.55
Direct soil emissions	2.75	5.35	5.95	7.33	9.98
Indirect soil emissions	5.42	5.90	6.63	7.68	8.90
Field burning of agricultural residues	0.32	0.50	0.60	0.74	1.16
Wheat	0.12	0.25	0.23	0.30	0.52
Maize	0.01	0.01	0.01	0.02	0.03
Sugar Cane	0.08	0.05	0.06	0.06	0.06
Other	0.05	0.10	0.12	0.15	0.26
Rice	0.05	0.04	0.07	0.08	0.08
Pulse	0.02	0.05	0.09	0.11	0.18
Peanuts	0.00	0.00	0.00	0.00	0.00
Other Crops	0.00	0.01	0.02	0.02	0.03
Total	92.20	86.18	93.46	112.15	132.51

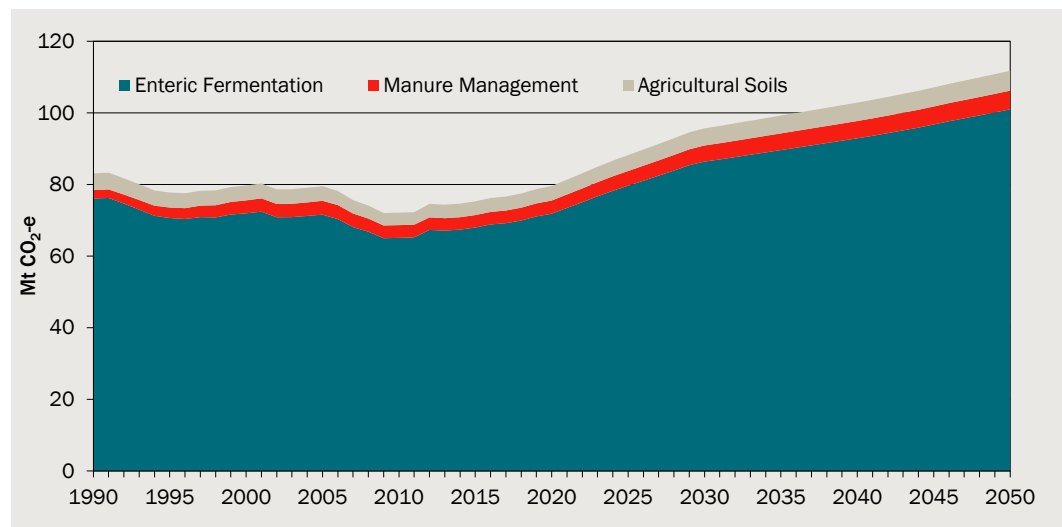
Note: All emissions are calculated using AR4 global warming potentials. Average emission reported. Results for 2012 are actual.

Data source: DIICSRTE emissions template, CIE projections

Livestock related emissions

Chart 3.2 summarises the history and projections for livestock related emissions. As already noted, enteric fermentation is the largest source of these. Variations in enteric fermentation emissions largely explain total changes in emissions. While these fell at around 0.6 per cent a year historically (to 2011) over the projection period they are expected to grow at around 1.15 per cent a year.

3.2 Livestock emissions



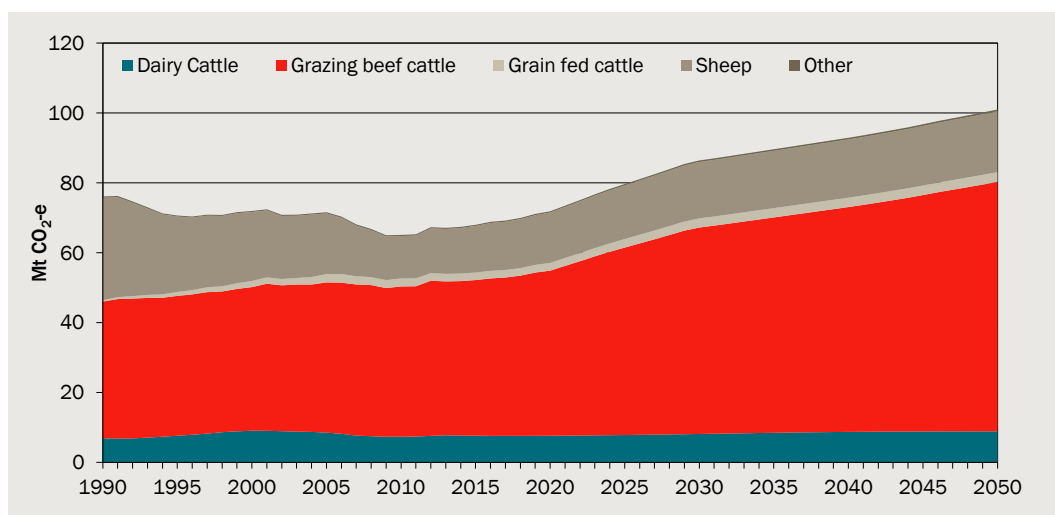
Note: All emissions are calculated using AR4 global warming potentials. Average emission reported.

Data source: DIICSRTE emissions template, CIE projections

Enteric fermentation

Chart 3.3 provides the history and projections for enteric fermentation emissions. This chart shows clearly that the reason for the historical decline in enteric fermentation emission was the decline in emission from sheep — other sources have tended to be constant or increase slightly over time.

3.3 Enteric fermentation



Note: Other includes swine and other

Data source: DIICSRTE emissions template, CIE projections

Historically, enteric fermentation from sheep declined at around 3.8 per cent a year. In contrast, this source is expected to increase at around 0.8 per cent a year over the forecast period. This is a consequence of an expected recovery in sheep numbers due to better wool prices and increased revenues from meat production.

Historically, enteric fermentation from grazing beef cattle increased at around 0.5 per cent a year. Some of this growth was constrained by drought (and flood) conditions. These emissions are projected to grow at just under 1.4 per cent a year over the forecast period. This is due largely to strong projections in beef exports, particularly to rapidly growing Asian economies. In addition, the projections do not incorporate the implications of potential future droughts.

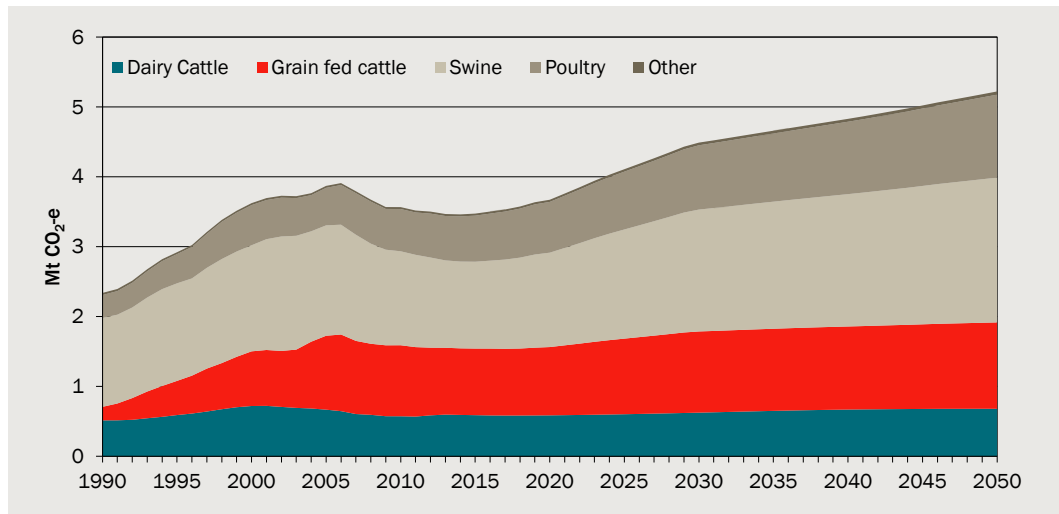
Enteric fermentation emissions from dairy cattle grew at around 0.4 per cent a year historically, and this is projected to continue at around 0.5 per cent a year over the forecast period.

Manure management

Chart 3.4 shows projections for livestock emissions related to manure management. The pattern for each of these components varies, particularly when compared with historical emissions.

For example, while emissions from grain fed beef grew rapidly historically (at just over 7 per cent a year) this is expected to stabilise at around 0.8 per cent a year over the projections period. In contrast, emissions associated with dairy cattle are expected to return to historic growth rates (0.5 per cent).

3.4 Manure management



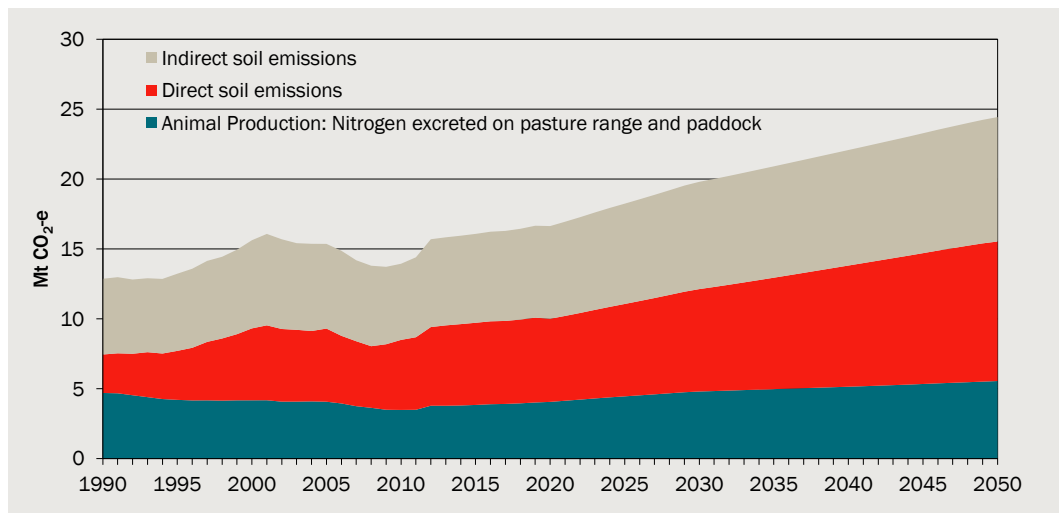
Note: Other includes grazing beef cattle, sheep and other

Data source: DIICSRTE emissions template, CIE projections

Agricultural soils

Chart 3.5 summarises emissions from agricultural soils. These relate to both animal and crop production and are each expected to grow at roughly the same rate as historically over the forecast period.

3.5 Agricultural soils



Note: All emissions are calculated using AR4 global warming potentials. Average emission reported.

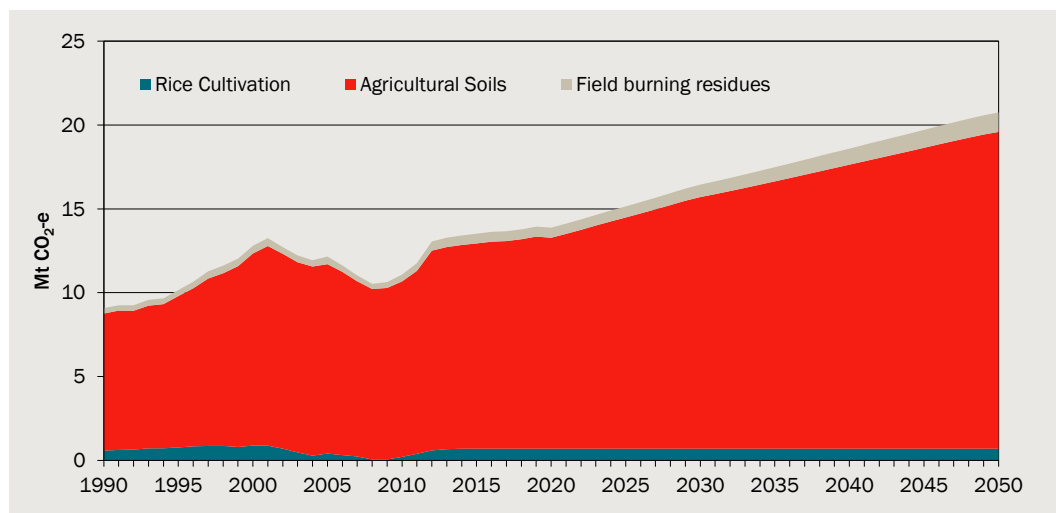
Data source: DIICSRTE emissions template, CIE projections

Crop emissions

Chart 3.6 summarises crop emissions. These mostly arise through agricultural soils and historically have been greatly influenced by drought. The effect of the millennial drought

is very clear in the historical values. Nevertheless, they are expected to grow at slightly less than the overall historic average over the projections period (1.3 per cent a year, compared with 1.4 per cent a year historically).

