www.TheCIE.com.au

Greenhouse gas emissions from agricultural sector

Projections to 2030

Prepared for

Department of Climate Change and Energy Efficiency

Centre for International Economics
Canberra & Sydney

October 25 2010

The Centre for International Economics is a private economic research agency that provides professional, independent and timely analysis of international and domestic events and policies.

TheCIE's professional staff arrange, undertake and publish commissioned economic research and analysis for industry, corporations, governments, international agencies and individuals.

Canberra

Centre for International Economics
Ground Floor, 11 Lancaster Place
Majura Park
Canberra ACT 2609

GPO Box 2203
Canberra ACT Australia 2601

Telephone +61 2 6245 7800
Facsimile +61 2 6245 7888
Email cie@TheCIE.com.au
Website www.TheCIE.com.au

Sydney

Centre for International Economics
Suite 1, Level 16, 1 York Street
Sydney NSW 2000

GPO Box 397
Sydney NSW Australia 2001

Telephone +61 2 9250 0800
Facsimile +61 2 9250 0888
Email ciesyd@TheCIE.com.au
Website www.TheCIE.com.au

Contents

1 Introduction and summary

This report

This report provides updated projections of key agricultural activity levels which when applied to the Department of Climate Change and Energy Efficiency (DCCEE) emissions spreadsheets give projections of agricultural greenhouse gas emissions in each year from 2009 to 2030.

It provides an update to previous projection rounds taken by the Centre for International Economics (CIE) for the then Australian Greenhouse Office (AGO) and DCCEE in 2003, 2005, 2007 and 2008. Like previous rounds, this report uses three economic models of Australian agriculture:

- The Global Meat Industries (GMI) model;
- The CIE Grain model; and
- The CIE Dairy model.

Descriptions of these models are provided in chapter 5 below. The current versions of these models are very similar to those used in the previous rounds of projections, except that the model databases have been fully updated to reflect information available since 2008. Specifically, the databases have been updated to reflect the situation in 2009. As before, projections for the rice, cotton and sugar industries are made with spreadsheet models.

Like the 2007 and 2008 rounds, emissions are estimated by applying projected activity levels to spreadsheets of emission coefficients provided by the DCCEE. The Department may revise some of these underlying coefficients, and therefore emissions estimates from the current round may not be directly compared with previous estimates. Activity levels, on the other hand, can be compared and it is appropriate to do so.

Like the previous rounds (except in 2003), some indication of the uncertainty surrounding the projections is provided by a number of scenarios that incorporate different settings for underlying assumptions.

The report is structured as follows. The remainder of this introductory chapter provides a summary of key emissions results, including providing an indication of the bounds around the baseline estimates. It also notes some caveats that must be applied to any forecasting exercises.

Chapter 2 presents the base projections, and where appropriate makes comparisons with projections from the 2008 round. Chapter 3 presents scenario variations around the baseline results. Chapter 4 provides a detailed description of the assumptions that lie behind each of the projections, and chapter 5 discusses in detail each of the economic models used.

Key results

The basic story

The Australian agricultural sectors were hit badly by the drought in recent seasons. With the widespread rainfall this year, farmers have become more optimistic and indications are for a successful winter crop in many parts of Australia.

Australian agricultural industries were also adversely affected by the global financial crisis in the past two years because the sectors are highly exposed to export markets. The world economy is on track for a slow recovery according to most international agencies.

We therefore project a recovery of the Australian agricultural sectors in 2010 and 2012 from both supply and demand sides. Beyond 2012 we expect the sectors to continue to grow at their long-run, more sustainable pace. The growth, as before, will be driven by growing demand for Australian agricultural products, mainly from overseas, and facilitated by continuing improvement in agricultural productivity.

The growth in demand is generated by both population and income growth overseas, leading to increases in exports to both traditional and new markets, as well as (to a lesser extent) by growth in the domestic market. Population growth, especially in our Asian markets, will tend to increase the base level of demand. At the same time, income growth will tend to lead to per capita consumption increases, especially for meat products. Export demand growth is also expected to continue because of declines in agricultural protection in our destination markets and amongst our competitors. All other things equal, this increase in demand will lead a movement along Australia’s supply curve, and will tend to lead to an increase in price that will both encourage additional production and cut off some of the initial demand increase.

The implementation of emissions trading scheme (ETS) in New Zealand may also help the growth of Australian agricultural exports. Although agriculture will not be included in the New Zealand ETS until 2015, New Zealand agriculture will be affected by higher input prices for energy and chemicals. As a result, New Zealand agricultural products will become more expensive, giving Australian products a more competitive edge. However, as these appear mainly as secondary effects — even when the agricultural sector is included in the ETS in 2015, it will be given free quotas equivalent to 90 per cent of base emissions and phased out gradually at 1.3 per cent per annum from 2016 — the net impact is likely to be small.

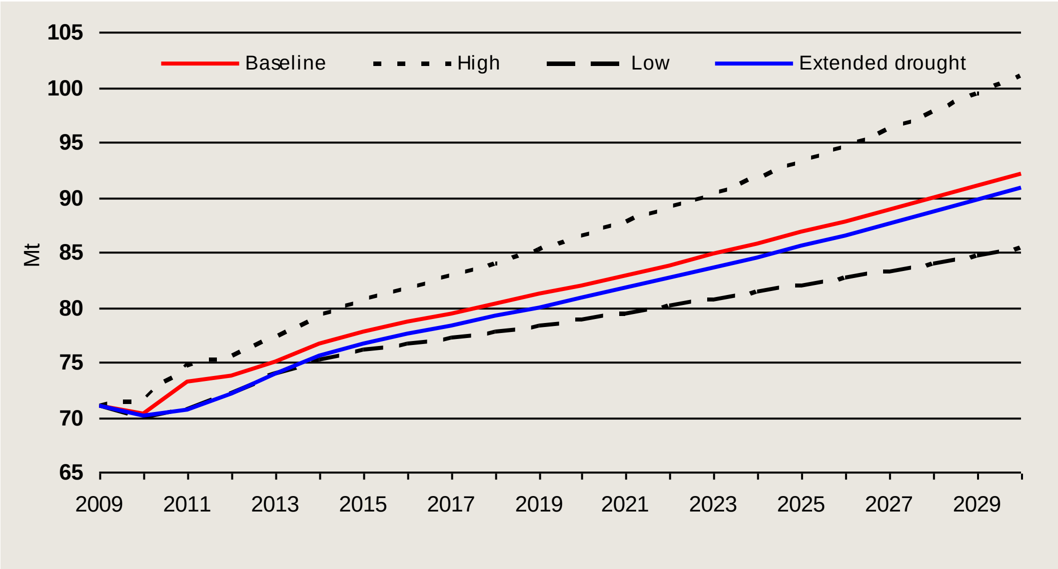
In addition to demand changes, however, we also expect increases in Australian agricultural productivity (shifts outwards in the supply curve), which tend to mitigate some of the price effects of the initial demand increases.

There are two types of productivity shift we attempt to capture. First, what could be called total factor productivity, or the extent to which efficiency in inputs (land, labour, capital and materials) increases, allowing more output for the same amount of inputs. Historically, this efficiency has tended to steadily increase (particularly in terms of partial productivity measures such as yield) and we consider that these productivity increases will continue in the future. This view is based on discussions with industry experts as well as on the expected outcomes of current research programs.

The second form of productivity deals specially with changes in the meat (or milk) output per animal. We use this factor to convert from meat or milk demand to the number of animals. We assume that this productivity also continues to increase as it has done historically.

Main results

1.1 **Total agricultural emissions — CO_2-equivalent**



[a] excluding emissions from prescribed burning of savannas.

Data source: CIE estimates of agricultural activity levels applied to AGO emissions calculation worksheet.

Chart 1.1 summarises our baseline (solid red line) and range (dashed lines) of projections, as well as a special case of assuming the drought will extend to 2011.

Under the baseline, total emissions are expected to reach 81.9 Mt of CO_2-e in 2020 and 92.2 Mt of CO_2-e in 2030 (prescribed burning of savannas are not included in our projections). These represent an increase of 8.9 Mt CO_2-e in 2020 and an increase of 19.1 Mt CO_2-e in 2030 over the emissions level in 2008 (excluding emissions from prescribed burning of savannas), and an average annual growth rate of 1.06 per cent over the period between 2008 and 2030. The composition of these emissions is expected to remain roughly constant over time (table 1.2). Enteric fermentation has been and will be the dominant source of emissions, accounting for three quarters of the total agricultural emissions excluding those from prescribed burning of savannas.

1.2 **Composition of total agricultural emissions**

	2008	***2009***	***2010***	***2015***	***2020***	***2025***	***2030***
	%	%	%	%	%	%	%
Enteric Fermentation	75.65	75.23	74.98	74.12	73.94	73.85	73.80
Manure Management	4.42	4.39	4.30	4.39	4.45	4.46	4.47
Rice Cultivation	0.02	0.06	0.15	0.82	0.78	0.74	0.70
Agricultural Soils	19.49	19.80	20.03	20.02	20.12	20.20	20.24
Field burning of agricultural residues	0.42	0.52	0.54	0.65	0.70	0.75	0.80

Note: excluding emissions from prescribed burning of savannas.

Source: CIE estimates of agricultural activity levels applied to DCCEE emissions calculation worksheet.

Four pairs of additional scenarios have been simulated to analyse the impact of underlying assumptions of some key variables. They are:

- HD and LD: higher and lower demand for Australian agricultural products — they are represented by 10 per cent higher and lower of the assumed population and income growth in Australia and other countries in the baseline projection.
- HP and LP: higher and lower productivity growth — they are represented by 10 per cent higher and lower of the productivity improvement in Australia in the baseline projection
  - Another pair of sensitivity analyses was conducted to investigate the impact of simultaneous increase or decrease in productivities in both Australia and the rest of the world. The finding is that there will be negligible impact on Australian emissions. This is because the impacts of Australian productivity change are cancelled by the impacts of productivity changes overseas. For example, higher productivity improvement in Australia tends to improve Australia's competitiveness, but a simultaneous increase in productivity in other countries with the same magnitude improves our competitors' competitiveness as well. Other things equal, demand for Australian products would not change. Therefore we will not report the results of these simulations.
- HS and LS: higher and lower growth rate in slaughtering weight and milk yield per cow — they are represented by 10 per cent increase or decrease of the growth rate in Australia as assumed in the baseline projection.

- HPI and LPI: higher and lower input prices — they are represented by 10 per cent higher and lower of the input prices as assumed in the baseline projection.

Table 1.3 reports the percentage change in emissions (excluding emissions from prescribed burning of savannas) relative to baselines for these scenarios as well as the extended drought scenario and the high and low scenarios discussed above.

1.3 **Percentage change of different scenarios relative to the baseline**

	2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2020*	*2025*	*2030*
	%	%	%	%	%	%	%	%	%
HD: Higher demand	0.2	0.4	0.6	0.7	0.9	1.1	2.1	3.1	4.4
LD: Lower demand	-0.2	-0.3	-0.5	-0.7	-0.9	-1.0	-2.0	-2.9	-4.0
HP: Higher productivity in Australia	0.1	0.2	0.3	0.3	0.4	0.5	0.9	1.4	1.8
LP: Lower productivity in Australia	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.7
HS: Higher slaughtering weight/milk yield	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.5
LS: Lower slaughtering weight/milk yield	0.1	0.2	0.3	0.4	0.5	0.5	0.9	1.3	1.6
HPI: Higher input prices	-2.2	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1
LPI: Lower input prices	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1
Extended drought	-0.5	-3.4	-2.1	-1.6	-1.5	-1.5	-1.4	-1.4	-1.5
High	1.6	2.0	2.4	2.8	3.2	3.5	5.4	7.4	9.5
Low	-0.6	-3.4	-2.1	-1.6	-1.9	-2.2	-3.8	-5.6	-7.4

Source: CIE estimates of agricultural activity levels applied to DCCEE emissions calculation worksheet.

The high and low scenarios are, respectively, combinations of the other scenarios in the same directions in the impacts. For example, higher slaughtering weight and cow milk yield growth and higher input prices have negative impacts on emissions, and they are therefore components of the low scenario together with higher demand and higher productivity scenarios.

Under the high scenario, emissions are projected to reach 101 Mt CO_2-e in 2030 (9.5 per cent higher than the baseline). This represents an increase of 30 Mt CO_2-e over the 2009 level, and an average growth rate of 1.7 per cent per annum.

The high and low scenarios are not symmetric to the baseline. Under the low scenario, emissions are projected to reach 85.4 Mt CO_2-e in 2030, 7.4 per cent lower than the baseline. The pattern is similar for other pairs of scenarios: the magnitude of deviation of a higher emissions scenario to the baseline is generally higher than that of a lower emissions scenario. For example, under the higher demand scenario emissions in 2030 are projected to be 4.4 per cent higher than the baseline, while under the lower demand scenario emissions in 2030 are 4 per cent lower than the baseline.

This reflects the nonlinearity of the models used in the analyses. It is also a reflection of accumulated difference in growth rates.[1]

It is also important to note that the high and low estimates are not necessarily equally likely. From our perspective, increase in the underlying drivers, such as higher demand (HD) and higher productivity (HP), are less likely than decreases in the underlying drivers.

Table 1.3 also illustrates that variations in demand drivers tend to have a larger impact on emissions than do variations in productivities and other input side drivers.

We will discuss in more detail the baseline projections in chapter 2 and scenarios variations in chapter 3.

Differences with previous projections

The projections presented here – particularly when looking at overall activity levels — differ to those provided in our 2007 round of projections. In general, the activity levels in 2020 are lower than those in the previous round, with the exception of sheep numbers. The differences are mainly due to different base numbers, that is, the starting points, between these rounds of projections.

On top of the difference in base numbers, the other reason for the difference is the difference with the underlying assumptions. The United Nations revised its world population growth projections in 2008. Meanwhile, income growth prospects are consistently lower according to the latest projections from the International Monetary Fund due to the global financial crisis. In other words, demand for Australian agricultural products is lower in this round of projections than the previous round. We will discuss these differences in more detail in chapter 4.

Caveats and qualifications

There are three important issues that need to be kept in mind when interpreting forecasts of the kind provided in this report.

The first is the problem of inherent uncertainty. Deterministic projections of agricultural activity such as those produced here tend to project continual growth, continual decline, or stasis. In any of these cases, the projections typically do not look much like historical time series. The reason is simply the tendency in Australia for regular, but unpredictable, droughts that can significantly change production.

---

1 For example, growing at 2.2 per cent over 20 years would be 4 per cent higher than the baseline overall growth with a rate of 2 per cent per annum, while the accumulated growth of 1.8 per cent per annum over 20 years would be 3.85 per cent lower than baseline growth.

Activity never really moves along a straight line, but can vary considerably from year to year. Our projections, on the other hand, do not incorporate any of this stochastic influence.2 Thus they should be interpreted as providing an indication of the overall economic impetus in agriculture, rather than a specific projection in a specific year.

The scenarios we examine are designed to give some indication of the magnitude of variations that are possible.

The second problem is to do with the inherently inductive nature of forecasting. We observe, for example, that agricultural productivity has been increasing over a very long period of time. This tends to lead to the reasonable conclusion that productivity will continue to increase in the future — particularly when we observe resources being devoted to agricultural R&D, as well as the incentives for farmers to adopt productivity enhancing techniques. Strictly, however, there is no justification for this conclusion. There is no guarantee that productivity will continue to increase.

The third issue relates to the purpose for which the forecasts are generated. Typically, organizations are interested in obtaining projections because they intend to take some action based on those projections. If sales are projected to decline, the firm can act now to ensure the forecasts are never in fact realized. Of course, forecasts are only one element of the decision to act — the costs and benefits of different actions must also be weighted.