3.6 Crop emissions

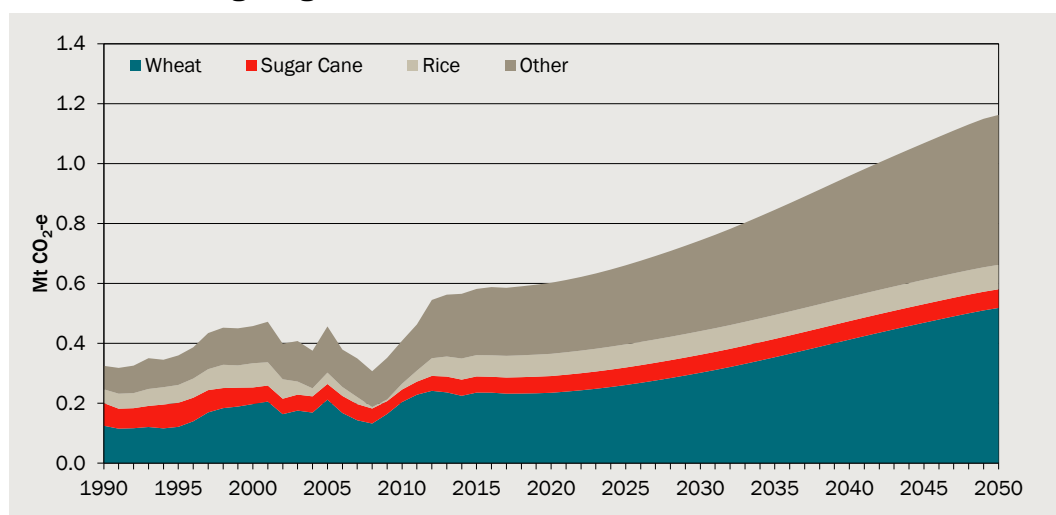


Note: All emissions are calculated using AR4 global warming potentials. Average emission reported.

Data source: DIICSRTE emissions template, CIE projections

Chart 3.7 shows emission from field burning of agricultural residues. These are due mostly to wheat and a combination of other crops. As before, the effects of drought are very evident in the historical emissions. Nevertheless, future emissions growth for wheat (around 2.5 per cent a year) is very similar to average historical growth (of around 2.3 per cent a year). The same overall result is true for other crops. Abstracting from the effects of drought, future growth is projected to be similar to historical growth.

3.7 Field burning of agricultural residues



Note: Other includes maize, pulses, peanuts and other crops

Data source: DIICSRTE emissions template, CIE projections

4 *Model based results*

Emissions projections are a combination of activity level forecasts (variables such as livestock numbers, area harvested and fertiliser application) along with the emissions associated with those activity level factors.

This chapter presents modelled activity level results in detail, working through the core outcomes and drivers of each of the economic models used for the projections analysis.

Meat industries

Basic economic mechanisms

For the meat industry, it is the number of animals that essentially determines emissions. In the GMI model, this is in turn determined by two factors:

- the growth in demand for Australian meat products (which is largely driven by export demand, which in turn depends on population and income growth in our trading partners); and
- the slaughter weight of the animals concerned — a higher slaughter weight, for example, means that a given meat demand is associated with fewer head of stock.

Slaughter weight growth

For a given growth in demand, the resulting number of animals required to meet this demand depends on the projected growth in the slaughter weight of the animals. The growth in slaughter weights is an exogenous variable in the GMI model and is largely determined according to historical trends. (Slaughter weight growth assumptions are set out in table B.3). For this round of projections, slaughter weight growth to 2018 was set to be consistent with ABARES projections. For 2019-20, we have assumed the average of the previous 8 years (2011 to 2018). For 2021-30 we assumed the average of the 10 year period from 2008 to 2018.

Slaughter weights tend to steadily increase over time for a variety of reasons — but are particularly related to improved genetics and husbandry of the livestock.

Demand for Australia meat products

The overall demand for Australian meat products is determined by three broad sets of factors:

- supply conditions and productivity growth in Australia, which determine how the Australian industry can respond to increases in demand or the extent to which the industry can competitively displace other sources of supply;
- supply conditions and productivity growth in countries that compete with Australia in export markets (including the rapidly growing South American countries in the case of beef); and
- growth in income and population in consuming countries
 - broadly, population growth will lead to an increase in total consumption for a given level of per capita consumption, while income growth will tend to lead to increases in per capita consumption.

Appendix B discusses the underlying exogenous assumption in detail.

Meat production

Table 4.1 summarises the central reference case projection of meat production in Australia. Beef, sheep, pig and poultry meat production is expected to grow by 1.6, 1.3, 1.5 and 2.2 per cent per annum, respectively.

4.1 Projected meat production: the central reference case

	2012	2013	2014	2015	2020	2030	2050	CAGR
	kt	kt	kt	kt	kt	kt	kt	%
Beef								
Grass fed	1654.4	1747.5	1804.1	1804.1	1940.6	2494.9	3141.5	1.7
Grain fed	364.3	382.4	392.3	389.5	404.9	498.7	566.7	1.2
Live	96.5	100.1	102.5	103.1	111.5	138.1	177.7	1.6
Sheep								
Sheepmeat	539.0	643.4	577.4	588.5	652.1	760.2	862.4	1.2
Live	63.1	79.7	70.3	72.5	85.2	106.9	133.1	2.0
Pigs								
	350.5	348.1	341.2	346.4	388.6	507.8	621.1	1.5
Poultry								
	1029.8	1050.5	1081.2	1111.7	1288.4	1702.3	2315.6	2.2

Source: CIE GMI model simulation

Meat production growth is mainly driven by growth in exports. As shown in table 4.2, meat exports are expected to grow faster than total production. As a result, export share of total production increases for all meat products, for example, from 68.2 per cent in 2012 to 75.5 per cent in 2050 for beef, from 64.4 per cent in 2012 to 74.3 per cent in 2050 for sheepmeat.

4.2 Projected meat exports: the central reference case

	2012	2013	2014	2015	2020	2030	2050	CAGR
	kt	kt	kt	kt	kt	kt	kt	%
Beef								
Grass fed	1129.0	1221.8	1266.6	1265.6	1391.6	1911.0	2506.7	2.1
Grain fed	217.5	233.1	236.7	229.3	221.3	280.1	250.5	0.4
Live	96.5	100.1	102.5	103.1	111.5	138.1	177.7	1.6
Sheep								
Sheepmeat	324.6	412.5	360.6	369.1	425.0	516.3	606.6	1.7
Live	63.1	79.7	70.3	72.5	85.2	106.9	133.1	2.0
Pigs								
	25.7	26.4	25.5	27.1	37.3	62.6	102.3	3.7
Poultry								
	24.2	31.1	37.0	44.2	91.0	220.8	383.0	7.5

Source: CIE GMI model simulation

However, because of the prolonged global economic downturn, export growth is projected to be lower than that in the 2010 round of projections. In conjunction with the lower level in the base year, the projected production of all meat products is smaller in relevant years than the previous projections.

Number of cattle

Table 4.3 summarises the projected beef cattle numbers that result from expected meat demand combined with the growth in slaughter weight. Grass fed cattle numbers are projected to fall initially before increasing to 24.8 million by 2015, to 26.52 million by 2020 and to 39.71 million by 2050. This represents an average annual growth rate of 1.27 per cent between 2012 and 2050.

Grain fed cattle numbers are projected to increase to 1.13 million by 2015, to 1.17 million by 2020 and to 1.46 million by 2050. This represents an average annual growth rate of 0.64 per cent between 2012 and 2050.

Comparing with the 2010 round projection, the current projections for cattle numbers are slightly higher in relevant years. This is due to higher base level of cattle numbers and the assumed slightly lower slaughter weight growth.

4.3 Projected beef cattle numbers: the central reference case

	2012	2013	2014	2015	2020	2030	2050
	million	million	million	million	million	million	million
Grass fed cattle							
NSW/ACT	5.04	4.99	4.97	5.09	5.44	6.73	8.15
TAS	0.46	0.46	0.46	0.47	0.50	0.62	0.75
WA - South West	1.03	1.02	1.02	1.04	1.11	1.38	1.67
WA – Pilbara	0.39	0.39	0.39	0.40	0.43	0.53	0.64
WA – Kimberley	0.48	0.48	0.48	0.49	0.52	0.65	0.78
SA	1.05	1.04	1.04	1.06	1.14	1.41	1.70
VIC	2.24	2.22	2.21	2.27	2.42	3.00	3.63
QLD	11.67	11.55	11.51	11.79	12.60	15.59	18.87
NT	2.18	2.16	2.15	2.20	2.35	2.91	3.52
Total	24.55	24.31	24.23	24.80	26.52	32.80	39.71
Grain fed cattle							
NSW/ACT	0.30	0.30	0.30	0.30	0.31	0.36	0.39
TAS	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WA	0.03	0.02	0.02	0.02	0.03	0.03	0.03
SA	0.05	0.05	0.05	0.05	0.05	0.06	0.06
VIC	0.10	0.10	0.10	0.10	0.10	0.12	0.13
QLD	0.67	0.66	0.65	0.66	0.68	0.80	0.85
NT	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.14	1.13	1.11	1.13	1.17	1.37	1.46

Source: CIE GMI model simulation

Sheep, pig and poultry numbers

Table 4.4 summarises the projected numbers for sheep, pigs and poultry in selected years.

Sheep numbers are projected to fall in 2013 and 2014 before rising to 78.63 million in 2015, 84.19 million in 2020 and 101.16 million in 2050. The average annual growth rate between 2012 and 2050 is 0.78 per cent.

Comparing with the 2010 round of projections, the current projections of sheep numbers are higher – 15.87 per cent higher in 2030. This is due to higher base level – 4.1 per cent higher in 2012, and higher growth rate between 2012 and 2030 which reflects the higher growth rate in sheepmeat demand during the same period.

Pig numbers are projected to fall between 2013 and 2015, and to increase to 2.34 million by 2020 and to 3.55 million by 2050. The average annual growth rate between 2012 and 2050 is 0.78 per cent.

4.4 Projected sheep, pig and poultry numbers: the central reference case

	2012	2013	2014	2015	2020	2030	2050
	million	million	million	million	million	million	million
Sheep							
NSW/ACT	27.69	27.42	27.11	28.91	30.96	34.44	37.20
TAS	2.42	2.39	2.36	2.52	2.70	3.00	3.24
WA	14.42	14.28	14.12	15.06	16.12	17.94	19.37
SA	11.34	11.23	11.10	11.84	12.68	14.11	15.23
VIC	15.67	15.52	15.34	16.36	17.52	19.49	21.05
QLD	3.76	3.73	3.68	3.93	4.21	4.68	5.06
NT	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	75.31	74.57	73.73	78.63	84.19	93.66	101.16
Pigs							
NSW/ACT	0.50	0.50	0.49	0.49	0.54	0.69	0.82
TAS	0.01	0.01	0.01	0.01	0.01	0.02	0.02
WA	0.24	0.24	0.23	0.24	0.26	0.33	0.39
SA	0.33	0.32	0.32	0.32	0.35	0.45	0.54
VIC	0.52	0.52	0.51	0.51	0.57	0.72	0.86
QLD	0.55	0.55	0.54	0.54	0.60	0.77	0.91
NT	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2.16	2.14	2.10	2.12	2.34	2.98	3.55
Poultry							
NSW/ACT	37.97	38.39	39.17	39.95	44.66	56.07	72.49
TAS	1.24	1.26	1.28	1.31	1.46	1.83	2.37
WA	10.47	10.59	10.80	11.02	12.32	15.46	19.99
SA	6.95	7.03	7.17	7.31	8.18	10.27	13.27
VIC	22.43	22.68	23.14	23.60	26.38	33.13	42.83
QLD	19.86	20.08	20.49	20.89	23.36	29.33	37.91
NT	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	98.91	100.01	102.06	104.08	116.36	146.09	188.87

Source: CIE GMI model simulation

Compared with the 2010 round of projections, the current projections of pig numbers are lower – 6.58 per cent lower in 2030. This is mainly due to lower base level – 6.09 per cent lower in 2012.

Poultry numbers are projected to increase continuously, to 104 million by 2015, to 116.36 million by 2020, and to 188.87 million by 2050. This represents an average annual growth rate of 1.72 per cent between 2012 and 2050.

Despite higher base value than the previous round projections (4.46 per cent higher in 2012), the projected poultry number in 2030 is only 1.54 per cent higher than previous project, due to slower growth between 2012 and 2030.

Dairy industry

As in the case of meat industries, emissions from dairy activities depend upon livestock numbers which themselves are determined by the demand for milk and milk products and assumptions about milk production per cow.

Production of milk and milk products

Table 4.5 shows projected milk production by state in selected years. Overall, milk production is expected to grow at 2.2 per cent per annum between 2012 and 2050.

The annual growth rate between 2012 and 2030 is 2 per cent, lower than the 2.7 per cent projected in the 2010 round. The lower growth rate from a lower base – 9.84 per cent lower in 2012 – lead to even lower level in the future – 17.45 per cent in 2030 – than the previous projections.

4.5 Projected milk production by state: the central reference case

	2012	2013	2014	2015	2020	2030	2050	CAGR
	million lt	million lt	million lt	million lt	million lt	million lt	million lt	%
NSW	1086.3	1065.3	1083.1	1107.3	1161.5	1460.0	2124.4	1.8
VIC	6213.4	6063.4	6216.3	6407.9	6935.9	9193.4	15489.5	2.4
QLD	484.6	469.6	475.8	485.5	503.7	615.0	883.9	1.6
SA	570.0	548.1	558.9	573.9	604.2	771.6	1150.7	1.9
WA	337.7	333.0	338.8	346.6	365.5	462.8	680.1	1.9
TAS	788.1	760.3	775.9	796.9	843.1	1092.8	1699.2	2.0
Total	9480.1	9239.7	9448.8	9718.2	10413.8	13595.7	22027.9	2.2

Source: CIE Dairy model simulation

4.6 Projected use of Australian milk, index of quantity: central reference case

	2012	2013	2014	2015	2020	2030	2050	CAGR
Domestic								
Fresh	100.0	100.4	101.4	102.6	107.7	120.6	140.7	0.9
UHT	100.0	101.3	102.1	102.8	107.3	115.5	120.0	0.5
Manufactured	100.0	100.5	101.3	102.2	106.5	117.9	137.7	0.8
Exports								
UHT	100.0	81.4	88.9	100.9	126.9	333.7	1914.4	8.1
Manufactured	100.0	90.8	96.4	103.9	119.4	207.7	448.6	4.0

Source: CIE Dairy model simulation

The lower growth rate of milk production in the current round of projections is caused by the lower growth in exports. As with other Australian agricultural projects, the dairy industry is highly dependent on foreign market for its growth. However, because of the economic difficulties in the world, dairy exports are projected to fall from 2012 to 2014 before rising from 2015 onwards (table 4.6). As a result, the projected annual growth rate between 2012 and 2030 is 6.9 per cent for UHT milk and 4.1 per cent for manufactured

dairy products, 2.7 and 1.4 percentage points, respectively, lower than the growth rates in the previous round projections.

Dairy cattle numbers

Table 4.7 reports projected dairy cattle numbers by state in selected years. The total number of dairy cattle is expected to reach 2.87 million by 2030 and 3.11 million by 2050. This represents a growth rate of 0.3 per cent per annum between 2012 and 2030 and between 2030 and 2050. This growth rate is slightly lower than that in the 2010 round projections.

4.7 Projected dairy cattle numbers by state: the central reference case

	2012	2013	2014	2015	2020	2030	2050	CAGR
	'000 head	'000 head	'000 head	'000 head	'000 head	'000 head	'000 head	%
NSW/ACT	347	346	345	337	331	342	335	-0.1
TAS	237	233	233	228	227	241	252	0.2
WA	120	120	120	117	116	121	119	0.0
SA	152	149	148	146	144	151	151	0.0
VIC	1706	1696	1704	1679	1703	1852	2100	0.5
QLD	173	170	169	165	160	161	155	-0.3
NT	0	0	0	0	0	0	0	0.0
Total	2733	2714	2719	2672	2681	2867	3113	0.3

Source: CIE Dairy model simulation

The dairy cattle number is 7.1 per cent lower in 2012 and will be 6.22 per cent lower in 2030 than those in the previous round projections. Therefore the majority of the difference between the two rounds of projections is the difference in the base number.

Grain industries

Along with seasonal conditions, Australian grain output is largely determined by export demands. This means that it is influenced by income and population growth in Australia's trading partners.

Grain output

Table 4.8 reports projected grain projection in selected years. Total wheat production is projected to reach 25.9 million tonnes by 2020, some 13.6 per cent lower than the level in 2012, 33.6 million tonnes by 2030 and 57.2 million tonnes by 2050. This represents an average annual growth of 0.59 per cent between 2012 and 2030, and of 1.71 per cent between 2012 and 2050.

4.8 Projected grain production: the central reference case

	2012	2013	2014	2015	2020	2030	2050	CAGR
	Kt	Kt	Kt	Kt	Kt	Kt	Kt	%
Wheat production								
NSW/ ACT	8550	6172	7319	7649	7406	9641	16567	1.76
TAS	32	23	27	28	28	36	61	1.70
WA	11092	8277	9570	9679	9625	12389	20872	1.68
SA	4553	3297	3873	3857	3916	5054	8588	1.68
VIC	3919	2812	3329	3411	3362	4362	7451	1.70
QLD	1880	1322	1588	1662	1599	2091	3641	1.75
NT	0	0	0	0	0	0	0	
Total	30027	21903	25705	26286	25937	33572	57179	1.71
Barley production								
NSW/ ACT	1619	1436	1473	1681	1858	2416	4285	2.59
TAS	25	22	22	25	28	36	64	2.55
WA	2532	2324	2318	2560	2914	3747	6524	2.52
SA	2113	1881	1908	2073	2416	3122	5499	2.55
VIC	1775	1564	1602	1791	2019	2619	4626	2.55
QLD	164	141	147	168	185	241	434	2.60
NT	0	0	0	0	0	0	0	
Total	8228	7368	7471	8298	9420	12182	21433	2.55
Other coarse grain								
Maize	419	447	447	506	492	628	1007	2.33
Oats	1505	1645	1616	1799	1779	2255	3566	2.30
Sorghum	2330	2465	2474	2806	2720	3477	5600	2.33
Triticale	577	625	618	688	680	863	1372	2.30
Millet	25	27	27	30	29	37	59	2.30
Rye	19	21	21	23	23	29	46	2.30

Source: CIE Grains model simulations

Comparing with the 2010 round of projections, despite a 33.2 per cent higher base level of wheat production in 2012, the lower growth rate leads to a 14.8 per cent lower output in 2030.

Barley production is projected to fall in 2013 and to recover to the 2012 level by 2015, and to reach 12.2 million tonnes by 2030 and 21.4 million tonnes by 2050. The average annual growth rate is 2.2 per cent between 2012 and 2030 and 2.55 per cent between 2012 and 2050.

Other coarse grains are projected to reach 7.3 million tonnes by 2030 and 11.7 million tonnes by 2050. This represents an average annual growth rate of 2.3 per cent between 2012 and 2050.

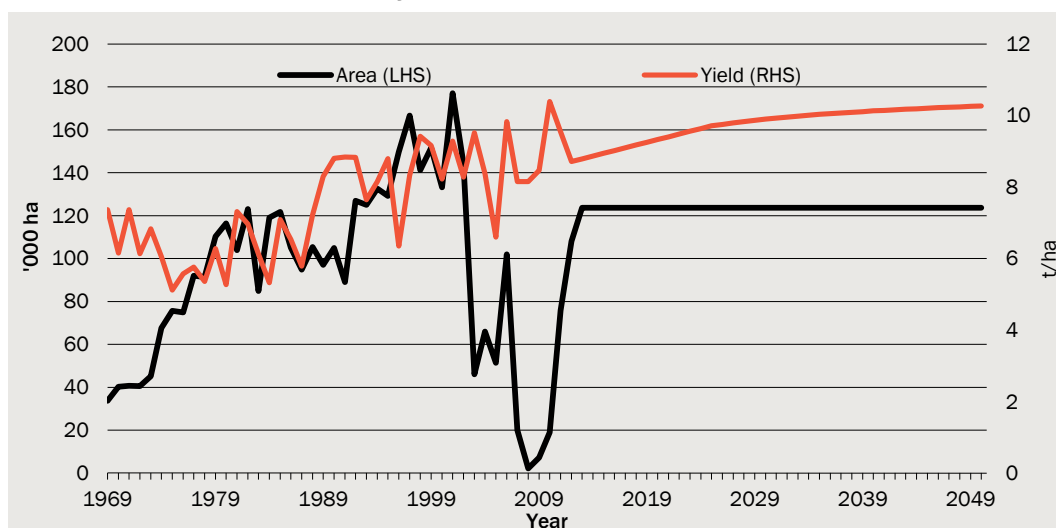
Other crops

Activities for other crops are estimated using simple spread sheet models. They are mainly assumed to follow historical trends.

Rice

Chart 4.9 reports the historical data of rice cultivation area and yield in Australia from 1969 to 2012 and our assumptions about their future values to 2050. The effect of drought is clearly evident in the historical record (accounting for the large reduction in area around 2000).

4.9 Rice cultivation area and yield



Data source: ABARES Australian Commodity Statistics; DIICCRSTE Inventory data; CIE assumptions

The area of rice cultivation increased up to 2002 when it fell sharply due to the drought. It has started to recover in the past couple of years. We assume the area will recover further with the drought conditions easing. However, we do not expect the area will fully return to pre-drought levels due to the strong likelihood of lower water allocations. Instead, we assume the cultivation area will stay at the average levels seen in the 1980s and 1990s. This reflects a reduction of 30 per cent from the peak level in 2001, and a reduction of almost 20 per cent from the average level between 1996 and 2001. This long term flat assumption for the area of rice cultivated area is the same as that in the 2010 round projections.

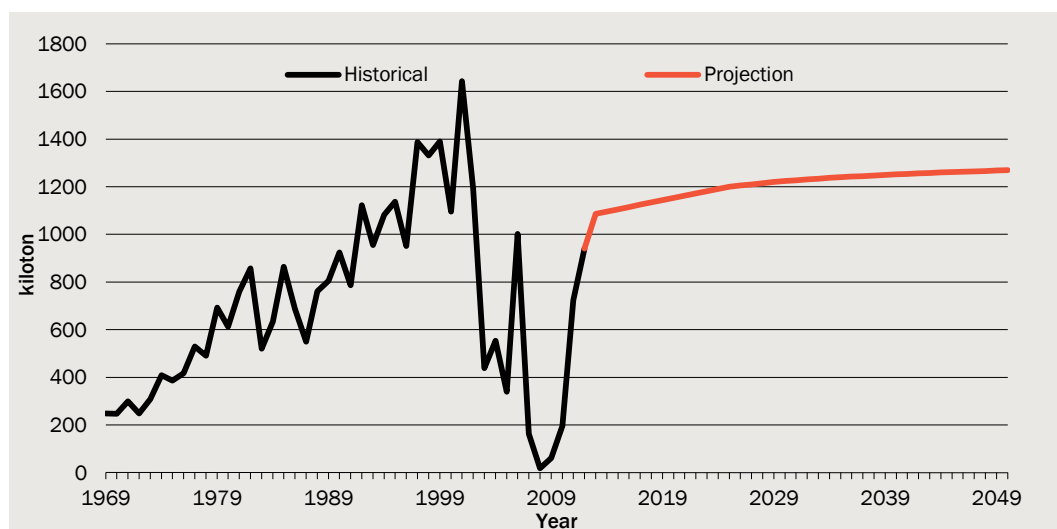
Despite fluctuations over time, rice yields have been trending upwards. The average annual increment in yield is about 76.9 kg per ha. We assume this trend continues into the future. With this assumption, the yield in 2050 is projected to be 10.27 ton/ha, slightly lower than the record level of 10.39 ton/ha in 2010.

Compared with the 2010 projection round, rice yields have improved significantly in the past few years. For example, they were 9.2 per cent higher than previously assumed for 2009, 27.4 per cent, 15.9 per cent and 4.9 per cent higher for 2010, 2011 and 2012,

respectively. Consequently, the assumed yield in the current round is 4.5 per cent higher than previously assumed for 2020 and 2.2 per cent higher for 2030.

With the above assumptions, rice production is projected to reach 1.22 million tonnes by 2030 and 1.27 million tonnes by 2050 (chart 4.10). Compared with the 2010 projection round, the current projections for rice production is 4.5 per cent higher for 2020 and 2.2 per cent higher for 2030. This is purely due to the higher yield assumptions based on the recent improvements in yield.

4.10 Rice production



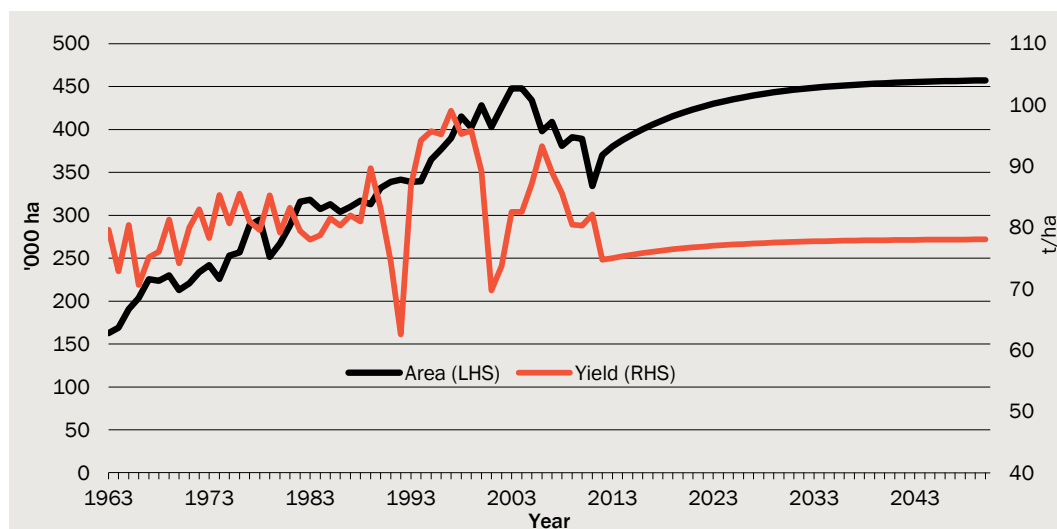
Data source: ABARES Australian Commodity Statistics; DIICRSTE Inventory data; CIE estimates

Sugar

Chart 4.11 reports the historical data of sugarcane cultivation area and cane yield in Australia from 1963 to 2012, and our assumptions about their future values to 2050.

Sugarcane area had been growing at a rate of 2.1 per cent per annum until 2003 when it started falling. However, it did not fall as much as the rice area. This is due to higher world demand for biofuel in the past few years. The long run trend between 1963 and 2012 has been about 1.69 per cent growth per annum. We assume the growth rate in sugarcane area will fall gradually after 2015. More specifically, the growth rate will fall by 10 per cent each year, that is, 1.69 per cent in 2015, 1.52 per cent in 2016, 1.37 per cent in 2017, and so on.

4.11 Sugarcane cultivation area and cane yield



Data source: ABARES Australian Commodity Statistics; DIICRSTE Inventory data; CIE assumptions

Compared with the 2010 projection round, the current assumption for sugarcane area is lower. This is due to a lower base and an assumed slowing growth rate in area. For example, the area was 17.5 and 11.7 per cent lower than previously assumed for 2011 and 2012, respectively. ABARES projected 387 770 ha of sugarcane in 2014,⁸ 13.4 per cent lower than the assumed area in the 2010 round. Consequently, the current assumption about sugarcane area is 12.5 per cent and 16.5 per cent lower than previously assumed for 2020 and 2030.