This may be relevant to the emissions projections as the government will revisit the climate change policies in this new parliament. Although it is not clear at this stage which policy targets and instruments the government will adopt, it is anticipated that it will take some action. Industries have also started formulating strategies to meet possibly more stringent requirement in the future. These may prevent the current projections, which assume no new climate policy and no fundamental structural changes in the projection period, from happening.

2 An exception is the projections for 2009 and 2010. We managed to model the impact of the drought on Australian agriculture because the drought is a realised event and some information about it has been revealed.

2 *Base results*

Overall results

Tables 2.1 and 2.2 summarise the overall emissions projections for the baseline scenario. It is important to note that emissions from prescribed burning of savannas are not included in the projections presented here.

2.1 **Baseline projections of agricultural emissions: summary**

IPCC Category	*4* *Total agriculture*	*4A* *Enteric fermentation*	*4B* *Manure management*	*4C* *Rice cultivation*	*4D* *Agricultural soils*	*4E* *Prescribed burning of savannas*	*4F* *Field burning of agricultural residues*
	Mt	Mt	Mt	Mt	Mt	Mt	Mt
2008	86.675	55.267	3.231	0.011	14.243	13.615	0.309
2009	71.065	53.461	3.123	0.042	14.070	0.000	0.368
2010	70.351	52.748	3.022	0.104	14.094	0.000	0.383
2011	73.170	54.527	3.109	0.530	14.567	0.000	0.437
2012	73.722	54.740	3.191	0.597	14.737	0.000	0.457
2013	75.076	55.639	3.270	0.642	15.047	0.000	0.478
2014	76.688	56.857	3.348	0.642	15.349	0.000	0.492
2015	77.811	57.669	3.420	0.642	15.575	0.000	0.505
2016	78.626	58.231	3.465	0.642	15.771	0.000	0.518
2017	79.436	58.805	3.514	0.642	15.943	0.000	0.531
2018	80.268	59.389	3.565	0.642	16.127	0.000	0.545
2019	81.095	59.981	3.606	0.642	16.306	0.000	0.560
2020	81.946	60.593	3.649	0.642	16.488	0.000	0.574
2021	82.862	61.256	3.691	0.642	16.684	0.000	0.589
2022	83.805	61.934	3.733	0.642	16.892	0.000	0.604
2023	84.769	62.627	3.777	0.642	17.104	0.000	0.620
2024	85.743	63.335	3.822	0.642	17.309	0.000	0.635
2025	86.744	64.064	3.868	0.642	17.519	0.000	0.652
2026	87.772	64.813	3.915	0.642	17.734	0.000	0.669
2027	88.826	65.580	3.963	0.642	17.955	0.000	0.686
2028	89.906	66.367	4.012	0.642	18.181	0.000	0.704
2029	91.022	67.181	4.063	0.642	18.414	0.000	0.722
2030	92.169	68.018	4.116	0.642	18.653	0.000	0.741

Note: Prescribed burning of savannas is not included in the projection.

Source: CIE projections of agricultural activities applied to DCCEE emissions spreadsheet.

2.2 Baseline projections of agricultural emissions: detail

	IPCC Category		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030
Disaggregated Greenhouse Results for Agriculture	**4**	**Total Agriculture**	86.67	71.07	70.35	73.17	73.72	75.08	76.69	77.81	78.63	79.44	80.27	81.09	81.95	86.74	92.17
	4A	**Enteric Fermentation**	55.27	53.46	52.75	54.53	54.74	55.64	56.86	57.67	58.23	58.81	59.39	59.98	60.59	64.06	68.02
	4A1	1. Cattle	43.91	42.90	42.22	44.03	44.06	44.78	45.83	46.63	47.18	47.75	48.32	48.90	49.49	52.56	56.06
	4A1a	Dairy Cattle	6.08	5.94	6.02	6.08	6.12	6.17	6.20	6.22	6.26	6.29	6.32	6.34	6.36	6.45	6.49
	4A1b	Grazing beef cattle	36.05	35.22	34.52	36.21	36.19	36.84	37.82	38.56	39.07	39.60	40.13	40.68	41.25	44.17	47.57
	4A1c	Grain fed cattle	1.78	1.74	1.67	1.74	1.74	1.77	1.81	1.84	1.85	1.86	1.87	1.88	1.89	1.94	2.01
	4A3	3. Sheep	11.28	10.50	10.47	10.43	10.61	10.79	10.95	10.97	10.97	10.98	10.99	11.00	11.02	11.41	11.86
	4A8	8. Swine	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.10
	4A2,4-7,9-10	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4B	**Manure Management**	3.23	3.12	3.02	3.11	3.19	3.27	3.35	3.42	3.47	3.51	3.57	3.61	3.65	3.87	4.12
	4B1	1. Cattle	1.46	1.43	1.40	1.45	1.45	1.47	1.49	1.51	1.52	1.53	1.53	1.54	1.55	1.59	1.63
	4B1a	Dairy Cattle	0.48	0.47	0.48	0.48	0.48	0.49	0.49	0.49	0.49	0.50	0.50	0.50	0.50	0.51	0.51
	4B1b	Grazing beef cattle	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
	4B1c	Grain fed cattle	0.96	0.94	0.91	0.94	0.94	0.96	0.98	1.00	1.00	1.01	1.01	1.02	1.02	1.05	1.09
	4B3	3. Sheep	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	4B8	8. Swine	1.20	1.11	1.06	1.09	1.14	1.19	1.22	1.25	1.27	1.30	1.32	1.34	1.36	1.47	1.58
	4B9	9. Poultry	0.57	0.58	0.56	0.57	0.60	0.62	0.64	0.65	0.67	0.69	0.71	0.72	0.74	0.81	0.90
	4B2,4-7,9-10	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4C	**Rice Cultivation**	0.01	0.04	0.10	0.53	0.60	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
	4D	**Agricultural Soils**	14.243	14.070	14.094	14.567	14.737	15.047	15.349	15.575	15.771	15.943	16.127	16.306	16.488	17.519	18.653
	4D (i)	Animal Production: Nitrogen excreted on pasture range and paddock	3.67	3.53	3.50	3.59	3.61	3.67	3.74	3.78	3.82	3.85	3.88	3.92	3.95	4.16	4.39
	4D (ii)	Direct soil emissions	4.60	4.81	4.86	5.07	5.18	5.34	5.47	5.59	5.69	5.79	5.89	5.98	6.08	6.62	7.21
	4D (iii)	Indirect soil emissions	5.98	5.73	5.74	5.91	5.94	6.04	6.14	6.20	6.26	6.31	6.36	6.41	6.45	6.74	7.05
	4E	**Prescribed burning of savannas**	13.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4F	**Field burning of agricultural residues**	0.31	0.37	0.38	0.44	0.46	0.48	0.49	0.50	0.52	0.53	0.55	0.56	0.57	0.65	0.74
		Wheat	0.11	0.17	0.17	0.18	0.18	0.19	0.20	0.20	0.21	0.22	0.22	0.23	0.24	0.27	0.32
		Maize	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
		Sugar Cane	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.08
		Other	0.10	0.09	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.14	0.16
		Rice	0.00	0.00	0.01	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07
		Pulse	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.08
		Peanuts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Other Crops	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Emissions from Livestock		**Total Livestock Emissions**	62.17	60.11	59.27	61.23	61.54	62.58	63.95	64.87	65.51	66.17	66.84	67.50	68.19	72.09	76.52
		Enteric Fermentation	55.27	53.46	52.75	54.53	54.74	55.64	56.86	57.67	58.23	58.81	59.39	59.98	60.59	64.06	68.02
		Manure Management	3.23	3.12	3.02	3.11	3.19	3.27	3.35	3.42	3.47	3.51	3.57	3.61	3.65	3.87	4.12
		Agricultural Soils	3.67	3.53	3.50	3.59	3.61	3.67	3.74	3.78	3.82	3.85	3.88	3.92	3.95	4.16	4.39
Emissions from Crops		**Total Crop Emissions**	10.89	10.95	11.09	11.94	12.18	12.50	12.74	12.94	13.11	13.27	13.43	13.59	13.75	14.66	15.65
		Rice Cultivation	0.01	0.04	0.10	0.53	0.60	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
		Agricultural Soils	10.57	10.54	10.60	10.98	11.13	11.38	11.61	11.79	11.95	12.09	12.24	12.39	12.54	13.36	14.26
		Field burning residues	0.31	0.37	0.38	0.44	0.46	0.48	0.49	0.50	0.52	0.53	0.55	0.56	0.57	0.65	0.74

Source: CIE projections of agricultural activities applied to DCCEE emissions spreadsheet.

A major feature of these numbers is the importance of livestock industries in overall agricultural emissions, accounting for more than 80 per cent of the total.

Meat industries

Basic economic mechanisms

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

- the growth in demand for meat products; and
- the weight of the animal concerned.

For a given growth in demand, the resulting number of animals required to meet this demand depends on the projected growth in the weight of the animals.

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.

Chapter 4 discusses the underlying exogenous assumption in detail, however two key points are important.

- First, income and population growth in our key current and emerging markets are assumed to be quite strong, leading to increasing demand for a range of Australia's meat products.
- Second, the scope for ongoing productivity growth in Australia is assumed to be very good, particularly when compared with our key competitors.

Meat production

Table 2.3 summarise the baseline projections of meat production. Compared with historical trends, these projections do not imply any slowing of previous growth. Beef, sheep, pigs and poultry meats are expected to grow by 2.2, 1.1, 2.4 and 3.6 per cent per annum, respectively.

2.3 Projected meat production: baseline

	2009	2010	2011	2012	2013	2014	2015	2020	2025	2030	CAGR
	kt	kt	kt	kt	kt	kt	kt	kt	kt	kt	%
Beef											
Grass fed	1630.8	1648.3	1742.6	1755.2	1800.6	1862.7	1913.8	2127.7	2367.8	2649.8	2.3
Grain fed	425.9	423.4	444.2	447.5	457.9	471.7	485.1	515.5	552.3	593.0	1.6
Live	168.2	170.9	177.5	179.4	183.4	188.4	192.8	217.8	248.5	283.8	2.5
Sheep											
Lamb	434.8	446.6	460.6	475.3	489.5	503.2	511.1	549.2	590.3	636.2	1.8
Mutton	214.2	188.8	176.2	176.5	176.9	177.4	174.2	159.3	164.9	171.1	-1.1
Live	88.4	84.5	87.2	89.7	92.1	94.2	96.1	105.8	115.5	126.4	1.7
Pigs	375.0	369.5	383.3	405.1	422.1	436.9	450.2	506.3	560.1	622.4	2.4
Poultry	850.0	851.3	882.6	932.7	978.5	1024.4	1071.0	1287.0	1518.2	1803.9	3.6

Source: CIE GMI model.

Despite strong growth in other meat products, mutton is projected to fall by 1.1 per cent per annum. This is mainly due to the assumption no long run productivity in mutton production (see table 4.5 below). As a result, this product becomes relatively more expensive compared to the price of other products, leading to less demand.

Compared with the 2007 round projections, beef production in 2020 is 8.6 per cent lower than the previous projections, while sheep production in the same year is 7.7 per cent higher. Pig and poultry meat productions are roughly similar between these two projections, with this round projection being 1.1 per cent lower for pig meat and 0.5 per cent higher for poultry meat. There are several factors contributing to these differences:

- The bases are different. Productions in 2009 in the current round projection are lower than the 2007 round projections for beef, pigs and poultry meats, and higher for sheep meat.
- The productivity growth assumptions are different. For example, beef productivity growth in Australia was assumed at 1.5 per cent per annum in the 2007 round projection, while it is 1 per cent for grass fed and 0.5 per cent for grain fed in the current round. Similarly, productivity growth in sheep meat production is 0.5 percentage point lower in the current projection.
- The demand growth represented by population and income growth is different. In general, population growth assumption is slightly higher in the current projection.

There are considerable structural changes in the destinations to which Australian production is targeted. Table 2.4 reports the relative growth in exports of various Australian meat products to different destinations. Exports to Asian countries except Japan and South Korea are projected to grow more significantly than on average. It should be also noted that some big numbers in percentage change may be due to very small value in the base year, for example, pigs exports to Indonesia and grass fed beef export to Mexico.

2.4 Average annual growth in Australian meat exports by destinations, 2005 to 2030

	Grass fed beef	*Grain fed beef*	*Sheep*	*Pigs*	*Poultry*
	%	%	%	%	%
New Zealand	7.6		-2.1	3.6	
United States	-2.1		-0.3		
Canada	-0.9		-0.4		
Japan	1.2	1.1	-1.1	3.0	
South Korea	-3.4	-2.4	-8.3	-1.8	
Taiwan	2.1		1.6		
Hong Kong	1.3		1.7	1.9	7.1
Singapore	0.9		2.5	-1.5	
Malaysia	13.1		8.5	8.8	
Indonesia	9.2		2.2	39.9	
Thailand	5.7		4.6		
Philippines	10.8		5.8	12.3	13.0
China	1.7		3.4	-4.6	3.8
European Union	9.5		9.0		
Mexico	-202.6		1.3		
Other	8.1	3.5	-1.2	11.5	16.4

Note: Big changes in percentage are due to small base value, e.g. grass fed beef exports to Mexico.
Source: CIE GMI model.

In the cases of grass fed beef and lamb and mutton, this point is further illustrated by table 2.5 which shows the changes in the composition of Australian exports to major destinations. For example, the share of grass fed beef export to Japan in total exports will decline from 29.2 per cent in 2020 to 11.7 per cent in 2030. The importance of the United States market will be declining from 34 per cent in 2009 to 25.9 per cent in 2020 and to 11.7 per cent in 2030. By contrast, the share of Australian exports to other Asian countries will grow from 29 per cent in 2009 to 49.2 per cent.

2.5 Structure of Australian export markets

	Grass fed beef			*Lamb and mutton*		
	2009	*2020*	*2030*	*2009*	*2020*	*2030*
	%	%	%	%	%	%
Japan	28.5	29.2	19.4	6.5	5.2	3.6
United States	34.0	25.9	11.7	15.6	13.5	10.2
Other Asia	29.0	30.2	49.2	21.0	24.5	33.5
Rest of the World	8.4	14.6	19.8	56.9	56.7	52.7

Source: CIE GMI model.

Many factors contribute to this structural change of Australian exports. A couple of them are mostly notable:

- Changes in overall demand. This is most obvious in the case of Japan. Japan's total demand for meat products is projected to grow at much slower pace than the world average, mainly due to its falling population (see table 4.1 below for population assumptions).
- Competition from other producers. For example, Australian grass fed beef will face strong competition in the United States market from South American products because the productivity in these countries is assumed to grow more faster than in Australia (see table 4.5 below for the long term productivity assumptions).

Number of cattle

Table 2.6 summarises the projected beef cattle numbers that result from expected meat demands. Grass fed cattle numbers are projected to increase to 25.3 million by 2015, to 27.06 million by 2020 and to 31.21 million by 2030. This represents an average annual growth rate of 1.4 per cent between 2009 and 2030.

2.6 **Projected beef cattle numbers** (million head)

	2009	*2010*	*2011*	*2012*	*2013*	*2015*	*2020*	*2030*
Grass fed cattle								
NSW/ACT	4.92	4.82	5.06	5.05	5.15	5.39	5.76	6.64
TAS	0.43	0.42	0.45	0.45	0.45	0.47	0.51	0.59
WA - South West	1.03	1.01	1.06	1.06	1.08	1.13	1.21	1.39
WA - Pilbara	0.41	0.40	0.42	0.42	0.43	0.45	0.48	0.55
WA - Kimberley	0.46	0.45	0.47	0.47	0.48	0.51	0.54	0.62
SA	0.90	0.89	0.93	0.93	0.95	0.99	1.06	1.22
VIC	2.12	2.08	2.18	2.18	2.22	2.33	2.49	2.87
QLD	10.83	10.62	11.14	11.13	11.33	11.86	12.69	14.63
NT	1.99	1.95	2.05	2.05	2.09	2.18	2.33	2.69
Total	*23.11*	*22.65*	*23.76*	*23.75*	*24.17*	*25.30*	*27.06*	*31.21*
Grain fed cattle								
NSW/ACT	0.29	0.28	0.30	0.30	0.30	0.31	0.32	0.34
TAS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WA	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
SA	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
VIC	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.09
QLD	0.63	0.60	0.63	0.63	0.64	0.67	0.68	0.73
NT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	*1.07*	*1.03*	*1.07*	*1.07*	*1.09*	*1.14*	*1.16*	*1.24*

Source: CIE GMI model

Grain fed cattle numbers are projected to increase to 1.14 million by 2015 and to 1.24 million by 2030. This represents an average annual growth rate of 0.7 per cent between 2009 and 2030.