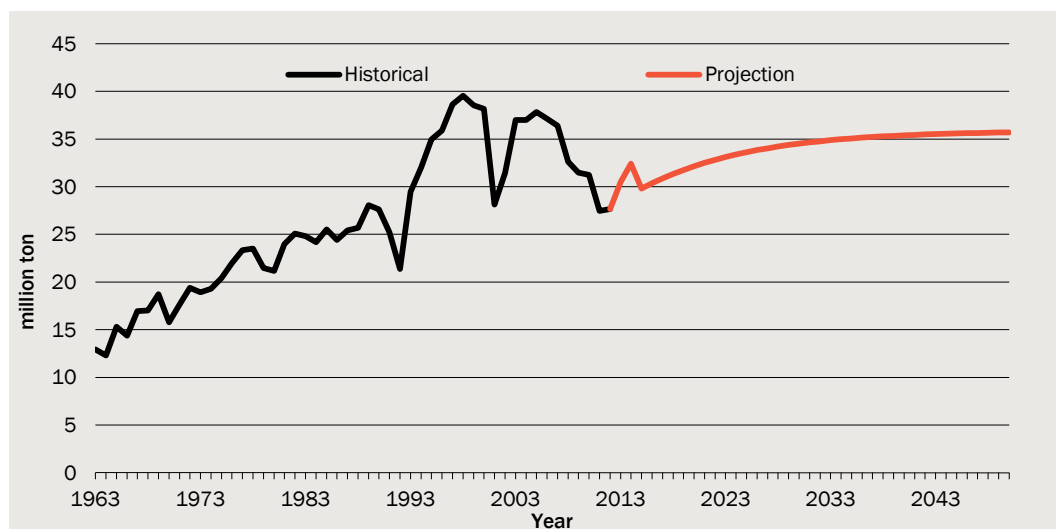
The long trend growth in cane yield is 0.37 per cent per annum. We assume the growth rate will fall gradually after 2015 in the same pattern as the assumed growth rate in sugarcane area.

The current assumption for sugarcane yield is also lower than the 2010 projection round. This is also due to worse than expected performance in yield in the past years. For example, the yield in 2009 through to 2012 was 2.5–16.2 per cent lower than previously assumed. With this lower base level, the assumed yield in 2020 and 2030 is 16 per cent and 17.1 per cent lower than previously assumed.

With these assumptions, it is projected that the cane crushed will reach 34.5 million tonnes by 2030 and 35.7 million tonnes by 2050 (chart 4.12). Because of the lower assumptions of area and yield as explained above, the currently projected crushed sugarcane is 26.5 per cent lower than the previous projection for 2020 and 30.8 per cent lower for 2030.

⁸http://data.daff.gov.au/data/warehouse/agcomd9abcc004/agcomd9abcc004201306/AgCommodities2013.No2_Ver1.0.0.pdf

4.12 Sugarcane crushed

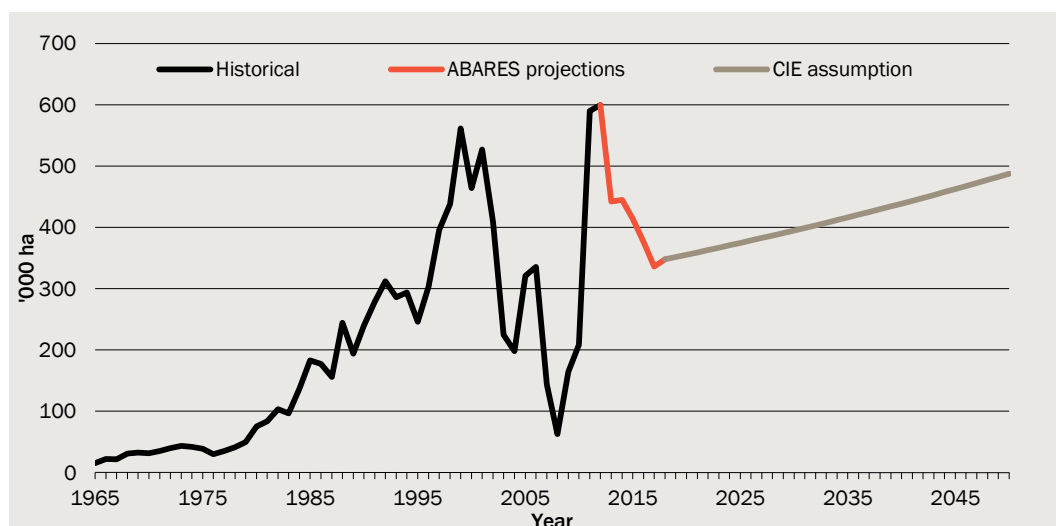


Data source: ABARES Australian Commodity Statistics; DIICCRSTE Inventory data; CIE estimates

Cotton

As shown in chart 4.13, the area of cotton cultivation dropped sharply between 2000 and 2008, and then quickly recovered in 2010-12. We adopt the ABARES projection of falling cotton area between 2012 and 2017 and a marginal recovery in 2018 and then assume area will grow by the average grow rate of 1.1 per cent per annum. It is assumed that the cotton area will reach 487 500 ha by 2050, about 20 per cent lower than the historical record level.

4.13 Cotton area



Data source: ABARES Australian Commodity Statistics; DIICCRSTE Inventory data; CIE assumptions

In the 2010 projection round we assumed that the cotton area would recover from the 2008 low and stabilise at 435 000ha in 2016. The good rainfall in 2011 and 2012 brought dramatic increase in cotton area – from 208 300ha in 2010 to 590 000ha in 2011 and

600 000ha in 2012. This short term jump is not sustainable and ABARES projected falling area until 2017. The ABARES projections of cotton harvest area in 2017 and 2018 will be 22.7 per cent and 20 per cent, respectively, lower than that assumed in our 2010 round projections. With the assumption of gradual growth, the current projection of cotton area is 18.3 per cent lower than the previous round projections for 2020 and 9.2 per cent lower for 2030.

Fertiliser use

Fertiliser use in pasture is estimated using the simulation results from the GMI model. Total fertiliser use is determined by meat production, grazing animal numbers and fertiliser use efficiency in pasture land.

In the CIE Grains model, fertiliser use is associated with all cropping activities. Fertiliser is combined with other inputs to determine the total productive capacity of a farm. Fertiliser use will depend on both the total output of grains, total area used for grain production as well as ongoing productivity improvement in the use of fertilisers.

Fertiliser uses for other crops are estimated in a way similar to the projection of grain fertiliser use. They are determined by the total output of the crops, total areas used for the production and the productivity improvement in the use of fertilisers.

Table 4.14 reports the projected fertiliser use in selected years. Total fertiliser use is estimated to reach 1420 Kt by 2030 and 1797 Kt by 2050. It represents an average growth rate of 1.3 per cent per annum.

Compared with the 2010 projections round, the current projection is 14.1 per cent higher for 2020 and 23.8 per cent higher for 2030. This is due to higher base level – 22.6 per cent higher in 2011 – and relatively slower growth rate between 2011 and 2020.

4.14 Projected fertiliser use – the central reference case

	2012	2013	2014	2015	2020	2030	2050	CAGR
	Kt	Kt	Kt	Kt	Kt	Kt	Kt	%
Irrigated pasture	25.9	27.4	27.4	27.6	29.8	36.8	43.9	1.4
Irrigated crops	25.2	25.3	25.4	25.6	26.7	32.1	48.6	1.7
Non-irrigated pasture	518.1	547.5	547.0	550.2	594.0	734.5	876.1	1.4
Non-irrigated crops	280.9	282.0	283.2	284.8	297.3	357.9	541.3	1.7
Sugar	64.4	70.1	73.5	66.8	69.1	71.3	72.4	0.3
Cotton	121.3	90.0	90.1	83.7	72.4	86.3	106.5	-0.3
Vegetable crops	67.3	70.4	73.4	76.2	87.8	100.9	108.0	1.3
Total	1103.1	1112.7	1120.0	1114.8	1177.0	1419.8	1796.8	1.3

Source: CIE estimates

5 Sensitivity analysis

The simulated outcomes from the economic models used as the basis for the emissions projections depend on a variety of ‘exogenous’ (or ‘outside’) input assumptions. The appropriate values for these assumptions are not known with certainty. This chapter reports results from sensitivity analysis around a number of the key input assumptions.

Variables for sensitivity analysis

Sensitivity analyses are conducted for several key variables affecting agricultural production and emissions as summarised in table 5.1. Each of these are investigated separately as well as being combined to establish upper and lower bounds for emissions projections.

5.1 Individual sensitivity analyses

Sensitivity	Shock variable	Magnitude
Demand for Australian exports	Annual growth rate in foreign income	20 per cent deviation from the central reference case assumption
Permanent reduction in live exports and no new live exports market to emerge	Live cattle and live sheep exports	50 per cent below current live export volume
Exchange rate	Australian exchange rate	20 per cent deviation from the central reference case assumption as provided by DIICCS RTE. Note that this 20 per cent variation is defined in terms of USD/AUD.
Productivity	Annual growth rate in Australian agricultural productivity	50 per cent deviation from the central reference case assumption
Slaughtering weight/yield	Annual growth rate in slaughtering weight for beef, milk yield for dairy cattle and yield for crops	50 per cent deviation from the central reference case assumption
Input cost	Agricultural input prices	20 per cent deviation from the central reference case assumption
Extended drought	Supply elasticities	Halve the relevant supply elasticities
Combined sensitivities	Combination of export demand, productivity, slaughter weight/yield and input prices.	Individual factors arranged to lead to the same directional impact on emissions, that is, high (low) export demand and productivity being joined by low (high) slaughtering weight/yield and input prices.

Source: CIE construction in consultation with DIICCS RTE

Each of these variables was chosen for the sensitivity analysis as they are all important drivers of agricultural output and therefore emissions.

- Export demand is a key driver of much Australian agricultural activity and for a number of products (particularly meat and dairy) growth in foreign income is a key determinant of export demand. Projections of income growth in trading partner countries reasonably vary over time and between different forecasting methodologies. They are also inherently uncertain due to uncertainties in the international environment. This sensitivity tests the impact of a 20 per cent variation in income growth rates.
- Live exports are currently, and are likely to remain a contentious issue within Australia. It is possible — but by no means certain — that live exports will be constrained in the future. This sensitivity tests the implications of live exports constrained at 50 per cent of their current levels.
- Like income, exchange rates are inherently difficult to forecast but they have major implications for export industries — both in terms of their competitiveness and in terms of how foreign income translates into Australian dollars. This sensitivity tests the implications of a 20 per cent variation in the baseline exchange rate values. Note that this variation is defined around an exchange rate defined in USD/AUD terms. While the variation is uniform when expressed in this way, the variation is not uniform when expressed as AUD/USD. This latter expression of the exchange rate is implemented in the economic models.
- Agricultural productivity varies over time, most frequently due to climatic conditions. Large variations in productivity are common in the historical record. This sensitivity tests the implications of a 50 per cent variation in assumed productivity growth.
- Slaughter weights, milk yields and crop yields are a subset of productivity and also vary over time. This sensitivity tests the implications of a 50 per cent variation in assumed productivity growth for these variables.
- Input costs, while often less variable than other factors associated with agriculture, are nevertheless subject to a number of uncertainties. This sensitivity tests the implications of a 20 per cent variation in assumed input cost changes.
- As noted a number of times in this report, climatic conditions, particularly drought, have a major influence on agricultural output. In order to test the effect of this on an ongoing basis, we re-do simulations with our models under the assumption that agricultural supply responses (the supply elasticities) are half the value used in the central simulations. This is designed to simulate the inability of agricultural industries to respond to growing demands.

Sensitivity analysis results

Implications of the sensitivity analysis for the activity levels of various industries are set out in Appendix C. Here we focus on the implications of projected total agricultural emissions.

Table 5.2 reports the percentage deviation of each sensitivity scenario from the central reference case for selected projection years. Chart 5.3 compares upper and lower emissions projections (with the central case) for each of the sensitivities.

5.2 Impact on emissions – percentage deviation from the central reference case

	2015	2020	2030	2050
Export demand				
High	0.73	2.24	4.54	11.26
Low	-0.72	-2.25	-4.06	-9.05
Live export reduction				
Low export	-2.69	-2.91	-3.51	-4.02
Exchange rate				
High	-2.15	-2.69	-7.40	-6.18
Low	4.21	10.25	10.74	9.04
Productivity				
High	0.98	2.52	5.32	12.15
Low	-0.97	-2.46	-4.96	-10.03
Slaughtering weight/yield				
High	-1.33	-2.69	-5.23	-8.74
Low	1.32	2.65	5.17	9.05
Input cost				
High	-7.48	-7.12	-6.13	-5.62
Low	7.46	7.10	6.10	5.56
Extended drought				
Drought	-0.72	-2.25	-4.06	-9.05
Combined				
High	10.87	14.89	21.65	39.45
Low	-10.90	-14.91	-20.93	-35.02

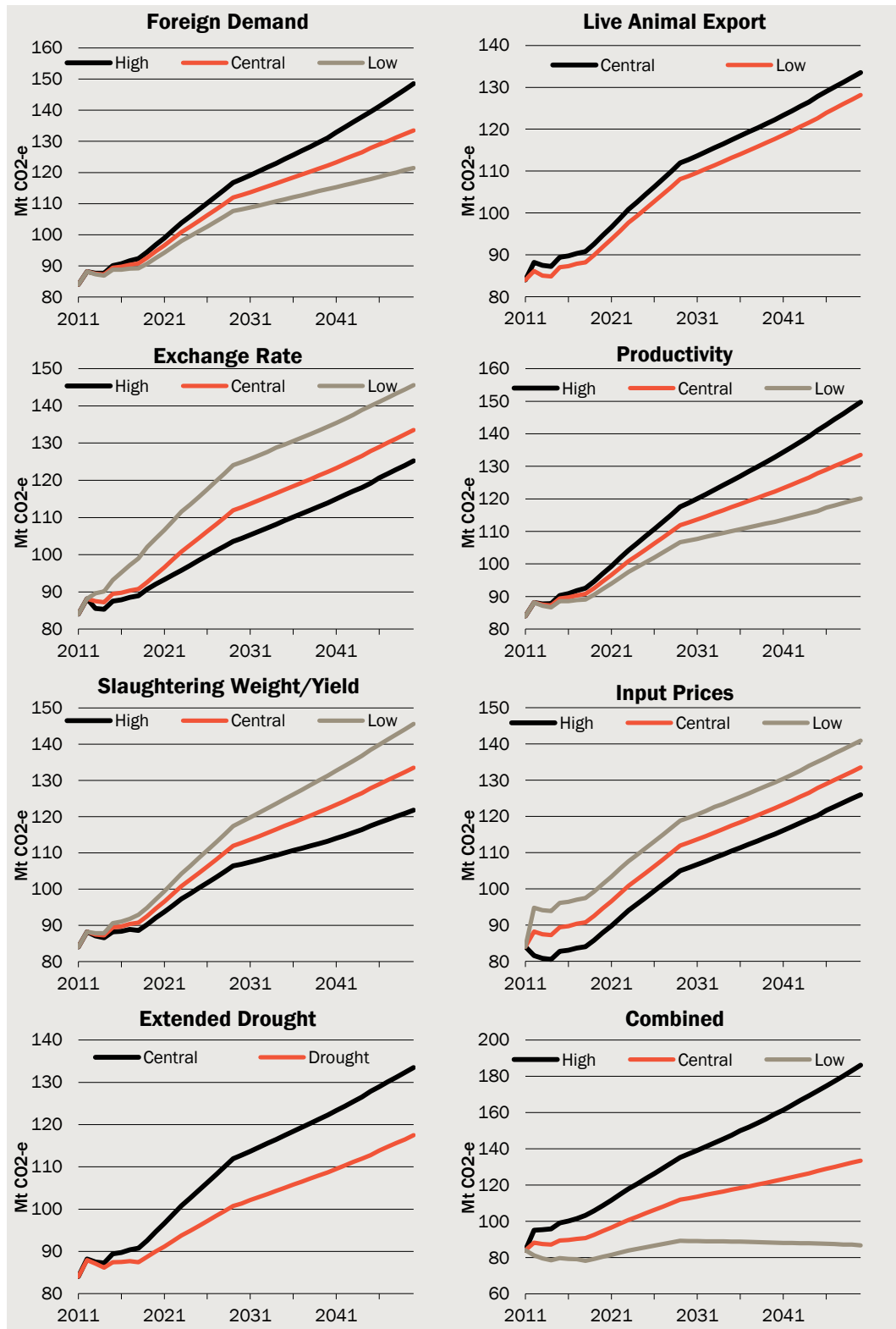
Note: The 'high's and 'low's under each sensitivity refer to the high and low values of shocked variables, while the high and low under the combined scenario refer to the high and low emissions.

Source: CIE Grains, Dairy and GMI simulations

Several points emerge from these results.

- The largest impacts in the short term (2015 and 2020) are from variations in the exchange rate and input costs. In 2020, for example, a more favourable exchange rate could lead to a 10 per cent increase in emissions (relative to the central reference case). A less favourable exchange rate could lead to a 3 per cent decline in emissions. Note that as pointed out above, these exchange rate deviations are not uniform because exchange rates are expressed in AUD/USD terms within the models.
- Different input costs could lead to a variation in emissions (up or down) of around 7 per cent by 2020.
- Over the longer term the largest impact is from changes in productivity growth – higher (lower) productivity growth leads to a 12.2 per cent higher (10 per cent lower) emissions in 2050.

5.3 Impact on annual emissions of sensitivity analysis



Note: The 'high's and 'low's under each sensitivity refer to the high and low values of shocked variables, while the high and low under the combined scenario refer to the high and low emissions.

Data source: CIE Grains, Dairy and GMI simulations

- This is followed (in 2050) by changes in export demand – 11.3 per cent higher (9 per cent lower) than the central reference case, and the extended drought – 9 per cent lower in 2050.
- The combination of sensitivities suggests that in 2020, emissions could vary by 15 per cent around the central reference case. By 2050 the variation could be around 35 to 40 per cent. Thus, under the combined low case scenario, emissions could remain unchanged (no growth) over the forecast period.

Land clearing in Queensland

One factor which may have an influence on overall emissions, but which is hard to quantify, are recently announced changes to land clearing rules in Queensland. The *Vegetation Management Amendment Act 2013* is expected to come in force in late 2013.

The amendments in this Act ...

...will allow sustainable vegetation management activities to occur to support the development of high-value agriculture. This will assist in the growth of the agricultural industry and contribute to the government's goal of doubling Queensland's food production by 2040.⁹

As such, the Act may have the effect of increasing agricultural production in Queensland above the estimates contained in the central reference case. It is difficult, however, to predict the extent of this effect for a number of reasons.

- First, a doubling, or near doubling of Queensland's food production is already evident in the central reference scenario, so some of the effect of the Act may already implicitly be incorporated.
- Second, the legislation essentially reverts to the pre-2009 situation for land clearing. This is consistent with the period over which most of the parameters within our models were calibrated.
- Third, the legislation is particularly concerned with high value agriculture. Effectively under the act, the only new pasture that can be established (for grazing) is irrigated pasture. This may limit the extent to which the Act leads to increased land clearing for grazing.

Overall, while it is possible that the Act will lead to higher activity levels (and therefore emissions) than in the central reference case, we have been unable to quantify the impact, but expect that it will be relatively small.

⁹ <http://www.nrm.qld.gov.au/vegetation/vegetation-management.html>

Appendixes



A The models

The models

Agricultural emissions projections are undertaken using three core bottom-up models. A brief summary of each of these models is provided in table A.1. The country coverage for each of these is set out in table A.2.

A.1 Summary

Model/Framework	Summary of key features	Developments required for this round of emissions projections
Global Meat Industries (GMI) model	A multicountry, multicommodity, Armington style model of world meat production, consumption and trade. It explains production and consumption in ten commodities (grass fed beef, grain fed beef, diaphragm beef, live cattle, lamb, sheep meat, pigmeat, poultry, seafood and wool) in 22 regions, and trade in eight commodities between 22 regional groupings (see table 2 for the list of regions)	Some updating to ensure alignment with National Greenhouse Gas Inventory (NGGI) activity levels; introducing carbon farming cost module to model the voluntary Carbon Farming Initiative (CFI).
Dairy model	Dynamic partial equilibrium non-linear representation of the Australian Dairy industry. It identifies six regions within Australia and covers Australia's major competitors in the world dairy export market (see table 2 for the list of country groups)	Some updating to ensure alignment with NGGI activity levels; introducing carbon farming cost module to model the voluntary CFI.
Grains model	Multiregion, multicommodity, dynamic partial equilibrium model. It covers production, consumption and trade in five grains or groups of grains (wheat, malting barley, other coarse grains, pulses and oil seeds) for Australia's major export destinations (see table 2 for the list of country groups)	Some updating to ensure alignment with NGGI activity levels; introducing carbon farming cost module to model the voluntary CFI.

Model parameters

Like all models, the GMI, Dairy and Grains models used for this round of forecasts contain a number of 'behavioural parameters'. In general, these parameters describe the response of economic agents (producers, consumers, importers and so on) to changes in their relevant decision variables (most commonly, prices). Parameters are often expressed as an 'elasticity', describing the percentage change in one variable (demand, for example) in response to a one per cent change in another variable (price, for example). The model parameters and their functions within the three models are described in table A.3.

A.2 Countries and regions in models

GMI		Dairy	Grains
Australia	Thailand	Australia	Australia
New Zealand	Philippines	New Zealand	Rest of Pacific
United States	China	United States	Africa
Canada	European Union	European Union	Americas
Japan	Mexico	Rest of World	Europe
South Korea	Argentina		Middle East
Taiwan	Uruguay		North Asia
Hong Kong	Paraguay		South Asia
Singapore	Brazil		Southeast Asia
Malaysia	India		
Indonesia	Rest of World		

The approach to deriving parameter values varies, depending on the nature of the parameter and the information sources available. Deriving parameter values is based around the following sets of alternatives.

- Econometric (statistical) estimation using historical data. This is the approach taken, for example, in deriving the income and price elasticities of demand within the GMI model (in this case, estimation was based around an Almost Ideal Demand System).
- Drawing on parameter estimates from published literature. Within agricultural economics there is a long history of statistically estimating and publishing a range of ‘elasticities’ including demand and supply elasticities. Drawing on published literature is the approach taken for some of the supply parameters within the grain and dairy models. Here we include parameters taken from the Global Trade Analysis Project (GTAP).
- Drawing on specific industry expertise, including industry knowledge of cost and production functions. This approach is used for a number of parameters within the GMI model where statistical estimation is not possible. Industry experience contains a rich source of information to help verify economic models.
- Calibration of model parameters using observed industry responses to particular economic changes. This approach is similar to statistical estimation but is specifically designed to use recent information (rather than a long time series) to ensure that model parameters reproduce observed market behaviour. This is the approach taken to the ‘Armington’ elasticities within the GMI model.

Table A.3 summarises the parameters used in each of the three models, while tables A.4 to A.8 provide values for some of the key model parameters.

A.3 Model parameters and their functions

Parameters	Function within the model
Global Meat Industry (GMI) model	
Income elasticity of demand	This captures changes in consumer demand for each meat type as income changes. Typically, red meats are 'income elastic', meaning that demand is highly responsive to changes in income.
Price elasticity of demand	Captures the response of consumers to changes in relative meat prices.
Elasticity of substitution between domestic and imported products as well as between imported products from different sources (the 'Armington' elasticities)	Captures the extent to which importing countries respond to relative price changes of products from different origins. Designed to capture the fact that different meat products from different countries have different quality specifications.
Price elasticity of supply	The extent to which supply (by country) is able to respond to price changes.
Dairy model	
Supply elasticity	The extent to which supply (by country) is able to respond to price changes.
Income elasticity of demand	This captures changes in consumer demand for each dairy product as income changes. Often, particular dairy products are 'income elastic', meaning that demand is highly responsive to changes in income.
Price elasticity of demand and elasticity of demand substitution between dairy products	Captures the response of consumers to changes in relative prices of different dairy products.
Elasticity of substitution between domestic and imported products as well as between imported products from different sources (the 'Armington' elasticities)	Captures the extent to which importing countries respond to relative price changes of products from different origins.
Grains model	
Income elasticity of demand	Captures changes in consumer demand for grain products as income changes.
Price elasticity of demand	Captures the response of consumers to changes in relative prices of different dairy products.
Elasticity of substitution between Australian and foreign grains (an 'Armington' elasticity).	Captures the extent to which importing countries respond to relative price changes of products from different origins.
Elasticity of transformation from gross grain output to individual grain output – supply elasticity	Captures the extent to which individual grain output changes (given total capacity) in response to relative price changes.
Elasticity of substitution between primary factors in farming and processing	Captures the technical ability to substitute between land, labour and capital in production and in response to relative price changes.
Elasticity of substitution between grain inputs in processing	Captures the ability of the grain processing industry to substitute between different grains in production.

A.4 Range of income elasticities in the GMI model

	Developing countries	Developed countries
Beef	0.8 to 1.0	0 to 0.8
Sheep meat	0.5 to 1.0	0 to 0.5
Pig meat	0.2 to 1.0	0 to 0.3
Poultry	0.5 to 0.9	0 to 0.2

Source: CIE GMI model assumptions

A.5 Range of price elasticities in the GMI model

	Demand	Supply
Beef	-0.8 to -1.4	0.4 to 0.6
Sheep meat	-0.8 to -2.5	~0.2
Pig meat	-0.7 to -2.5	0.2 to 0.7
Poultry	-0.6 to -0.9	1.0 to 2.0

Source: CIE GMI model assumptions

A.6 Demand elasticities for dairy products

	Developing countries	Developed countries
Income elasticities		
Fresh and UHT milk	1	0
Other dairy products	2	0
Price elasticities		
Fresh and UHT milk	-0.15	-0.15
Other dairy products	-0.25	-0.25

Source: CIE Dairy model assumptions

A.7 Demand elasticities for grain products

	Developing countries	Developed countries
Income elasticities		
	0.6	0
Price elasticities		
Export demand for grains	-0.5	-0.5
Export demand for processed products and feed	-10	-10
Domestic demand for processed products and feed	-2	-2

Source: CIE Grains model assumptions

A.8 Elasticities of transformation or substitution in the Grains model

Transforming to individual grain output	1
Substitution between primary factors in grain farming	1
Substitution between primary factors in processing	0.5
Substitution between individual grain in processing	1
Substitution between Australian and foreign products	10

Source: CIE Grains model assumptions

B Key assumptions for the central reference case

Table B.1 summarises the key exogenous set of assumptions used for each of these models, along with the sources for these assumptions. Tables B.2, B.3, B.4 and B.5 summarise the underlying productivity improvements assumed for the GMI and Dairy models.