The growth in beef cattle numbers is smaller than the beef production growth (table 2.3) due to the assumption of growing slaughtering weight (see table 4.3 below for details).

Comparison with previous projections

In the 2007 round projections, we projected grass fed cattle numbers of 28.59 million and grain fed cattle numbers of 1.58 million in 2020. The current projections for cattle numbers in 2020 are 5.3 per cent lower for grass fed and 26.5 per cent lower for grain fed.

As discussed above, the discrepancies in projections between the two rounds are mainly due to different base values. The grass fed and grain fed cattle numbers for 2008 provided by the Department for the current projection are 2 and 20 per cent, respectively, lower than those in the previous round. The numbers for 2009 in the statistics are 6.9 and 24 per cent, respectively, lower than the numbers in the previous round.

Numbers of sheep, pigs and poultry

Table 2.7 summarises the projected numbers for sheep, pigs and poultry.

Sheep numbers are projected to decline to 71.56 million in 2009 and to 71 million in 2011 before rising from 2012. The number will recover to the level of 2008 around 2023, and further grow to 80.8 million by 2030. The average annual growth rate between 2009 and 2030 is 0.6 per cent. The slow growth in sheep numbers reflects the slow growth in sheep meat demand, which in turn is determined by the assumed slower growth in sheep meat productivity compared to other Australian meats.

Pig numbers are projected to reach 2.75 million by 2020 and 3.19 million by 2030, representing an average annual growth rate of 1.7 per cent between 2009 and 2030. This is consistent with the historical growth.

Poultry numbers are projected to reach 116.9 million by 2020 and 143.9 million by 2030. This represents an average annual growth rate of 2.1 per cent between 2009 and 2030. This growth rate is consistent with historical data, although fluctuations occurred over time.

2.7 **Projected sheep, pigs and poultry numbers** (million head)

	2009	*2010*	*2011*	*2012*	*2013*	*2015*	*2020*	*2030*
Sheep								
NSW/ACT	25.08	25.01	24.91	25.35	25.77	26.19	26.32	28.32
TAS	2.03	2.02	2.01	2.05	2.08	2.12	2.13	2.29
WA	15.52	15.47	15.41	15.68	15.94	16.21	16.29	17.52
SA	10.06	10.03	9.99	10.17	10.34	10.51	10.56	11.36
VIC	14.79	14.74	14.69	14.95	15.19	15.44	15.52	16.70
QLD	4.10	4.09	4.07	4.14	4.21	4.28	4.30	4.63
NT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	*71.56*	*71.36*	*71.08*	*72.34*	*73.54*	*74.75*	*75.12*	*80.83*
Pigs								
NSW/ACT	0.71	0.68	0.70	0.74	0.76	0.80	0.88	1.02
TAS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
WA	0.24	0.23	0.24	0.25	0.26	0.27	0.30	0.35
SA	0.34	0.32	0.33	0.35	0.36	0.38	0.41	0.48
VIC	0.37	0.35	0.36	0.38	0.39	0.41	0.45	0.52
QLD	0.57	0.54	0.55	0.58	0.60	0.64	0.70	0.81
NT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	*2.24*	*2.13*	*2.19*	*2.30*	*2.39*	*2.52*	*2.75*	*3.19*
Poultry								
NSW/ACT	34.16	33.03	33.74	35.12	36.30	38.61	43.35	53.35
TAS	1.22	1.18	1.21	1.26	1.30	1.38	1.55	1.91
WA	7.35	7.10	7.26	7.55	7.81	8.30	9.32	11.47
SA	6.91	6.68	6.82	7.10	7.34	7.81	8.76	10.79
VIC	27.73	26.81	27.38	28.50	29.46	31.33	35.18	43.30
QLD	14.73	14.25	14.55	15.14	15.65	16.65	18.70	23.01
NT	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04
Total	*92.13*	*89.08*	*90.98*	*94.70*	*97.89*	*104.12*	*116.91*	*143.88*

Source: CIE GMI model.

Comparison with previous projections

Compared with the 2007 round projections, the current projected sheep numbers are 24.5 per cent lower for 2020. This is due to a lower base value and the assumption of slower productivity growth. The base number of 2009 in the current projection is 19 per cent lower than the 2009 number in the previous projection. The assumed productivity growth rates in the current round are half a percentage point lower than those assumed in the previous round.

Compared to the 2007 projection results, the pig numbers in 2020 is 2.5 per cent lower, despite a much lower base value (13.5 per cent lower in 2009). The quicker growth are driven by the reinforcing factors — relatively higher productivity growth compared to those assumed for other meat products, and lower growth in slaughtering weight compared to that assumed in the previous round.

The projected poultry number in 2020 by this round projection is 5.8 per cent higher than the number in the 2007 round projection. This is again mainly due to two factors: higher base value (the number in 2009 is 3.4 per cent higher than that in the previous round) and higher productivity growth than other sectors which leads to higher growth in the sector.

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.

Production of milk and milk products

Table 2.8 shows projected milk production in selected years. Overall, milk production is expected to grow at 2.7 per cent per annum between 2009 and 2030. This average growth rate is broadly consistent with historical data.

2.8 **Projected milk production by state**

	2009	*2010*	*2011*	*2012*	*2013*	*2015*	*2020*	*2030*	*CAGR*
	Million lt	Million lt	Million lt	Million lt	Million lt	Million lt	Million lt	Million lt	%
NSW	1064.6	1100.1	1133.0	1166.0	1199.8	1265.8	1419.9	1722.8	2.3
VIC	6134.8	6417.6	6680.2	6941.8	7210.0	7721.6	8874.3	11175.0	2.9
QLD	511.9	524.9	537.7	551.0	564.9	592.9	658.6	784.8	2.1
SA	627.9	650.3	671.2	691.9	713.1	753.9	848.4	1034.5	2.4
WA	340.5	351.6	362.2	373.0	384.3	406.5	458.6	560.7	2.4
TAS	708.4	737.6	764.4	790.5	816.6	865.2	973.8	1192.1	2.5
Total	9388.2	9782.1	10148.7	10514.3	10888.7	11605.8	13233.6	16469.8	2.7

Source: CIE Dairy model

In the 2007 round, milk production was projected to reach 12.1 billion litres by 2015 and 14 billion litres by 2020. Thus the current projections are 4.2 per cent lower for the 2015 estimates and 5.6 per cent lower for the 2020 estimates. This is mainly due to lower base numbers.

Table 2.9 summarises the projected use of Australian milk. Because milk products have different raw-milk-equivalents, use is expressed as an index. Domestic use is projected to grow moderately in line with the population growth during the period. By contrast, export growth is projected to be considerably higher, reflecting higher demand from overseas and the maintenance of Australia’s competitiveness on world markets.

2.9 **Projected use of Australian milk, index of quantity**

	2009	*2010*	*2011*	*2012*	*2013*	*2015*	*2020*	*2030*	*CAGR*
Domestic									
▪ Fresh	100.0	101.2	102.3	103.4	104.5	106.6	111.7	120.7	0.9
▪ UHT	100.0	100.0	99.9	99.8	99.6	99.1	97.8	93.1	-0.3
▪ Manufactured	100.0	100.6	101.1	101.6	102.1	103.0	105.9	111.6	0.5
Exports									
▪ UHT	100.0	125.9	150.9	176.6	203.2	256.2	388.8	691.8	9.6
▪ Manufactured	100.0	111.9	122.8	133.7	145.1	166.6	214.1	309.3	5.5

Source: CIE Dairy model.

Dairy cattle numbers

Table 2.10 summarises projected dairy cattle numbers. By 2030, total number of dairy cattle is expected to reach 2.7 million, representing an average growth rate of 0.4 per cent between 2009 and 2030. This growth rate is in line with the historical average.

2.10 **Projected dairy cattle numbers by state**

	2009	*2010*	*2011*	*2012*	*2013*	*2015*	*2020*	*2030*	*CAGR*
	‘000/head	‘000/head	‘000/head	‘000/head	‘000/head	‘000/head	‘000/head	‘000/head	%
NSW/ACT	322	323	324	324	324	324	326	324	0.04
TAS	218	221	223	224	225	226	228	229	0.23
WA	87	87	87	87	88	88	89	89	0.13
SA	179	180	181	181	182	182	183	184	0.13
VIC	1528	1555	1574	1591	1608	1629	1680	1735	0.61
QLD	144	143	143	142	142	141	140	137	-0.22
NT	1	1	1	1	1	1	1	1	0.00
Total	2478	2510	2533	2552	2570	2591	2647	2699	0.41

Source: CIE Dairy model.

Comparison with previous projections

The 2007 round projection estimated that total dairy cattle number would reach 3.1 million by 2020. Thus the current projection for 2020 is 15.6 per cent lower than the previous one. This is mainly due to two reasons. The base value for 2009 in the current projection is 9.2 per cent lower than the previous one. On top of that, a higher growth in milk yield per cow is assumed in this round of projection.

Grain industry

Grain output

Table 2.11 summarises grain production in selected years. Total wheat production is projected to reach 29.2 million tonnes by 2020 and 39.4 million tonnes by2030, representing an average growth rate of 3.1 per cent per annum between 2009 and 2030.

Barley production is projected to reach 10.5 million tonnes by 2020 and 13.9 million tonnes by 2030, representing an average growth rate of 2.9 per cent per annum between 2009 and 2030.

Other coarse grains are projected to reach 6.8 million tonnes by 2020 and 8.9 million tonnes by 2030, representing an average growth rate of 2.9 per cent per annum between 2009 and 2030.

Comparison with previous projections

Compared to the 2007 round projections, the current projections are 17.4 per cent and 10.5 per cent lower, respectively, for wheat and barley in 2020. The difference is due to the lower base values — production of wheat and barley in 2009 are 18.5 per cent and 22.2 per cent, respectively, lower than those in the previous round of projection.

2.11 **Projected grain production, kt**

	2009	***2010***	***2011***	***2012***	***2013***	***2015***	***2020***	***2030***	***CAGR***
	Kt	Kt	Kt	Kt	Kt	Kt	Kt	Kt	%
Wheat									
NSW/ACT	6861	6917	7136	7357	7657	8151	9522	12855	3.04
TAS	35	35	36	38	39	42	49	66	3.06
WA	8161	8279	8544	8841	9243	9823	11441	15380	3.06
SA	2376	2394	2471	2547	2652	2825	3305	4470	3.05
VIC	1724	1738	1793	1849	1925	2051	2400	3248	3.06
QLD	1781	1794	1851	1907	1983	2113	2471	3345	3.05
NT	0	0	0	0	0	0	0	0	3.05
Total	*20938*	*21157*	*21832*	*22539*	*23499*	*25005*	*29187*	*39363*	*3.05*
Barley									
NSW/ACT	1435	1456	1497	1543	1603	1694	1952	2589	2.85
TAS	28	28	29	30	31	33	38	51	2.88
WA	2808	2862	2945	3044	3174	3351	3852	5094	2.88
SA	1855	1881	1936	1996	2074	2194	2532	3364	2.87
VIC	1387	1405	1446	1490	1548	1638	1891	2516	2.88
QLD	155	157	162	167	174	184	212	281	2.87
NT	0	0	0	0	0	0	0	0	
Total	*7668*	*7790*	*8016*	*8270*	*8604*	*9094*	*10477*	*13894*	*2.87*
Other coarse grain									
Maize	368	371	383	395	411	437	508	681	2.97
Oats	1206	1220	1258	1300	1356	1439	1672	2237	2.99
Sorghum	2671	2693	2777	2863	2978	3165	3683	4940	2.97
Triticale	503	508	524	541	563	598	696	932	2.98
Millet	23	24	24	25	26	28	32	43	2.98
Rye	18	18	19	20	20	22	25	34	2.98

Source: CIE Grain model.

Other crops

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

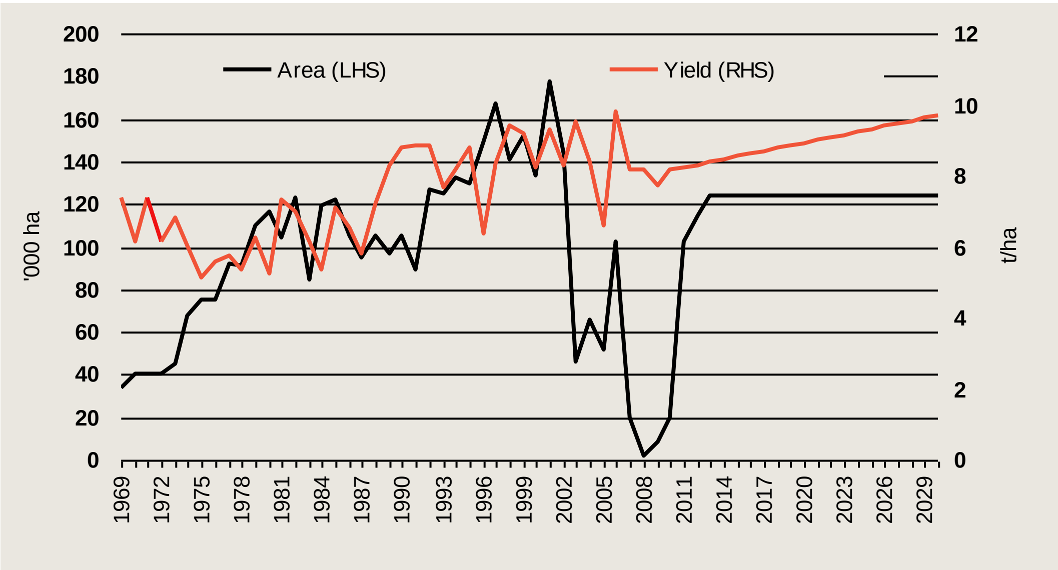
Rice

Chart 2.12 reports the historical data of rice cultivation area and yield in Australia from 1969 to 2009 and our assumptions about their future values to 2030.

The area of cultivation under rice had been increasing since until 2002 when it fell sharply due to the drought. We assume the area will recover with the drought condition is 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 level in the 1980's and 1990's. 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 assumption is broadly consistent with the modelling results of ABARE-BRS (2010a,b) that a 3500GL sustainable diversion limits in the Murray-Darling Basin would see rice area fall by between 20 and 31.6 per cent depending on the scenarios.

Despite fluctuation over time, rice yield has been trending upwards. The average annual increment in yield is about 76.9 kg per ha. We assume the trend continues into the future. With this assumption, the yield in 2030 will be 9.69 ton/ha, slightly lower than the record level of 9.83 ton/ha in 2006.