B.1 Assumption for exogenous variables

Key exogenous variables by model	Sources
Global Meat Industry (GMI) model	
Annual population growth by region	United Nations (UN) Population Division; Director-General of Budget, Accounting and Statistics, Executive Yuan, Taiwan.
Total income growth by region	International Monetary Fund (IMF) World Economic Outlook 2012; Organisation for Economic Cooperation and Development (OECD) Long-term baseline projections 2012.
Per capita income growth by region	Derived from the above two (for each region, total income divided by total population).
Growth in average slaughter weight	Historical data, and industry expertise.
Total factor productivity growth by region and meat commodity (table 4)	Industry expertise.
Exchange rates by region	Historical data, Reserve Bank, and Treasury.
Production cost indexes	Estimated based on Treasury commodity prices.
Dairy model	
Annual population growth by region	UN Population Division.
Per capita GDP growth by region	Derived from IMF projections of total GDP growth and UN population growth projections.
Milk production per cow	Historical data, and industry expertise.
Ratio of cow to cattle numbers	Historical data, and industry expertise.
Input use efficiency (table 5)	Historical data, and industry expertise.
Industry input prices	Consistent with Treasury modelling.
Grains model	
GDP growth by region	IMF World Economic Outlook 2012.
Population growth by region	UN Population Division.
Total factor productivity growth by region	Historical data, and industry expertise for forward projections. Set at 0.6 per cent a year for Australia.
Capital stock growth	Consistent with Treasury modelling.
Total cropping area	Historical data, and industry expertise and expectations. Assumed to grow at 0.4 per cent a year over projection period.
Global food prices	United States Department of Agriculture (USDA), and Treasury.
Input costs	Consistent with Treasury modelling.

B.2 Total productivity improvement assumption for meat type and region in the GMI model

Region	Grass fed	Grain fed	Diaphragm	Live cattle	Lamb	Sheep meat	Pig meat	Poultry	Sea food	Live sheep	Wool
	%	%	%	%	%	%	%	%	%	%	%
Australia	1.00	0.50	0.00	1.00	0.50	0.00	1.00	2.00	0.00	1.00	0.20
New Zealand	0.50	0.00	0.00	0.00	-1.00	-1.00	1.00	2.00	0.00	0.00	0.20
United States	0.75	1.00	0.00	0.00	-2.00	-2.00	1.50	2.00	0.00	0.00	0.00
Canada	0.75	1.00	0.00	0.00	0.50	0.00	1.50	2.00	0.00	0.00	0.00
Japan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
South Korea	0.00	1.50	0.00	0.00	0.33	0.00	1.00	1.00	1.00	0.00	0.00
Taiwan	0.66	0.00	0.00	0.00	0.33	0.00	0.00	1.00	1.00	0.00	0.00
Hong Kong	0.44	0.00	0.00	0.00	0.33	0.00	1.00	1.00	1.00	0.00	0.00
Singapore	0.44	0.00	0.00	0.00	0.33	0.00	1.00	1.00	1.00	0.00	0.00
Malaysia	0.44	0.00	0.00	0.00	0.33	0.00	1.00	1.00	1.00	0.00	0.00
Indonesia	0.44	0.00	0.00	0.00	0.33	0.00	1.00	1.00	1.00	0.00	0.00
Thailand	0.44	0.00	0.00	0.00	0.33	0.00	1.00	1.00	1.00	0.00	0.00
Philippines	0.44	0.00	0.00	0.00	0.33	0.00	1.00	1.00	1.00	0.00	0.00
China	0.88	0.00	0.00	0.00	0.33	0.00	1.00	1.00	1.00	0.00	0.00
Economic Union	0.50	0.00	0.00	0.00	0.00	0.00	1.00	0.50	0.00	0.00	0.10
Mexico	1.22	0.00	0.00	0.00	1.00	0.00	1.00	2.00	0.00	0.00	0.00
Argentina	1.22	1.44	0.00	0.00	1.00	0.00	1.00	2.00	0.00	0.00	0.50
Uruguay	1.22	1.44	0.00	0.00	1.00	0.00	1.00	2.00	0.00	0.00	0.50
Paraguay	1.22	1.44	0.00	0.00	1.00	0.00	1.00	2.00	0.00	0.00	0.00
Brazil	3.00	1.44	0.00	0.00	1.00	0.00	1.00	2.00	0.00	0.00	0.00
India	1.00	0.00	0.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00
Other countries	0.44	0.00	0.00	0.00	0.33	0.00	1.00	1.00	0.00	0.00	0.20

B.3 Growth in slaughtering weight: GMI model

	Beef and veal	Mutton	Lamb	Pigs	Poultry
2012	0.210	-0.265	0.498	0.315	0.000
2013	-1.106	-1.875	-1.592	0.393	0.893
2014	-0.478	1.571	0.694	-0.052	0.893
2015	1.534	1.187	-1.450	0.414	0.893
2016	-0.229	-2.486	-0.576	0.339	0.893
2017	-0.284	-0.659	-0.144	0.404	0.893
2018	-2.128	2.876	-0.994	0.309	0.893
2019-20	0.212	0.380	-0.150	0.344	0.893
2021-30	0.653	0.945	0.261	0.398	0.893
2031-40	0.523	0.756	0.209	0.319	0.714
2040-50	0.418	0.605	0.167	0.255	0.572

Source: Historical and industry data, CIE assumptions

B.4 Growth in the ratio of animal number to slaughtered: GMI model

	Beef and veal	Mutton	Lamb	Pigs	Poultry
2012	-0.09	-3.43	-3.43	0.00	0.00
2013	-7.26	-18.23	-18.23	0.00	0.00
2014	-4.26	11.90	11.90	0.00	0.00
2015	4.29	3.79	3.79	0.00	0.00
2016	-1.71	-1.04	-1.04	0.00	0.00
2017	-0.74	-2.98	-2.98	0.00	0.00
2018	0.18	-2.16	-2.16	0.00	0.00
2019-20	-0.49	-0.59	-0.59	0.00	0.00
2021-30	-0.10	-0.12	-0.12	0.00	0.00
2031-40	-0.01	-0.01	-0.01	0.00	0.00
2040-50	0.00	0.00	0.00	0.00	0.00

Source: Historical and industry data, CIE assumptions

B.5 Productivity improvement: the Dairy model

	2012	2013	2014-15	2016-20	2021-50
Milk production per cow in Australia	1.3	-2.6	1.1	1.1	0.5
Ratio of cow number to cattle number	-0.6	0.0	0.0	0.0	0.0
Input efficiency					
Australia	2.2	1.5	1.5	1.5	1.5
New Zealand	1.5	1.5	1.5	1.5	1.5
European Union	0.0	0.0	0.0	0.0	0.0
United States	0.5	0.5	0.5	0.5	0.5
Rest of the world	1.0	1.0	1.0	1.0	1.0

Source: CIE assumptions.

C Sensitivity analysis

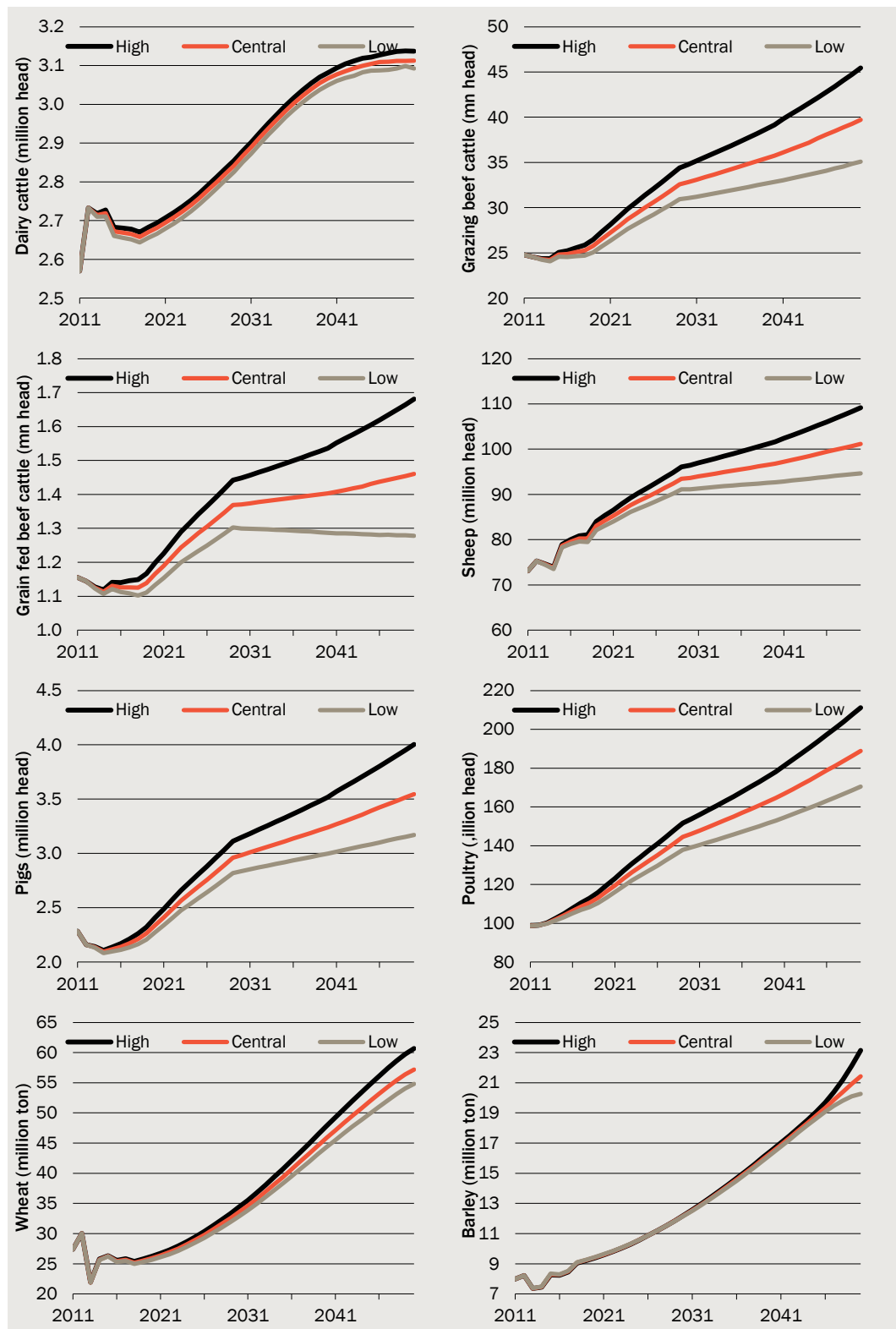
Foreign demand

Australian agricultural sectors are highly exposed to export markets. Fluctuations in foreign markets will have significant impacts on the domestic production. Typically, foreign demand is determined by foreign population and income levels. Variation in population projections have not been considered for this exercise, consistent with DIICSRTE assumptions. Consequently, as shown in table 5.1, the sensitivity analysis of foreign demand is modelled by different assumptions about the annual growth in foreign income.

Chart C.1 shows the impact of changing foreign demand on Australia's major agricultural outputs. In general the higher the foreign demand, the higher the output.

The impacts on dairy cattle number are smaller than those on meat animal numbers and grains because of the fact that export share of Australian dairy products is smaller than that of meat and grains.

C.1 Impact of foreign demand on agricultural output

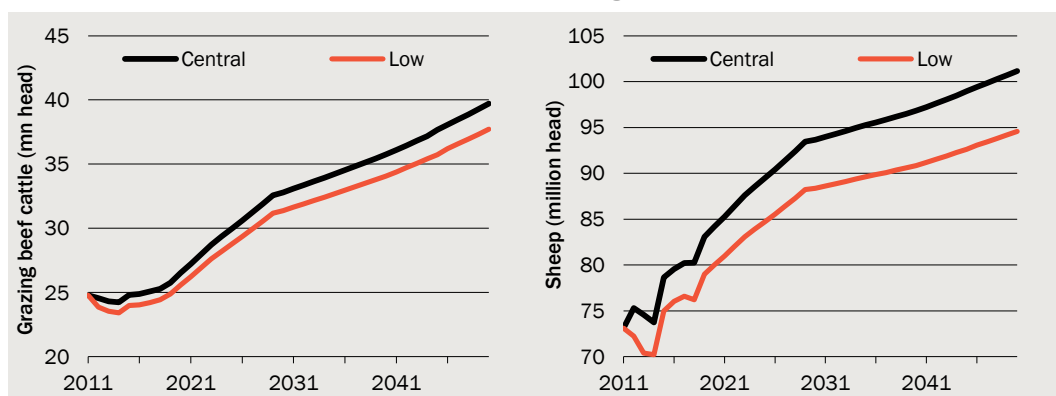


Data source: CIE Grain, Dairy and GMI model simulations

Permanent reduction in live animal export

Halving the live cattle and sheep exports from existing levels will see grazing cattle and sheep numbers fall by 3.5 per cent and 4.9 per cent, respectively, from the central reference case levels in 2020, by 4.3 per cent and 5.7 per cent respectively in 2030, and by 5.0 per cent and 6.5 per cent respectively in 2050 (Chart C.2).