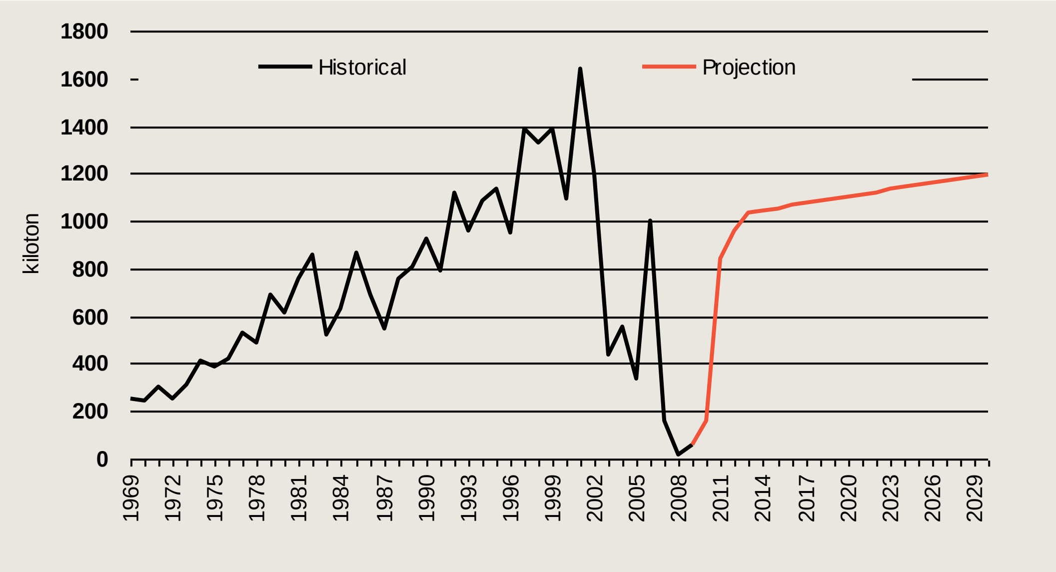
2.12 **Rice cultivation area and yield**



Data source: ABARE Australian Commodity Statistics; DCCEE Inventory data; CIE assumptions.

With the above assumptions, the rice production is projected to 1.1 million ton by 2020 and 1.2 million ton by 2030 (chart 2.13).

2.13 **Rice production**



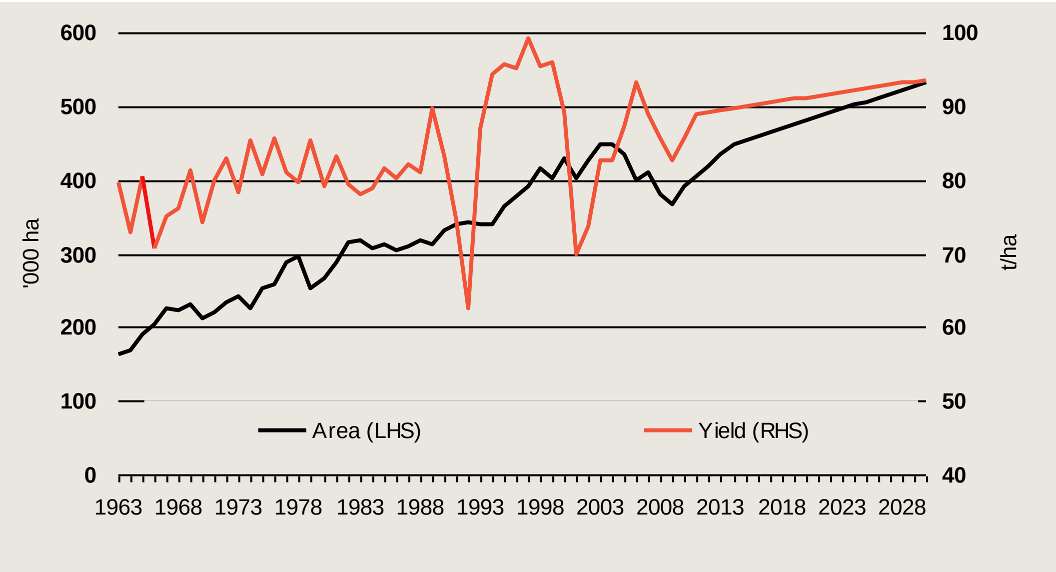
Data source: ABARE Australian Commodity Statistics; DCCEE Inventory data; CIE estimates.

Sugar

Chart 2.14 reports the historical data of sugarcane cultivation area and cane yield in Australia from 1963 to 2009, and our assumptions about their future values to 2030.

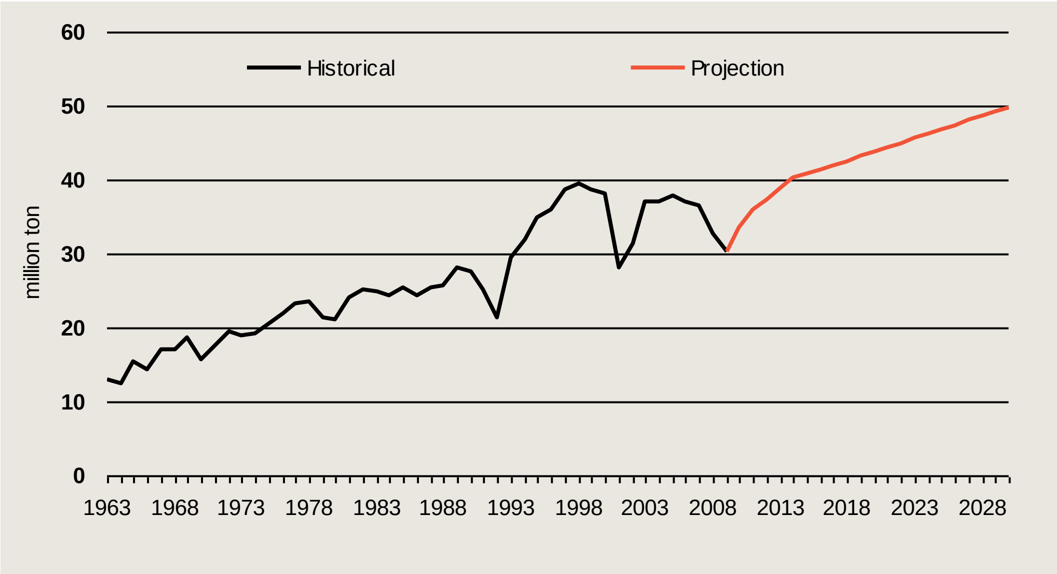
Sugarcane area did not fall as much as the rice area in the recent drought. This is due to higher world demand for biofuel in the past few years. The long run trend has been about 5000ha increment every year. It is therefore assumed that this long run trend will continue after a relatively quick recovery period between 2010 and 2014.

2.14 **Sugarcane cultivation area and cane yield**



Data source: ABARE Australian Commodity Statistics; DCCEE Inventory data; CIE assumptions.

2.15 **Sugarcane crushed**



Data source: ABARE Australian Commodity Statistics; DCCEE Inventory data; CIE estimates.

The cane yield has been increasing by 240 kg/ha per annum on average since 1960s despite significant fluctuation in the last two decades. It is assumed this trend will continue after a relatively quicker recovery period between 2010 and 2014.

With these assumptions, it is projected that the cane crushed will reach 43.7 million tonnes by 2020 and about 50 million tonnes by 2030 (chart 2.15).

Cotton

As shown in chart 2.16, it is assumed that the cotton area will recover to about 435,000 ha by 2016 and stay at that level during the remaining projection period. This level reflects a 16 per cent reduction from its peak levels between 1999 and 2001, which is consistent with the modelling results of ABARE-BRS (2010a,b) that a 3500GL of sustainable diversion limits (SDL) would see the land use of cotton fall by 16 per cent.

Fertiliser use

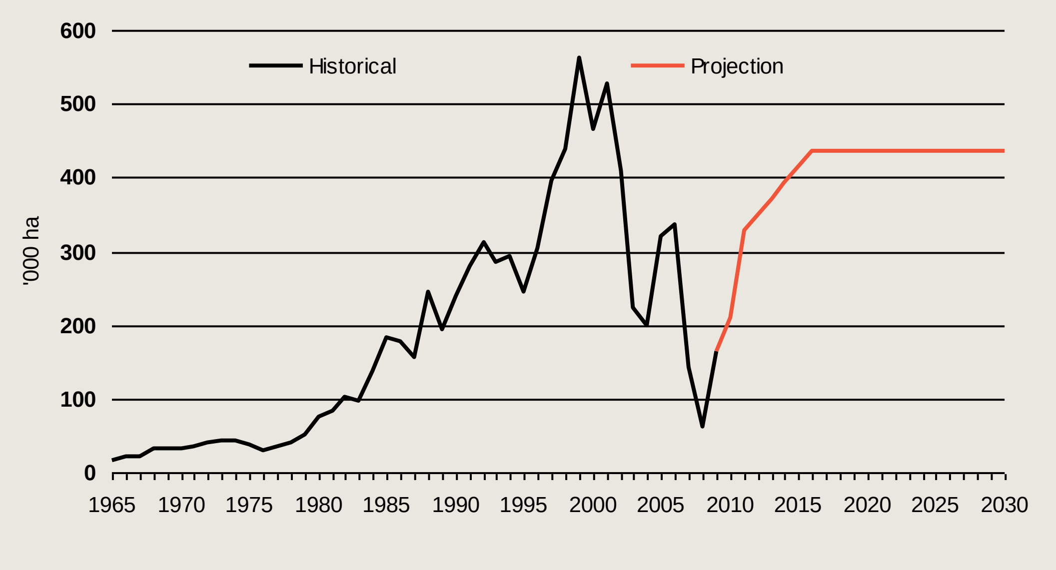
Fertiliser use in pasture is estimated using the simulation result from the GMI model. Total fertiliser use is determined by the meat production, grazing animal numbers and fertiliser use efficiency in pasture land.

In our grain 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 grain, 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 2.17 reports the fertiliser use in selected years and the comparison with the 2007 round projections.

2.16 **Cotton area**



Data source: ABARE Australian Commodity Statistics; DCCEE Inventory data; CIE assumptions.

2.17 **Fertiliser use**

	2009	***2010***	***2011***	***2012***	***2013***	***2015***	***2020***	***2030***	***CAGR***
	Kt	Kt	Kt	Kt	Kt	Kt	Kt	Kt	%
Irrigated pasture	22.4	21.8	22.5	22.9	23.5	24.8	26.9	32.2	1.7
Irrigated crops	39.4	39.8	40.2	40.6	41.5	42.3	44.4	48.4	1.0
Non-irrigated pasture	228.0	221.7	229.5	233.8	239.8	252.3	274.5	328.2	1.7
Non-irrigated crops	383.3	387.2	391.2	395.3	403.4	411.3	431.6	471.3	1.0
Sugar	65.3	71.4	75.9	77.9	79.9	82.0	82.6	82.1	1.1
Cotton	37.0	46.0	68.7	72.6	76.7	84.9	90.0	96.4	4.7
Vegetable crops	65.4	70.2	72.6	74.5	75.9	78.0	81.7	88.6	1.5
Total	840.9	858.1	900.6	917.7	940.6	975.5	1031.8	1147.2	1.5
The 2007 round	1058.3	1071.3	1084.4	1097.6	1109.9	1128.9	1156.2		
current over 2007	-20.5	-19.9	-16.9	-16.4	-15.3	-13.6	-10.8		

Source: CIE estimates.

Total fertiliser use is estimated to reach 1032kt by 2020 and 1147kt by 2030, representing an average growth rate of 1.5 per cent per annum.

Compared to the 2007 round projection, the fertiliser use in 2009 is 20.5 per cent lower and will be 10.8 per cent lower in 2020.

3 Scenarios

Purpose and description of scenarios

In order to assess the importance of the key underlying assumptions that comprise our baseline estimates, we have undertaken simulations for 11 additional scenarios.[3] These scenarios are defined as follows:

- HD and LD: higher and lower demand for Australian agricultural products — they are represented by 10 per cent higher and lower of the assumed population and income growth in Australia and other countries in the baseline projection.
- HP and LP: higher and lower productivity growth — they are represented by 10 per cent higher and lower of the productivity improvement in Australia in the baseline projection
  - Another pair of sensitivity analyses was conducted to investigate the impact of simultaneous increase or decrease in productivities in both Australia and the rest of the world. The finding is that there will be negligible impact on Australian emissions. This is because the impacts of Australian productivity change are cancelled by the impacts of productivity changes overseas. For example, higher productivity improvement in Australia tends to improve Australia's competitiveness, but a simultaneous increase in productivity in other countries with the same magnitude improves our competitors' competitiveness as well. Other things equal, demand for Australian products would not change. Therefore we will not report the results of these simulations.
- HS and LS: higher and lower growth rate in slaughtering weight and milk yield per cow — they are represented by 10 per cent increase or decrease of the growth rate in Australia as assumed in the baseline projection.
- HPI and LPI: higher and lower input prices — they are represented by 10 per cent higher and lower of the input prices as assumed in the baseline projection.
- XD: extended drought — the current drought will extend to 2011 with similar severity and recovery in 2012.
- High and Low: the combination of the above scenarios with the same direction in impacts on emissions. More specifically,

3 In fact we have conducted more simulations to identify the important driving factors.

– High scenario combines HD, HP, LS and LPI; and
– Low scenarios combines LD, LP, HS, HPI and XD.

For the spreadsheet models of rice, sugar, cotton and vegetables, the scenarios are formulated in a similar way, but implemented as different combinations of impacts on cropping areas, yields and fertiliser application rates. For example, under the higher demand scenario, rice cultivation areas will increase above the baseline level, while under the higher productivity scenario, the yield will be higher than the baseline level. The magnitudes of these deviations are approximate and drawn from the aggregate impacts implied by the formal Grain model. Because their share in total emissions is very small, these approximations would not affect the results very much.

The variations that comprise these scenarios can be interpreted in two broad ways. First, future rates of demand and productivity growth are uncertain. The variations in the scenarios are designed to capture this uncertainty. On the down side, lower productivity growth could result from drought, disease, research failures, environmental problems (salinity), pest and weed resistance and a wide variety of other factors. Lower demand growth could result from lower population growth than expected, slower recovery form the recent global financial crisis, recession in key export destination countries, taste shifts away from Australian products or a sudden increase in competition in export markets. In the case of beef it could also be the result of unexpected events such as the outbreak of foot and mouth disease or BSE.

The second interpretation of use of these scenarios is to capture the fact that underlying parameters in the models — the responses of producers and consumers to price and income changes, for example — are also uncertain. Changed rates of productivity and demand growth can also be used as a proxy for this sort of parameter uncertainty.

Key mechanisms in the scenarios

Demand side changes are in effect increases in willingness to pay, and so producers experience a price increase and they are able to increase output to the extent to which they are able to purchase and use the necessary inputs (that is, to the extent of their supply elasticity).

The productivity related scenarios involve changing the inputs required to produce a unit of output. These inputs include land, labour, capital and materials. Reduced productivity, for example, means that the purchase of the same amount of inputs will result in lower output (equivalently, the same output can only be produced with more inputs). A productivity decline is therefore broadly equivalent to a cost increase, and unless consumers are willing to pay more to cover this cost increase, producers will be forced to reduce output. The reverse is true in the case of a productivity improvement. As a result, output and therefore emissions move in the same direction as the productivity change.

While in general emissions move in the same direction as the productivity change, a special form of productivity change affects emissions in the other way. This is the slaughtering weight per animal or the milk production per cow. Higher (lower) slaughtering weight or milk yield means less (more) animals are required to produce the same amount of meat or milk, and thus less (more) emissions.

Changes in emissions by scenario

Tables 3.1 and 3.2 report the changes in emissions in 2030, relative to the baseline, for each of the scenarios. We will focus on discussing changes in emissions in 2030 for all the scenarios, as by then the differences are the greatest. However, exactly the same story emerges by comparing results in other years.