C.2 Impact of live animal export reduction on agricultural output



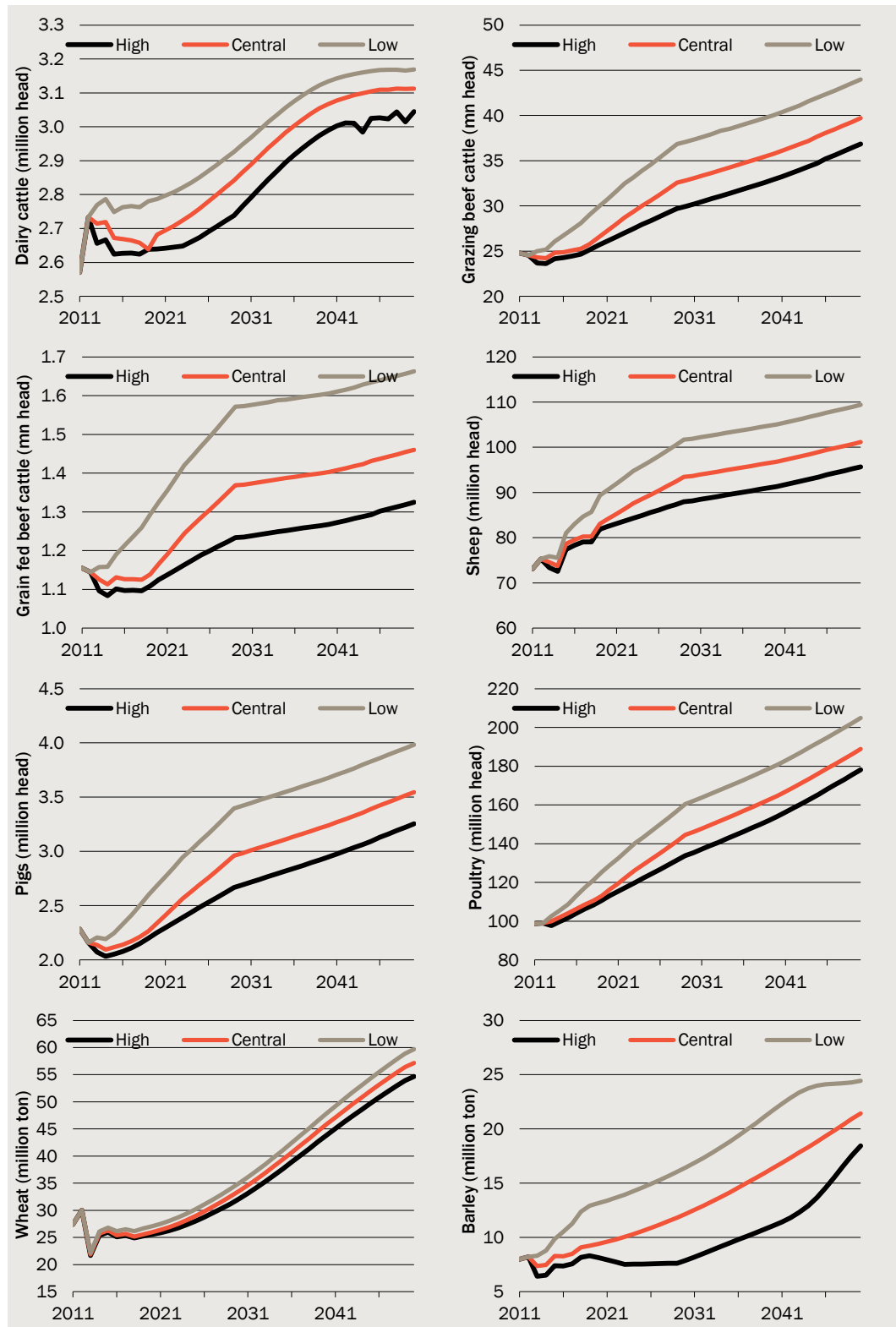
Data source: CIE GMI model simulations

Exchange rates

A higher Australian dollar means higher prices for Australian exports and cheaper prices for imports, leading to lower demand for Australian products. On the other hand, a lower Australian dollar would boost the demand for Australian products, as Chart C.3 illustrates.

For the same reason as in the case of foreign demand sensitivity analysis, the impact of exchange rate changes on dairy cattle numbers is relatively smaller than that on meat animal numbers and grain output. For example, the dairy cattle number in 2050 is estimated to be 2.2 per cent lower (1.8 per cent higher) than the central reference case level if the Australian exchange rate is 20 per cent higher (lower). By contrast, the impact of similar exchange rate change would be 7.2 per cent lower (10.8 per cent higher) for grazing beef cattle numbers, 9.3 per cent lower (13.9 per cent higher) for grain fed beef cattle numbers.

C.3 Impact of exchange rates on agricultural output



Data source: CIE Grain, Dairy and GMI model simulations

Productivity

Chart C.4 reports the agricultural activities under different assumptions of productivity growth. Higher productivity improvement brings about more reduction in cost, leading to higher demand and thus production.

Slaughtering weight and yield

Chart C.5 reports the agricultural activities under different assumptions of the growth in slaughtering weight and yield. The impacts on animal numbers and on grain production are on the opposite direction.

Higher slaughtering weight in the meat industry and higher milk production per cow in the dairy industry mean that, for a certain output, fewer animals are needed. As shown by the top 6 diagrams in the chart, higher (lower) growth in slaughtering weight/yield is associated with lower (higher) animal numbers.

The dairy industry stands out in the sensitivity analysis – dairy cattle numbers would fall if the yield growth rate is 50 per cent higher than the assumed growth in the central reference case. This is partly due to the relatively high growth assumption of yield in dairy industry compared with other industries in the central reference case.

By contrast, higher yield in grain production means more production for given amount of land. So it is the same as the productivity improvement in the sector. As shown in the bottom 2 diagrams in the chart, higher (lower) yield growth is associated with higher (lower) grain production.

Input prices

Chart C.6 reports the agricultural activities under different assumptions of the prices of inputs into the production system. The impact is opposite to that from a productivity improvement. Higher input prices mean higher cost of a product, depressing the demand and thus production.

Extended drought

There are several ways to model the impact of drought. A common way is through reductions in productivity (yields). As the impact of different productivity assumptions has been investigated separately, we adopt an alternative approach through a permanently reduced elasticity of supply — that is, a reduced ability of each of the agricultural sectors to respond to changes in demand.

This approach is taken as we often observe lower output and higher prices in a drought, that is, a higher price is required to encourage farmers to produce the same amount of products – a lower supply elasticity.

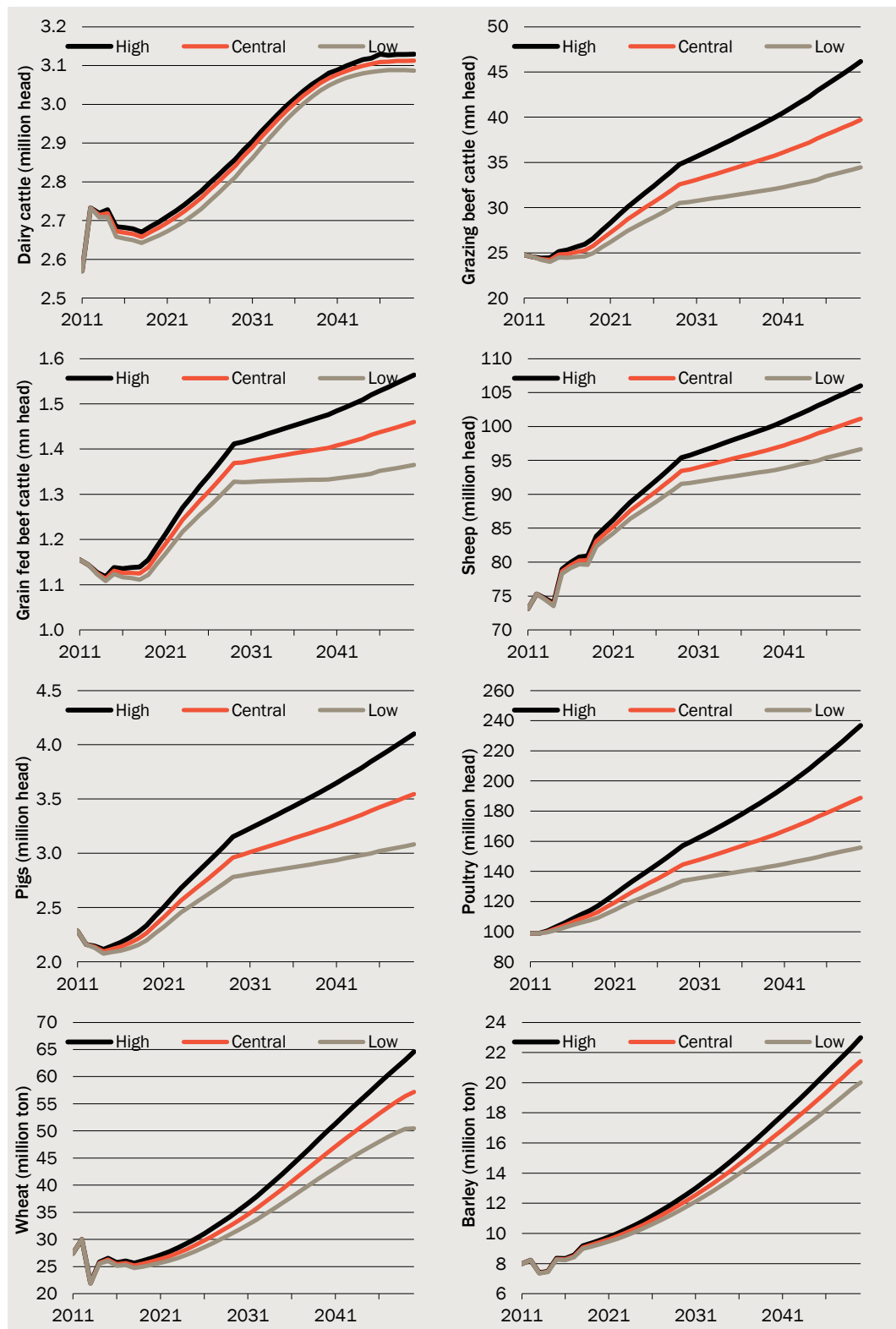
Chart C.7 reports the agricultural activities under the extended drought case along with the central reference case.

As expected, in most cases this sensitivity results in lower output of each commodity compared with the central reference case.

It is interesting to note that because of the way the reduction in the supply elasticity is implemented in the Grains model, output of wheat actually increases slightly, while that of other grains declines, relative to the central case.

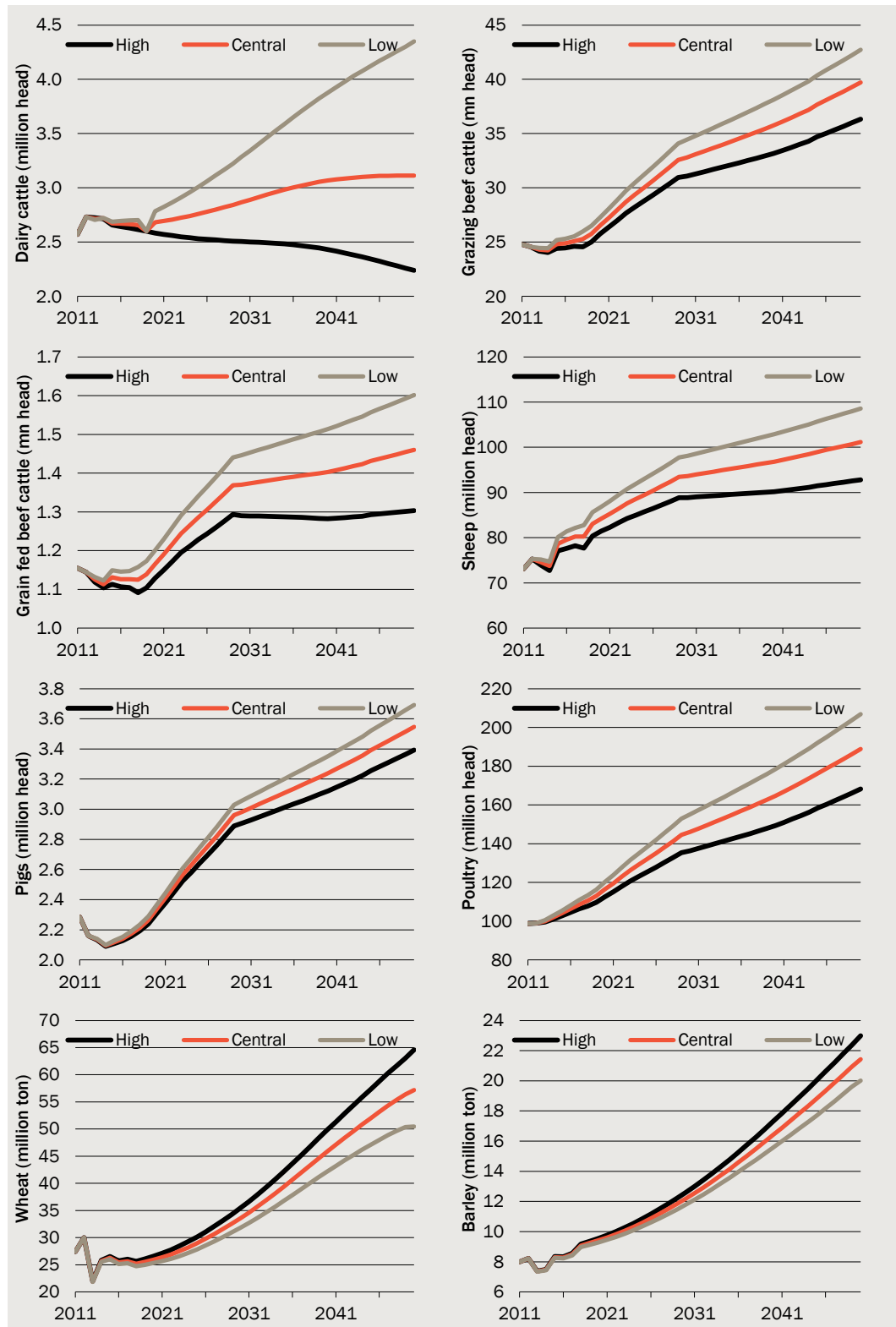
In the Grains model, the supply elasticity refers to the overall supply responsiveness of a 'bundle' of grain products (or equivalently, the total productive capacity of the farm which could be applied to a number of different grains). Within this bundle, it is possible to have a shift between grain products (towards wheat and away from other grains, for example). That is, while overall supply falls, the supply of a particular grain can increase at the expense of other grains. This is what occurs in this simulation. This sort of shift is only possible in the short term as eventually the overall reduction in supply outweighs any ability to shift between grain types.