3.1 **Deviation from baseline emissions in 2030**

	Total	*Enteric Fermentation*	*Manure Management*	*Rice Cultivation*	*Agricultural Soils*	*Field burning of agricultural residues*
	Mt	Mt	Mt	Mt	Mt	Mt
HD	**4.01**	3.12	0.20	0.02	0.65	0.02
LD	**-3.71**	-2.88	-0.19	-0.02	-0.61	-0.02
HP	**1.67**	1.20	0.09	0.00	0.34	0.03
LP	**-1.58**	-1.14	-0.08	0.00	-0.32	-0.03
HS	**-1.40**	-1.22	-0.08	0.00	-0.10	0.01
LS	**1.49**	1.29	0.09	0.00	0.12	-0.01
HPI	**-1.95**	-1.50	-0.12	0.02	-0.34	-0.01
LPI	**1.91**	1.46	0.11	-0.02	0.34	0.01
XD	**-1.34**	-0.94	-0.06	0.00	-0.32	-0.03
High	**8.79**	6.79	0.47	0.02	1.46	0.05
Low	**-6.78**	-5.20	-0.35	-0.02	-1.16	-0.05

Source: CIE estimates of activity levels applied to DCCEE emissions spreadsheet.

Table 3.1 reports changes in total emissions (in the first column) as well as changes in the composition of emissions in subsequent columns. Table 3.2 gives more detailed breakdown of the changes. Under Scenario HD (higher demand), for example, total emissions are 4.01 Mt highr in 2030 than under the baseline. This is composed of a 3.12 Mt rise due to enteric fermentation sources of emissions, with most of the remainder from agricultural soil related emissions. The enteric fermentation rise is in turn made up of a 2.60 Mt rise from grazing beef cattle, a 0.37 Mt rise from sheep, and most of the remainder from a rise in dairy cattle.

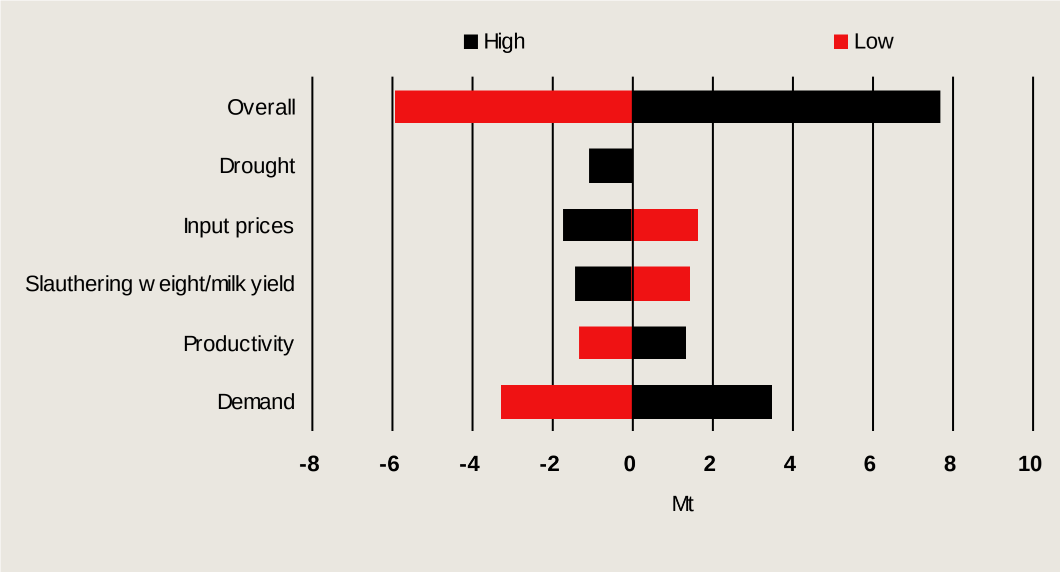
Charts 3.3and 3.4 illustrate changes in livestock and crop emissions in 2030 under different scenarios.

3.2 Deviation from baseline emissions in 2030: detailed breakdown

	HD	*LD*	*HP*	*LP*	*HS*	*LS*	*HPI*	*LPI*	*XD*	*High*	*Low*
	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt
Enteric Fermentation	***4.01***	***-3.71***	***1.67***	***-1.58***	***-1.40***	***1.49***	***-1.95***	***1.91***	***-1.34***	***8.79***	***-6.78***
Dairy cattle	0.05	-0.02	0.23	-0.18	-0.28	0.33	-0.02	0.01	-0.14	0.63	-0.54
Grazing beef cattle	2.60	-2.42	0.88	-0.86	-0.75	0.76	-1.25	1.23	-0.62	5.21	-3.94
Grain fed cattle	0.09	-0.09	0.02	-0.02	-0.03	0.03	-0.05	0.05	-0.03	0.18	-0.13
Sheep	0.37	-0.35	0.08	-0.08	-0.17	0.17	-0.17	0.16	-0.15	0.76	-0.58
Swine	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.01
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manure Management	***0.20***	***-0.19***	***0.09***	***-0.08***	***-0.08***	***0.09***	***-0.12***	***0.11***	***-0.06***	***0.47***	***-0.35***
Diary cattle	0.00	0.00	0.02	-0.01	-0.02	0.03	0.00	0.00	-0.01	0.05	-0.04
Grazing beef cattle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grain fed cattle	0.05	-0.05	0.01	-0.01	-0.02	0.02	-0.03	0.03	-0.01	0.10	-0.07
Sheep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Swine	0.08	-0.08	0.03	-0.03	-0.02	0.02	-0.05	0.05	-0.02	0.17	-0.12
Poultry	0.07	-0.06	0.03	-0.03	-0.02	0.02	-0.04	0.04	-0.01	0.16	-0.11
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rice Cultivation	***0.02***	***-0.02***	***0.00***	***0.00***	***0.00***	***0.00***	***0.02***	***-0.02***	***0.00***	***0.02***	***-0.02***
Agricultural soils	***0.65***	***-0.61***	***0.34***	***-0.32***	***-0.10***	***0.12***	***-0.34***	***0.34***	***-0.32***	***1.46***	***-1.16***
Animal production	0.18	-0.17	0.08	-0.07	-0.08	0.09	-0.09	0.08	-0.06	0.42	-0.32
Direct soil emissions	0.23	-0.22	0.16	-0.16	0.06	-0.06	-0.14	0.14	-0.17	0.51	-0.42
Indirect soil emissions	0.24	-0.22	0.10	-0.09	-0.08	0.09	-0.11	0.11	-0.09	0.53	-0.42
Field burning of agricultural residues	***0.02***	***-0.02***	***0.03***	***-0.03***	***0.01***	***-0.01***	***-0.01***	***0.01***	***-0.03***	***0.05***	***-0.05***
Wheat	0.01	-0.01	0.01	-0.01	0.01	-0.01	-0.01	0.01	-0.01	0.02	-0.02
Maize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar Cane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.01
Other	0.00	0.00	0.01	-0.01	0.00	0.00	0.00	0.00	-0.01	0.01	-0.01
Rice	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.01
Pulse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.01
Peanuts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Crops	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

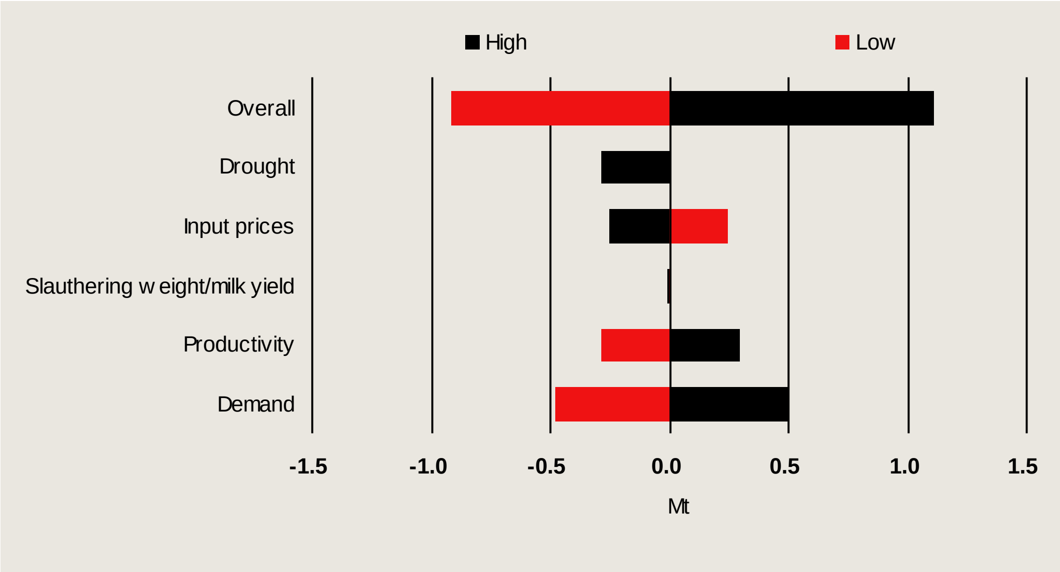
Source: CIE models estimates of activity levels applied to DCCEE emissions spreadsheet.

3.3 Deviation from baseline emissions of livestock in 2030



Data source: CIE models estimates of activity levels applied to DCCEE emissions spreadsheet.

3.4 Deviation from baseline emissions of crop in 2030



Data source: CIE models estimates of activity levels applied to DCCEE emissions spreadsheet.

The colour of the bars in the charts denotes the direction of the changes in the underlying factors under each of the scenarios — black for higher than baseline assumptions and red for lower assumptions, while the position of the bars denote the impact of the changes in assumptions — left for a lower emission and right for a higher emission. For example, input prices have black bar at the left side of the vertical axis, which means higher input prices (denoted by the black colour) lead to lower emissions (at the left) than the baseline emissions. Similarly for the extended drought scenario — black colour denotes longer period of the current drought while the left position denotes it lowers the total emissions.

A number of points are evident from the tables and the charts. First, the largest changes in emissions come from the demand scenarios rather than the productivity scenarios. A decline or increase in demand growth generates more than twice the impact on emissions as does an equivalent proportion decline or increase in productivity growth. The impacts of other factors are in similar magnitudes.

Second, changes in emissions from livestock dominate the total changes in emissions. This is simply because in the baseline projection emissions from livestock account for more than 80 per cent of total agricultural emissions excluding emissions from prescribed burning of savannas.

Over three quarters of changes in total agricultural emissions are from changes in enteric fermentation emissions, which are in turn dominated by fermentation emissions from cattle (accounting for two thirds of the total change in enteric fermentation emissions).

Third, the effects of positive and negative changes are not symmetric around the baseline — a positive change tends to have higher impact than a negative change with similar magnitude. For example, the higher demand scenario (HD) leads to 4 Mt CO_2-e more emissions than the baseline, while the lower demand scenario (LD) leads to only 3.7 Mt CO_2-e fall in emissions.

This is due to difference in accumulated growth. For example, growing at an annual rate of 2.2 per cent over 20 years will lead to 4 per cent higher than the overall growth under the baseline with an annual rate of 2 per cent, while growing at 1.8 per cent per annual would lead to 3.85 per cent lower than the baseline. It also reflects the non-linearity relationship in our models.

4 Baseline assumptions

The base year for the projection is 2009 when the drought continued to affect parts of Australia. With wide spread raining in 2010, it is expected a recovery this year and the following year.

Meat model

Population growth

4.1 **Annual population growth assumption**

	2008-2010	*2011-2015*	*2016-2020*	*2021-2025*	*2026-2030*
	%	%	%	%	%
Australia	1.053	0.993	0.923	0.850	0.757
New Zealand	0.899	0.857	0.774	0.682	0.574
EU	0.317	0.236	0.147	0.067	0.006
United States	0.970	0.904	0.815	0.714	0.617
Canada	0.967	0.924	0.886	0.822	0.730
Japan	-0.123	-0.191	-0.341	-0.470	-0.566
South Korea	0.350	0.267	0.130	0.003	-0.137
Taiwan	0.381	0.381	0.381	0.381	0.381
Hong Kong	0.694	0.909	0.803	0.684	0.535
Singapore	2.129	0.898	0.625	0.540	0.362
Malaysia	1.676	1.469	1.274	1.066	0.872
Indonesia	1.133	0.980	0.805	0.701	0.613
Thailand	0.563	0.521	0.426	0.329	0.228
Philippines	1.846	1.663	1.505	1.338	1.178
China	0.632	0.609	0.497	0.305	0.128
Mexico	0.962	0.864	0.707	0.606	0.495
Argentina	0.988	0.905	0.809	0.700	0.589
Uruguay	0.351	0.337	0.366	0.302	0.236
Paraguay	1.813	1.626	1.447	1.269	1.107
Brazil	0.884	0.748	0.601	0.449	0.310
India	1.413	1.272	1.098	0.916	0.732
Rest of World	1.699	1.601	1.490	1.369	1.222

Source: UN Population Division, 2010, World Population Prospects: The 2008 Revision; Director-General of Budget, Accounting and Statistics, Executive Yuan, Taiwan.

Table 4.1 sets the assumptions of annual population growth in Australia and other countries/regions identified by the GMI model. These growth rates are mainly drawn from the United Nations Population Division's (UNPD) latest population projection — revised in 2008. The medium variant series are used in this projection.

In the previous 2007 round of projections, we used UNPD's 2006 population projections. The new population projection is roughly the same as the previous one in term of total world population — only 0.1 per cent higher in 2015 and 2025 and 0.45 per cent lower in 2050. But country projections are different. For example, Australian population growth rates increase from 0.951 per cent per annum to 0.993 per cent per annum for the period between 2011 and 2015, and from 0.896 per cent per annum to 0.923 per cent per annum for the period between 2016 and 2020.

Real income growth

Projections of real income growth for 22 countries/regions identified by the GMI model are mainly sourced from latest World Economic Outlook (WEO) by the International Monetary Fund for the period up to 2015. Beyond that point of time, a gradual transform path is assumed to ensure individual country/region reach its long-term growth rate (20 or 30 years average growth rate prior to 2008). Table 4.2 details these assumptions.