C.4 Impact of productivity on agricultural output



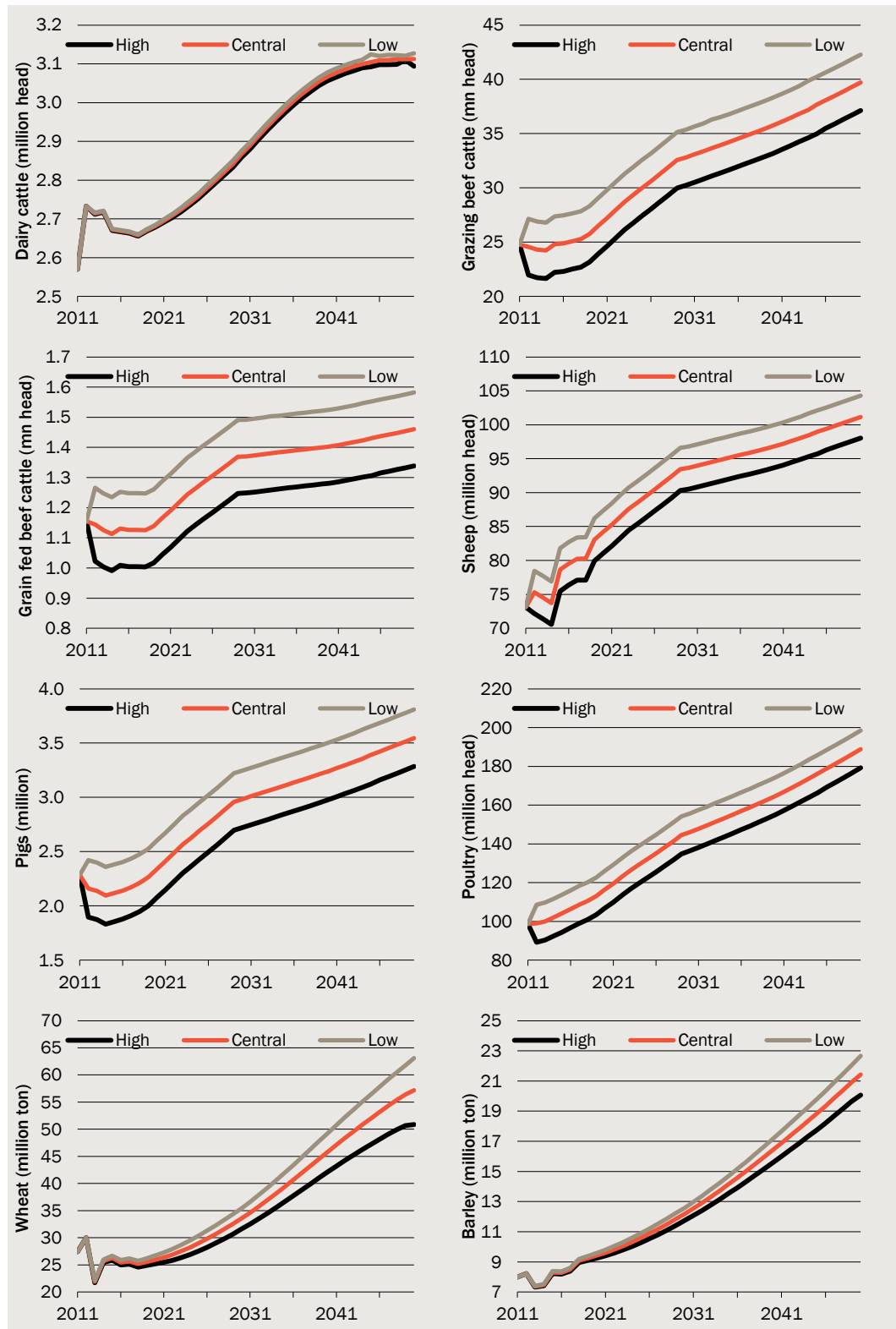
Data source: CIE Grain, Dairy and GMI model simulations

C.5 Impact of slaughtering weight and yield on agricultural output

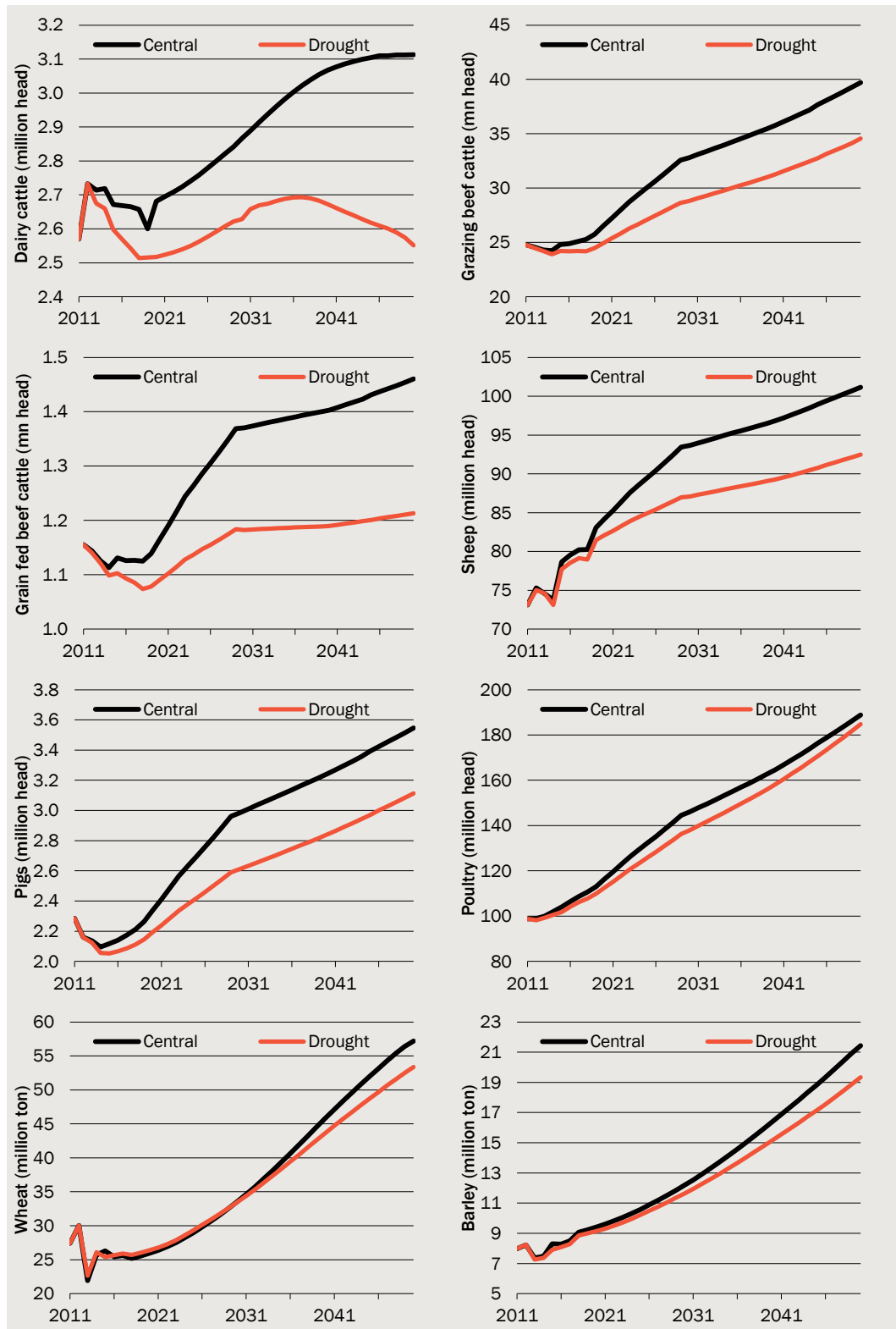


Data source: CIE Grain, Dairy and GMI model simulations

C.6 Impact of input prices on agricultural output



C.7 Impact of extended drought on agricultural output



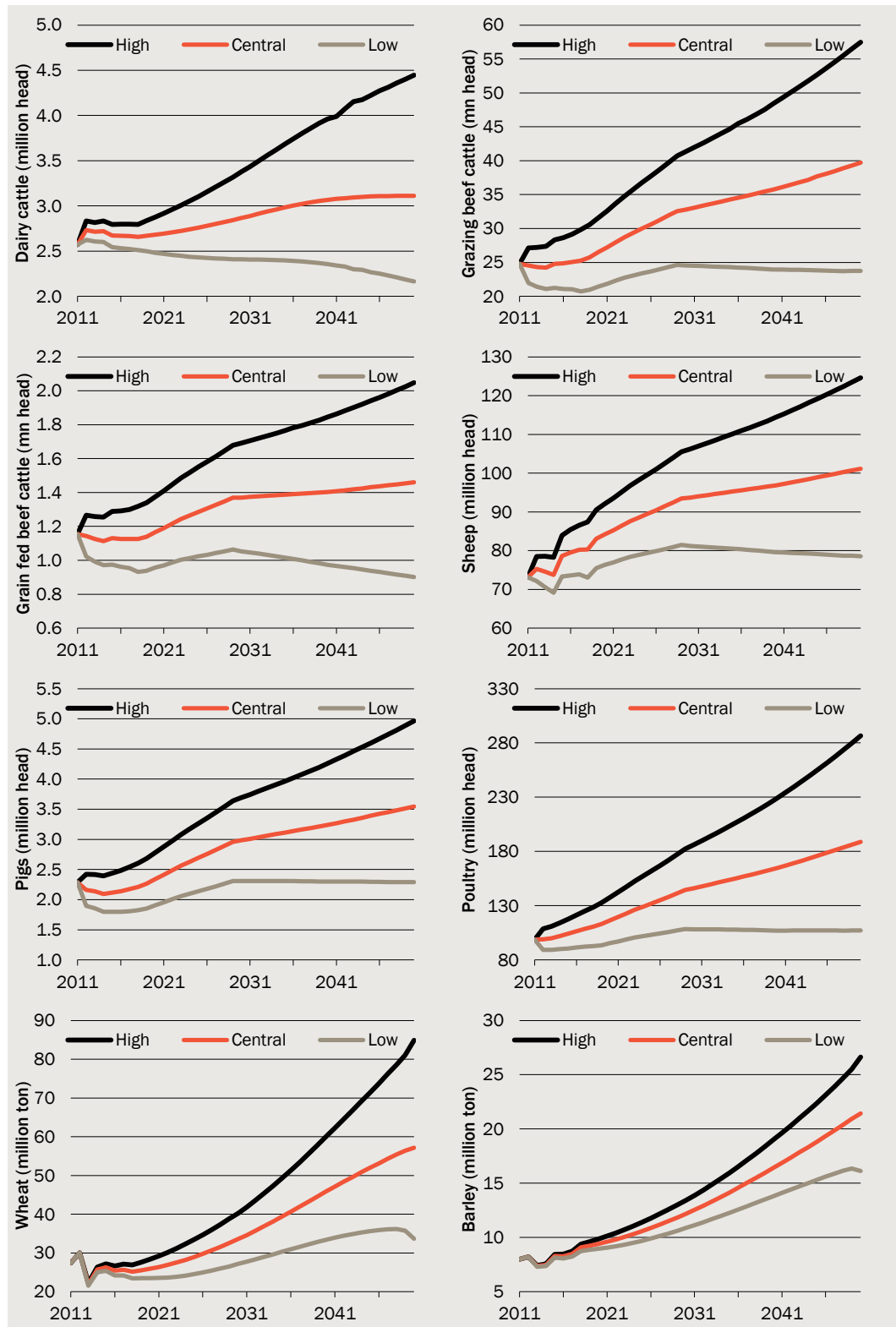
Data source: CIE Grain, Dairy and GMI model simulations

Combined sensitivity analysis

Chart C.8 reports the sensitivity analysis results of combining foreign income, productivity, slaughtering weight/yield and input price together.

It can be seen from the chart that the animal numbers are more sensitive than is grain production. By 2050 the animal numbers could be 40 per cent away from the central reference case projection, while the grains outputs have a 10-20 per cent deviation.

C.8 Combined sensitivity analysis result



Data source: CIE Grain, Dairy and GMI model simulations



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