4.2 **Growth rate of per capita income**

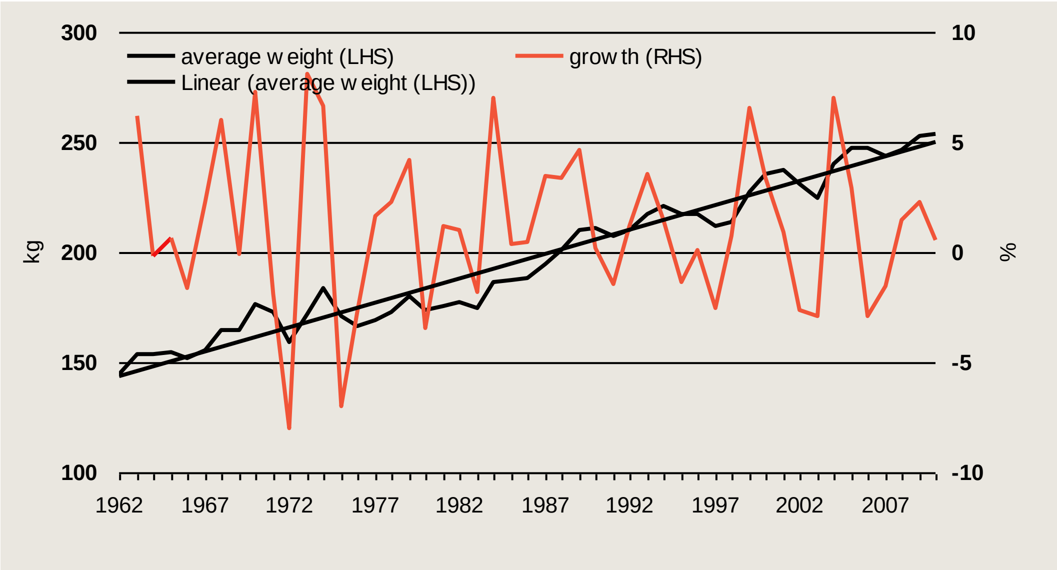
	2008	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016-20*	*2021-25*	*2026-30*
Australia	1.32	0.27	2.81	2.28	2.48	2.33	2.27	2.16	2.31	2.47	2.56
New Zealand	-1.05	-2.49	2.88	2.17	2.18	1.97	1.89	1.58	1.73	1.89	2.00
European Union	0.63	-4.40	0.70	1.39	2.00	2.03	1.97	1.86	2.07	2.27	2.33
United States	-0.53	-3.41	2.33	1.95	1.49	1.60	1.49	1.49	1.92	2.37	2.47
Canada	-0.55	-3.61	2.67	1.88	2.05	1.63	1.48	1.18	1.56	1.97	2.06
Japan	-1.07	-5.07	2.52	1.96	2.23	1.98	2.00	1.92	2.36	2.78	2.88
Korea	1.95	-0.15	5.35	4.78	3.87	3.85	3.72	3.73	5.48	7.21	7.35
Taiwan	0.35	-2.25	7.32	4.42	4.53	4.52	4.65	4.65	5.24	5.83	5.83
Hong Kong	1.45	-3.36	5.31	3.50	3.29	3.33	3.29	3.31	3.90	4.51	4.66
Singapore	-0.74	-4.15	7.77	4.39	4.17	3.82	3.72	3.57	5.10	6.45	6.63
Malaysia	2.96	-3.40	4.04	3.48	3.83	3.73	3.63	3.53	4.31	5.10	5.30
Indonesia	4.87	3.41	5.87	5.12	5.52	5.72	6.02	6.02	5.09	4.10	4.19
Thailand	1.90	-2.84	5.96	4.85	4.88	4.78	4.68	4.48	5.01	5.54	5.64
Philippines	1.99	-0.93	2.78	2.19	2.34	2.34	2.34	2.34	2.01	1.70	1.86
China	8.92	8.10	9.91	9.00	9.18	9.05	9.02	8.88	8.25	7.70	7.87
Mexico	0.53	-7.50	3.50	3.50	4.38	4.06	3.54	3.12	2.60	2.03	2.14
Argentina	5.77	-0.14	3.31	2.10	2.10	2.10	2.10	2.10	1.74	1.39	1.50
Uruguay	8.18	2.51	6.16	3.59	3.56	3.56	3.57	3.54	2.53	1.61	1.68
Paraguay	4.01	-6.36	4.26	3.37	3.28	3.37	3.17	2.87	2.12	1.37	1.54
Brazil	4.25	-1.07	6.21	3.45	3.36	3.35	3.35	3.35	2.65	1.95	2.09
India	5.93	4.25	7.96	7.16	6.76	6.82	6.82	6.81	5.96	5.11	5.30
Rest of World	2.81	0.59	2.88	3.31	3.65	3.81	3.84	3.92	3.81	3.71	3.86

Source: IMF World Economic Outlook 2010; The CIE assumption.

Growth in average weight of meat production

Although the growth rate of average slaughtering weight of beef and veal fluctuates over time, the average weight rises over longer period of time (chart 4.3). The long term growth rate is assumed for the period beyond 2011. Similar assumptions are made for other meat products (table 4.4).

4.3 **Average slaughtering weight of beef and veal**



Data source: ABARE 2010, Australian Commodity Statistics 2009.

4.4 **Annual growth rate assumption of average slaughtering weight**

	2008	*2009*	*2010*	*2011-*
Beef and veal	1.43	2.29	0.58	0.77
Mutton	-0.58	5.25	-4.34	0.23
Lamb	-1.79	2.82	-2.10	0.71
Pigs	-0.40	-0.14	0.59	0.59
Poultry	-2.88	1.28	1.28	1.28

Source: ABARE (2010), Australian Commodity Statistics 2009; The CIE assumptions.

Long term technical progress: input efficiency growth

Table 4.5 indicates the long-term trend of technical progress in meat sectors across countries/regions.

The higher growth assumption of grass fed over grain fed cattle in Australia is due to the following considerations:

- Productivity reflects both on farm productivity and processing productivity, with the former at about 2/3 of the total
- On-farm component of grass fed is higher because of the high productivity in the northern industry which accounts for about 45 per cent of the total production

- Grass-fed sector 'sells' feeders to grain fed sector, so the grain fed productivity reflect the assessment of feed use efficiency and economies of scale in feedlots following ongoing consolidation.

Brazil's grass fed beef productivity is assumed to be 3 per cent per annum. The high productivity growth assumption is mainly due to the high growth of the on-farm component, which is in turn a reflection of the relatively low carcass weight and improvement in breeding.

4.5 **Long-term annual technical progress rate**

	Grass-fed beef	*Grain-fed beef*	*Lamb*	*Mutton*	*Pigs*	*Poultry*	*Seafood*	*Wool*
Australia	1.0	0.5	0.5	0.0	1.0	2.0	0.0	0.2
New Zealand	0.5	0.0	-1.0	-1.0	1.0	2.0	0.0	0.2
United States	0.8	1.0	-2.0	-2.0	1.5	2.0	0.0	0.0
Canada	0.8	1.0	0.5	0.0	1.5	2.0	0.0	0.0
Japan	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
South Korea	0.0	1.5	0.3	0.0	1.0	1.0	1.0	0.0
Taiwan	0.7	0.0	0.3	0.0	0.0	1.0	1.0	0.0
Hong Kong	0.4	0.0	0.3	0.0	1.0	1.0	1.0	0.0
Singapore	0.4	0.0	0.3	0.0	1.0	1.0	1.0	0.0
Malaysia	0.4	0.0	0.3	0.0	1.0	1.0	1.0	0.0
Indonesia	0.4	0.0	0.3	0.0	1.0	1.0	1.0	0.0
Thailand	0.4	0.0	0.3	0.0	1.0	1.0	1.0	0.0
Philippines	0.4	0.0	0.3	0.0	1.0	1.0	1.0	0.0
China	0.9	0.0	0.3	0.0	1.0	1.0	1.0	0.0
European Union	0.5	0.0	0.0	0.0	1.0	0.5	0.0	0.1
Mexico	1.2	0.0	1.0	0.0	1.0	2.0	0.0	0.0
Argentina	1.2	1.4	1.0	0.0	1.0	2.0	0.0	0.5
Uruguay	1.2	1.4	1.0	0.0	1.0	2.0	0.0	0.5
Paraguay	1.2	1.4	1.0	0.0	1.0	2.0	0.0	0.0
Brazil	3.0	1.4	1.0	0.0	1.0	2.0	0.0	0.0
India	1.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0
Other countries	0.4	0.0	0.3	0.0	1.0	1.0	0.0	0.2

Source: TheCIE GMI model assumption.

Exchange rate

It is extremely hard to project changes in exchange rate, and there is no authoritative sources of such projections in the future. We therefore try to model the changes in exchange rate in 2010 only and assume it does not change beyond 2011 (table 4.6). The assumption in the exchange rate change is formulated based on the observed changes.

4.6 **Changes in exchange rate**

	2010	*2011-*
	%	%
Australia	-12.8	0.0
New Zealand	1.7	0.0
United States	0.0	0.0
Canada	1.7	0.0
Japan	-3.5	0.0
South Korea	-5.0	0.0
Taiwan	0.3	0.0
Hong Kong	3.3	0.0
Singapore	0.0	0.0
Malaysia	2.6	0.0
Indonesia	-3.1	0.0
Thailand	2.4	0.0
Philippines	1.1	0.0
China	-0.3	0.0
Economic Union	-9.0	0.0
Mexico	-3.2	0.0
Argentina	-9.9	0.0
Uruguay	0.0	0.0
Paraguay	0.0	0.0
Brazil	1.5	0.0
India	1.8	0.0
Other countries	0.0	0.0

Note: Negatives indicate appreciation of the local currency.
Source: CIE assumptions.

Dairy model

Population growth

Table 4.7 details the assumptions about population growth in regions identified by the Dairy model (Australia, New Zealand, European Union, United States and rest of the world). They are derived from the medium variant population projection by the United Nations Population Division.

4.7 **Annual population growth rate for Dairy model**

	2008-2010	*2010-2015*	*2015-2020*	*2020-2025*	*2025-2030*
Australia	1.05	0.99	0.92	0.85	0.76
New Zealand	0.90	0.86	0.77	0.68	0.57
European Union	0.32	0.24	0.15	0.07	0.01
United States	0.97	0.90	0.82	0.71	0.62
Rest of the world	1.27	1.18	1.07	0.93	0.78

Source: UN Population Division, 2010, World Population Prospects: The 2008 Revision.

Per capita GDP growth

Table 4.8 details the assumptions about per capita GDP growth in countries/regions of the Dairy model. These assumptions are mainly formulated according to GDP and population projections by the IMF World Economic Outlook and UNPD.

4.8 **Per capita GDP growth**

	2008	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016-20*	*2021-25*	*2026-30*
Australia	1.3	0.3	2.8	2.3	2.5	2.3	2.3	2.2	2.3	2.5	2.6
New Zealand	-1.0	-2.5	2.9	2.2	2.2	2.0	1.9	1.6	1.7	1.9	2.0
European Union	0.6	-4.4	0.7	1.4	2.0	2.0	2.0	1.9	2.1	2.3	2.3
United States	-0.5	-3.4	2.3	1.9	1.5	1.6	1.5	1.5	1.9	2.4	2.5
Rest of the world	1.2	-3.0	3.5	3.3	3.5	4.2	4.3	4.3	4.0	3.6	3.6

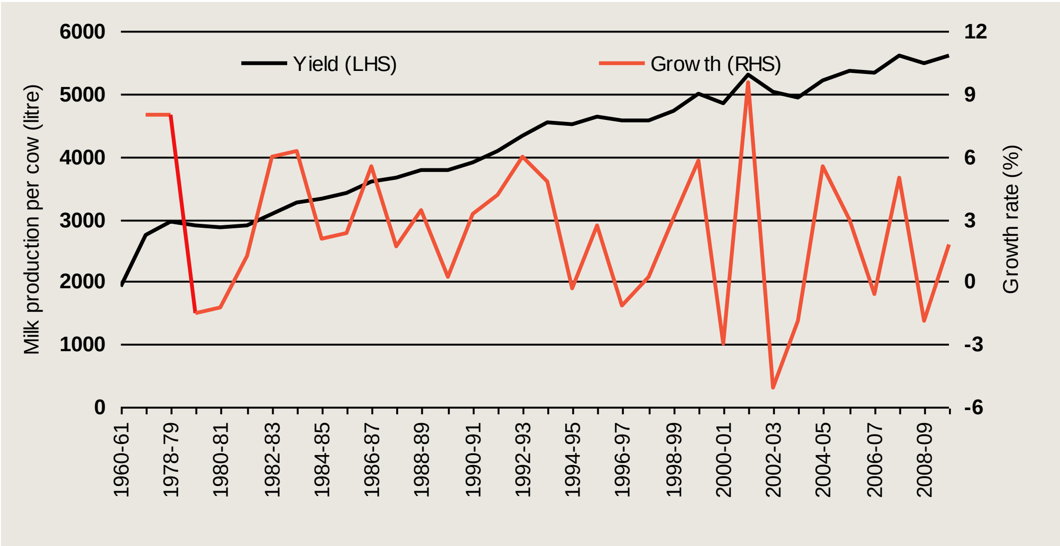
Source: IMF World Economic Outlook 2010; The CIE assumption.

Technical progress

Milk production per cow

Milk production per cow in Australia grew at 2.2 per cent per annum on average between 1960-61 and 2009-10. In the 1990s it grew at 2.8 per cent per annum on average. In the recent years, the growth rate was down to about 1.1 per cent per annum (chart 4.9). It is assumed that the average production per cow will grow at 2.8 per cent per annum between 2010 and 2015 reflecting recovering from the drought, before turning to longer term growth of 2.2 per cent per annum between 2016 and 2020 and 2 per cent per annum between 2021 and 2030.

4.9 **Milk production per cow**

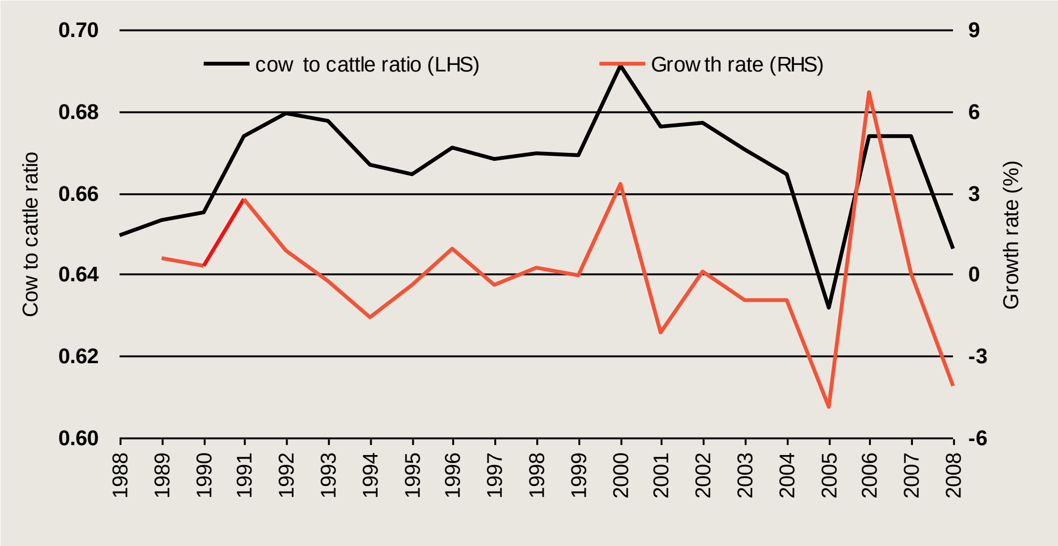


Data source: Australian Commodity Statistics 2009.

Ratio of cow number to cattle number

The ratio of cow number to dairy cattle number grew by more than 0.5 per cent per annum on average over the period between 1988 and 2000, but dropped by 0.8 per cent per annum on average in the last decades (chart 4.10).

4.10 **Ratio of cow to dairy cattle numbers**



Data source: Australian Commodity Statistics 2009; AGGI.

Grain model

GDP growth

Similar to the assumptions for other models, the GDP growth assumptions for the Grain model are mainly sourced from latest World Economic Outlook (WEO) by the International Monetary Fund for the period up to 2015. Beyond that point of time, a gradual transform path is assumed to ensure individual country/region reach its long-term growth rate (20 or 30 years average growth rate prior to 2008). Table 4.11 lists the detailed assumption for each of the country groups identified by the Grain model.

Population growth

Annual population growth for Australia and other country groups is derived from the medium variant projections of the United Nations' *World Population Prospects: The 2008 Revision*. Table 4.12 reports the detailed assumptions.

4.11 **Annual GDP growth rate for the Grain model**

	2008	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016-20*	*2021-30*
South Asia	7.35	5.67	8.78	8.43	8.03	8.09	8.10	8.08	7.05	6.03
Southeast Asia	4.71	1.69	5.40	5.61	5.82	5.88	5.99	5.95	5.99	6.02
North Asia	3.55	1.24	5.48	5.64	5.32	5.19	5.14	5.07	5.46	5.84
Pacific	1.12	-0.13	2.92	3.35	3.26	3.08	3.00	2.80	2.87	2.94
Middle East	5.09	2.42	4.51	4.78	4.81	4.69	4.77	4.81	4.66	4.51
Europe	3.17	-4.79	2.59	2.97	3.48	3.62	3.74	3.70	3.99	4.87
Africa	5.31	2.27	4.61	5.31	5.18	5.13	5.12	5.09	4.91	4.73
Americas	2.57	-2.07	3.82	3.25	3.21	3.21	3.08	2.99	2.87	2.75

Source: IMF World Economic Outlook 2010; CIE assumption.

4.12 **Annual population growth for the Grain model**

	2008-2010	*2010-2015*	*2015-2020*	*2020-2025*	*2025-2030*
South Asia	1.54	1.40	1.23	1.06	0.87
Southeast Asia	1.22	1.09	0.95	0.84	0.71
North Asia	0.56	0.53	0.42	0.24	0.07
Pacific	1.33	1.23	1.14	1.07	0.95
Middle East	1.95	1.69	1.54	1.43	1.22
Europe	0.04	-0.01	-0.08	-0.15	-0.22
Africa	2.42	2.19	2.03	1.89	1.69
Americas	1.04	0.95	0.84	0.73	0.60

Source: UN World Population Prospects: The 2008 Revision.

World food price

World food prices, especially grain prices, had risen sharply since mid 2007, catching the world's attention. This was labeled a 'silent tsunami' by the Economist magazine (19 April 2008).

However, the high price was not sustainable and did not last long. Historically the food prices have closely correlated to the oil price and the crude oil price has been falling and will continue due to the global financial crisis and a slow recovery from the crisis.

In fact, even in the midst of the full cry of the food price crisis, the United States Department of Agriculture (USDA) together with other organisations projected that food prices would fall. This statement was renewed in the latest projections by USDA (table 4.13).

For the world food prices in the Grain model, we adopt the assumption of food grains price change by USDA for the period to 2019, and further assume the growth grate in 2019 will continue to 2030.

4.13 **Long term projections on prices received by farmers**

	Food commodities	*Food grains*	*Oil-bearing crops*	*Fruit and nuts*	*Vegetables*
2008	6.50	39.20	47.40	-6.30	1.50
2009	-12.24	-28.57	-11.88	-6.76	7.20
2010	8.22	-6.49	-7.70	3.91	3.67
2011	0.72	-0.29	-2.19	0.70	1.47
2012	1.78	-3.65	1.12	1.87	1.45
2013	1.05	-3.97	1.11	1.90	1.49
2014	1.38	1.25	0.00	2.33	1.47
2015	1.02	0.43	0.49	1.96	1.45
2016	0.95	1.23	0.00	2.30	1.42
2017	0.87	0.43	0.00	1.94	1.46
2018	1.13	0.48	0.00	2.33	1.38
2019	0.92	0.42	-0.48	1.92	1.47

Source: USDA 2010, Long-term Agricultural Projection to 2019, Table 38 'Prices received by farmers, selected food commodities, long-term projections, available at http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url= http://usda.mannlib.cornell.edu/usda/ers/94005/./2010/index.html.

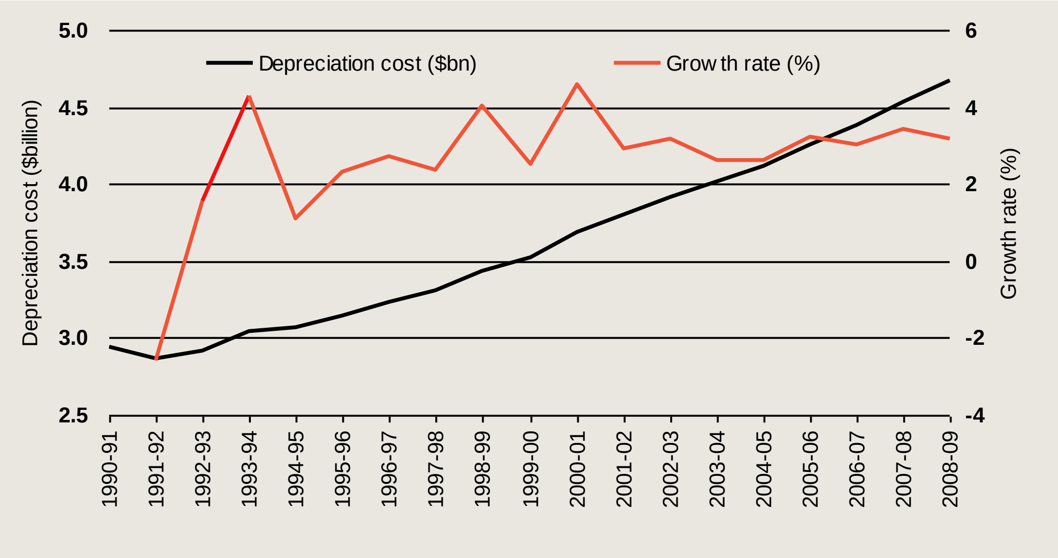
Technical progress

According to Nossal and *et al* (2009), the long run productivity growth has been 2.1 per cent per annum. We adopt this estimate of productivity growth as our long term assumption in the baseline projection. In the short term, growth rates in technical progress will be determined to ensure a recovery from the drought.

Capital growth

There are no statistics of the capital stock of the Australian farm sector. We therefore use the depreciation costs of the farm sector as a proxy. It was growing at 2.3 per cent per annum during the 1990's and at 3 per cent per annum during the 2000's (chart 4.14). Based on the historical experience, it is assumed that the capital growth rate will be 3 per cent in 2010, 2.5 per cent per annum between 2011 and 2020, and 2.27 per cent per annum for years beyond 2020.

4.14 **Depreciation cost and its growth rate of Australian farm sector**



Data source: ABARE Australian Commodity Statistics 2009

5 Details of the models

This report uses three models developed by the CIE: the Global Meat Industries (GMI) model, the CIE Grain model and the CIE Dairy model. Each of these three models was originally developed for purposes quite different to emissions projections. In particular, the original uses were:

- strategic market analysis
- research evaluation and portfolio allocation
- analysis of policy and market reforms

To use them for emissions projects, we made modifications to each of the models in the previous two rounds of projections. Most significantly, in the 2003 round of projections, time dimensions were built into the initially static Grain and Dairy models.

For the 2005 round of projections, as well as updating all of the model databases, we have made a minor modification to the theoretical structure of the Grain model. For this round of projections, the databases have been updated to 2006 for Grain and Dairy models and to 2005 for GMI model.

Despite the modifications, the original purposes of the models remain embedded in their structure. The most important implication of this is that each of the models focuses in more detail on the demand side of agricultural projections and on the broad supply responses of competitors than they do on the detailed dynamics of Australian supply relationships.

The GMI model

The GMI model is a multi-country, multi-commodity, Armington style model of world meat production, consumption and trade. It explains production and consumption in ten commodities in 22 regions, and covers trade in eight commodities between 22 regional groupings. Commodities and regions distinguished in the model are shown in table 5.1.

Commodities are distinguished by source, and commodities from different sources are imperfect substitutes. In principle, the model covers all bilateral trade flows of traded commodities (although, in practice, some of these flows are zero) and accounts for all bilateral trade barriers. Its key features are summarised in box 5.2. The model is dynamic and produces results on an annual basis.

5.1 Data and country coverage of the GMI database

	Beef and veal			*Poultry meat*	*Pig meat*	*Sheep meat*		*Sea-food*	*Live sheep*	*Live cattle*
	Grain	*Grass*	*Diaphr agm* [a]			*Mutton*	*Lamb*			
Australia	✓	✓	✓	✓	✓	✓	✓		✓	✓
USA	✓	✓	✓	✓	✓	✓	✓			
Japan	✓	✓	✓	✓	✓	✓	✓	✓		
Canada	✓	✓	✓	✓	✓	✓	✓			
Chinese Taipei		✓	✓	✓	✓	✓	✓	✓		
South Korea	✓	✓	✓	✓	✓	✓	✓	✓		
New Zealand		✓	✓	✓	✓	✓	✓		✓	
Mexico		✓	✓	✓	✓	✓	✓			
Argentina		✓	✓	✓	✓	✓	✓		✓	
Uruguay		✓	✓	✓	✓	✓	✓			
Paraguay		✓	✓	✓	✓	✓	✓			
Brazil		✓	✓	✓	✓	✓	✓			
China		✓	✓	✓	✓	✓	✓	✓		
Malaysia		✓	✓	✓	✓	✓	✓	✓		✓
Indonesia		✓	✓	✓	✓	✓	✓	✓		✓
Thailand		✓	✓	✓	✓	✓	✓	✓		
Philippines		✓	✓	✓	✓	✓	✓	✓		✓
European Union		✓	✓	✓	✓	✓	✓			
Hong Kong		✓	✓	✓	✓	✓	✓	✓		
Singapore		✓	✓	✓	✓	✓	✓	✓		
India		✓	✓	✓	✓	✓	✓			
Other countries		✓	✓	✓	✓	✓	✓			✓

[a] Diaphragm beef comes from the inner lining of the rib cage. It is usually classified as offal. Wee keep it separate because in Japan it receives a special tariff treatment (15 per cent compared with 38.5 per cent for beef in general).

Source: CIE.

Demand side

Like other models of this class, the GMI model is demand side determined. The demand side of the model is based on a three level nesting (see chart 5.3). At the first level is consumer demand for meat. Population and real income growth determine the total level of meat expenditure by region. Consumers then choose between different species of meats on the basis of relative prices through an Almost Ideal Demand System (AIDS).

At the second level, wholesalers choose between imported and domestic sources of a particular meat type, based on relative prices and aggregate consumer spending on that meat aggregate grouping. Demand systems at this level are also AIDS. At this level, meat commodities are combined to consumer level commodities. For example, local and imported grass and grain fed beef are combined by the wholesaler to form the aggregate beef bundle.

5.2 **Key features of the GMI model**

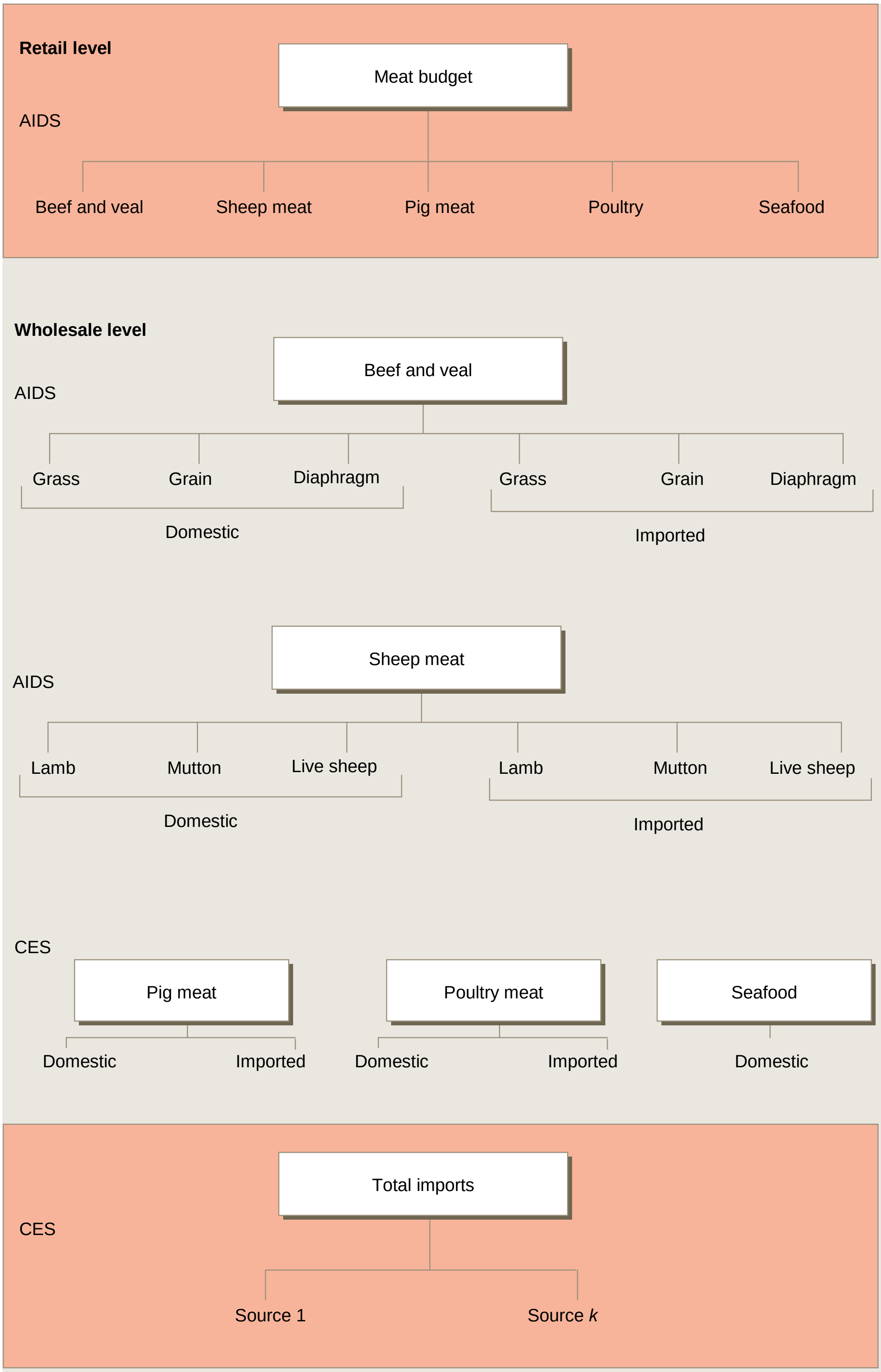
- For each of 22 regions and ten meat types, it provides annual projections of:
  - domestic production of each type of meat;
  - consumption of each type of meat;
  - price outcomes for each type of meat; and
  - trade flows (exports and imports) by each region for each type of meat.
- It treats meat commodities produced in different countries as different products — for example, Australian grass fed beef is a different product from South Korean Hanwoo and dairy beef.
- It treats all bilateral trade flows for a particular commodity as trade in different products — for example, South Korean grain fed beef imports from Australia are distinguished from South Korean imports of grain fed beef from the United States.
- It allows importing countries to choose the source of their meat imports on the basis of trade policies, relative prices and their preferences for meat from particular sources.
- It explicitly incorporates the major trade policies affecting world meat trade flows such as tariffs, variable levies, quotas, voluntary restraint agreements, foot and mouth disease trade bans and export subsidies.
- It is supported by the GMI database — an extremely detailed time series database covering production, consumption, trade and price statistics for each type of meat for each of the countries and regions represented in the model.

At the final level, importers choose imports of each commodity by source, based on relative import prices (landed duty paid) and the aggregate demand for imported product at the wholesale level. The aggregate import bundle is a constant elasticity of substitution (CES) combination of imports by source.

Supply side

Output is based on prices and a supply elasticity. In principle, the supply system contains lagged prices, but in practice no lags are implemented. Instead, lagged responses are entered as the short term forecasts of experts in the major countries (see later).

5.3 Demand system of the GMI model



Data source: The CIE

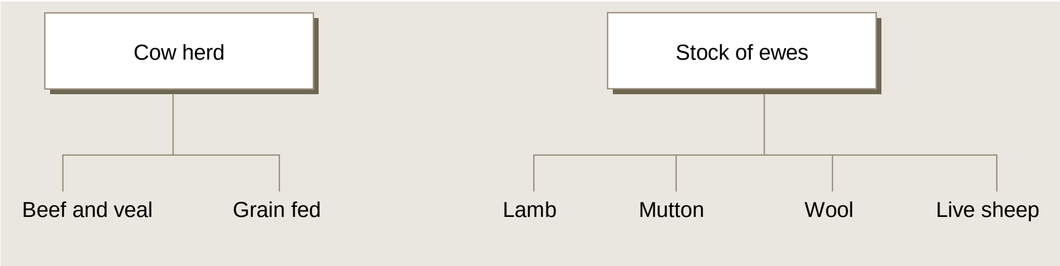
Total cow numbers depend on the average price of grass, grain and diaphragm beef sales. For a given cow herd in any country or region producers can then choose to produce grass or grain fed beef on the basis of relative prices. This is true for the beef systems in Australia, the United States and Canada because these regions produce both grass and grain fed cattle. Two other special cases exist — Japan and South Korea — where we identify the production of dairy cattle (recorded in the model as grass fed) and native cattle (Wagyu and Hanwoo steers recorded in the model as grain fed beef).

There is a similar story for sheep supply. The stock of ewes depends on supply elasticities and the prices of lamb, mutton, wool and live sheep. For a given stock of ewes, regions then choose between four outputs on the basis of relative prices. Chart 5.4 summarises the production nestings.

The model does not explicitly include any regional constraints on agricultural activity levels. Nor does it include any constraints on carrying capacity of particular regions for livestock. No such restrictions operate at the country and country aggregate level distinguished by the model.

The model does, however, include restrictions on the trade of meat from foot and mouth disease (FMD) endemic regions into FMD free regions. These restrictions recognise the realities of the current global meat market.

5.4 **Production nestings of the GMI model**



Data source: The CIE.

Trade relationships

Any country's exports are simply equal to the sum of imports from that country by all other countries. Thus, by specifying the demand system, we have already specified the trade system. All that remains is adding up.

Price relationships

The model recognises different prices — farm prices, import prices, wholesale prices and retail prices. These are all treated in a straightforward manner through constant ad valorem margins. Import prices are related to source country export prices through exchange rates and tariffs.

Livestock numbers and greenhouse gas emissions

The model calculates the livestock numbers in Australia from the meat supply in two steps. Firstly, the Australian meat supply is transformed to slaughter numbers using average slaughter weights derived from historical data. The number of livestock slaughtered is in turn transformed to a livestock inventory through a constant transformation ratio. The constant relationship between inventories and livestock slaughtered, justified by the data in recent years, is a simplified version of the traditional relationship in that the change in livestock numbers equals the difference between natural growth and slaughter rates.

National livestock numbers are distributed to each state using shares in the base year. Greenhouse gas emissions are then calculated using the spreadsheets provided by the AGO.

Other equations

The model also contains equations to explain the demand for live cattle into various overseas markets.

GMI model parameters

Key model parameters relate to the meat demand and meat supply specifications. On the demand side, the model contains elasticities to specify behaviour:

- at the trade level (where importers choose between meat from different foreign sources — substitution elasticities);
- at the wholesale level (where wholesalers choose between foreign and domestic meats — substitution elasticities); and
- at the retail level (where consumers choose between meats — expenditure, own and cross price elasticities).

On the supply side, the model contains supply elasticities for each type of meat for each country. Values for elasticities are drawn from the literature, and are reviewed and updated annually.

Assumptions underlying model elasticities are presented below.

Income elasticities

Income elasticities in the model vary according to the income level of the country concerned. For developing countries, these elasticities typically range, in the base period, from:

- 0.8 to 1.0 for beef;
- 0.5 to 1.0 for sheep meat;

- 0.2 to 1.0 for pig meat; and
- 0.5 to 0.9 for poultry.

For developed countries, the elasticities typically vary from:

- 0 to 0.8 for beef;
- 0 to 0.5 for sheep meat;
- 0 to 0.3 for pig meat; and
- 0 to 0.2 for poultry.

Income elasticities themselves are not fixed parameters in the model, but vary as the underlying income varies. This captures the fact that, as countries develop, their propensity to devote extra income to meat consumption also changes.

Price elasticities of demand

The model's underlying demand system is the Almost Ideal Demand System (AIDS). Price elasticities are therefore not fixed parameters, but are themselves a function of budget shares and the underlying AIDS parameters (for price and income).

Price elasticities change throughout the simulation as budget shares change. Price elasticities can also differ significantly between countries which themselves often have markedly different budget shares.

- Own price elasticities for beef vary from -0.8 to -1.4.
- Own price elasticities for sheep meat vary from –0.8 to -2.5
- Own price elasticities for pig meat vary from -0.7 to -2.5.
- Own price elasticities for poultry vary from -0.6 to -0.9.

Price elasticities of supply

Supply elasticities also vary by country. Their broad ranges are:

- 0.4 to 0.6 for beef;
- around 0.2 for sheep meat;
- 0.2 to 0.7 for pig meat; and
- 1.0 to 2.0 for poultry.

The grains model

The CIE Grain model is a multi-region, multi-commodity, dynamic partial equilibrium model. It is designed to capture production, consumption and exports of five grains or groups of grains:

- Wheat;

- malting barley;
- other coarse grains (including feed barley);
- pulses (or grain legumes, in particular lupins); and
- oil seeds (most importantly, canola).

The model also includes an 'other' agricultural activity designed to cover the alternatives to grain that exist on predominantly grain farms.

The model distinguishes production by state, with each state having a different production mix and supply responsiveness.

Demand side

Grain is exported to foreign markets or sold in domestic market. The demands in these two markets are specifically modelled.

Export demand for grains

Most grain is exported and the GRAIN model distinguishes eight destinations:

- Africa;
- America;
- Europe;
- Middle East;
- Pacific;
- South Asia;
- North Asia; and
- South-East Asia.

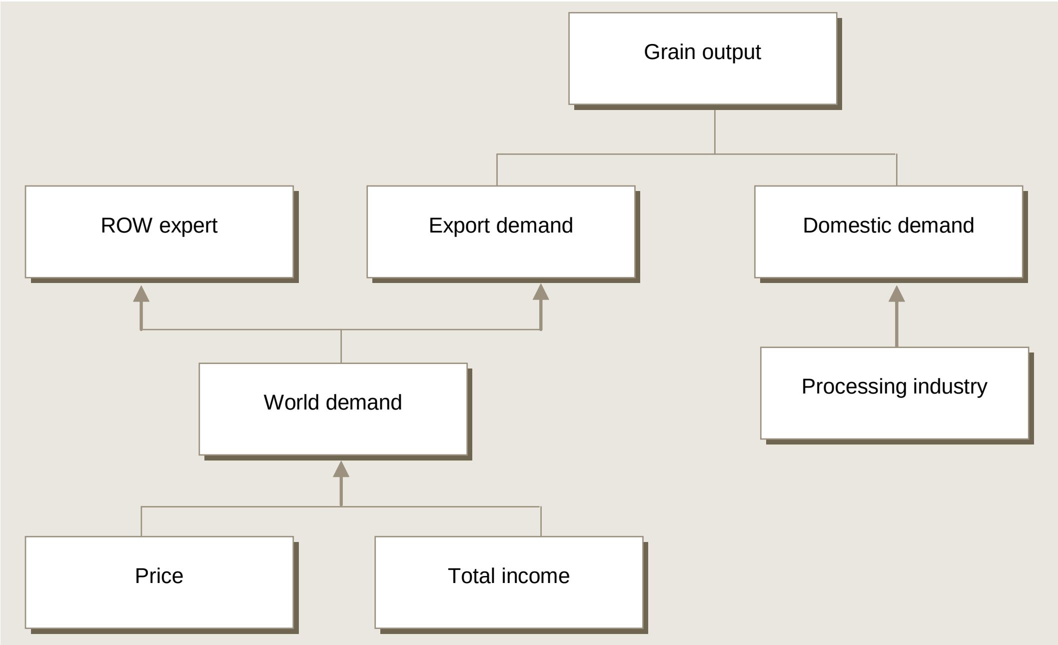
Total export demand in each region is determined by population and income growth. The demand for Australian exports of grain is determined by the region's total export demand for grains and the relative price of Australian versus foreign grains through a constant elasticity of substitution (CES) process, which implies imperfect substitution between Australian and foreign grains (chart 5.5).

Domestic demand for grains

Domestic demand includes domestic processing demand and feed demand for grains. Domestic processors use grains to produce various products including flour and malt (in the case of wheat and barley), and the model covers the basic processing of dehulling (pulses) and crushing (oilseeds). These products are in turn domestically consumed or exported (chart 5.6). Some grain is used domestically for feed purposes.

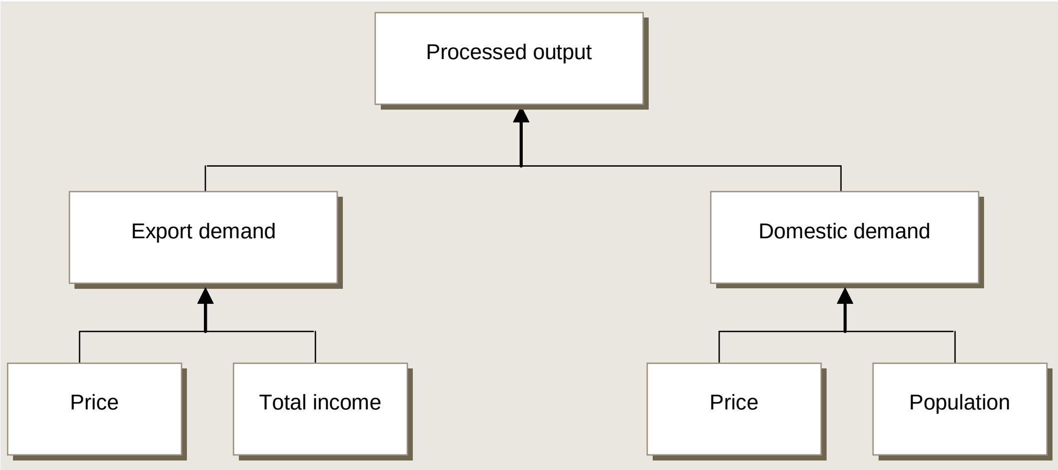
The output of each industry in processing and feed manufacturing is a Leontif function of aggregate primary factor, intermediate input and other material inputs. The aggregate primary factor and intermediate input are in turn CES functions of individual primary factors (labour and capital) and individual grains respectively. Therefore, demand for each grain depends on the total level of industrial production, the relative price of different feed grains and the technical ability to substitute between feed grains. Chart 5.7 shows the production nesting of the processed grain products.

5.5 **Demand for grains**



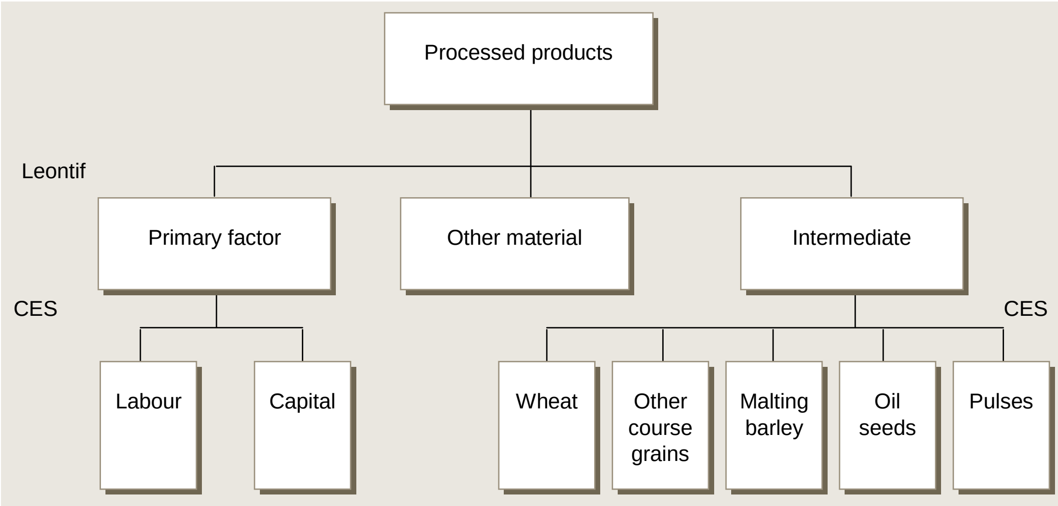
Data source: The CIE

5.6 **Demand for processed grain products**



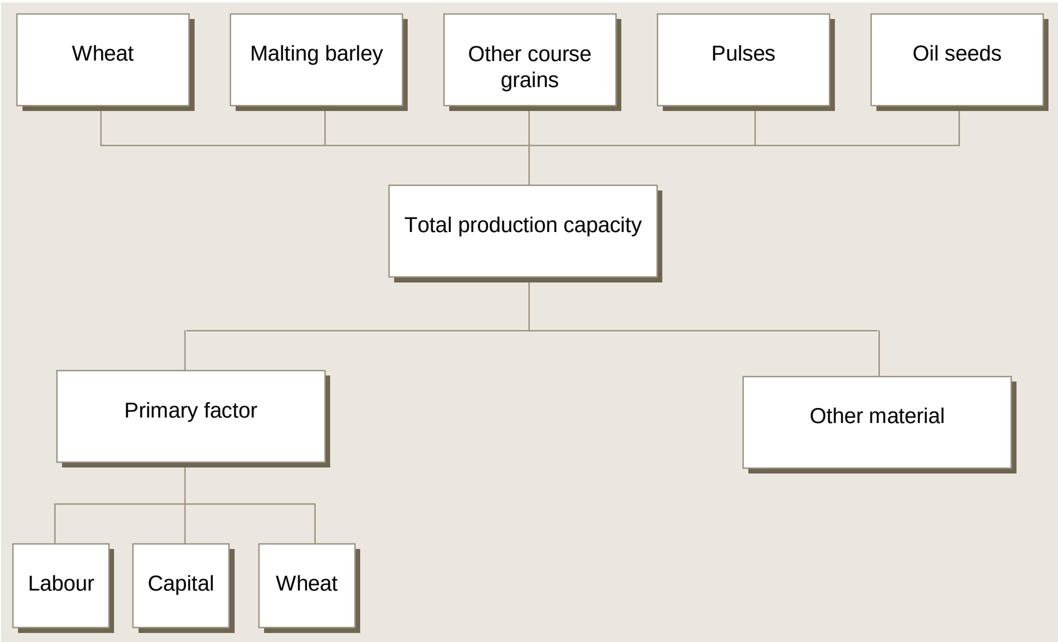
Data source: The CIE.

5.7 Production nesting of processed grain products



Data source: The CIE.

5.8 Production nesting of grains



Data source: The CIE.

The domestic demand for processed products and feed is determined by population and income growth and the price of the product. Similarly, the export demand for these products is a function of the population and income growth in the rest of the world and the price.

Supply side

The production nesting of grains is shown in chart 5.8. Each state's grain production capacity is determined by the employment of productive factors (labour, land and capital) and other intermediate inputs (including fertiliser). It is assumed that the total capacity is a Leontief function of aggregate primary factors and intermediate inputs, while the aggregate primary factor is a CES function of labour, capital and land. The productivity of factors and materials is modelled by a set of shifters representing output and input technological change. For example, higher yield implies lower use of land for given production, which can be achieved by increasing the input technical shifter of land.

The total capacity is transformed to the production of specific grains or groups of grains according to the relative prices of individual grains through a constant elasticity of transformation (CET) function.

Market clearing equations

These equations are used to close the model. They ensure that demand equals supply and so allow the model to determine prices through the grain value chain.

Greenhouse gas emissions

Greenhouse gas (GHG) emissions from grain production are determined by three factors: sown area, fertiliser application and crop residual burning. For this round of projections, emissions are determined using AGO spreadsheets.

Parameter assumptions

Income elasticity

The income elasticity of demand for grain is 0 for Australia and 0.6 for the rest of the world.

Price elasticity

- Price elasticity of foreign demand for Australian grain exports is -0.5.
- Price elasticity of export demand for processing products and feed is -10.
- Price elasticity of domestic demand for processing products and feed is -2.

It should be pointed out that there is no direct price elasticity of domestic demand for grains. Domestic grain demand comes from the food processing and feed manufacturing industries. The demand for grains by these industries is determined by the elasticity of substitution, which is given below, the relative price of individual grain and the demand for processed grain products.

Elasticity of transformation or substitution

- The gross grain output is transformed to the output of individual grain according to the relative price of each grain with an elasticity of transformation of 1.

- Elasticity of substitution between individual primary factors in grain farming is 1.
- Elasticity of substitution between Australian and foreign grains in each country group's import demand is 10.
- Elasticity of substitution between individual grains in processing and feed manufacturing is 1.
- Elasticity of substitution between individual primary factors in processing and feed manufacturing is 0.5.

The dairy model

The current version of the CIE Dairy model is a dynamic partial equilibrium, non-linear representation of the Australian dairy industry. It identifies six regions: New South Wales (including the ACT), Victoria, Queensland, South Australia, Western Australia and Tasmania. It also includes Australia's major competitors (New Zealand, European Union and the United States) in the world dairy export market.

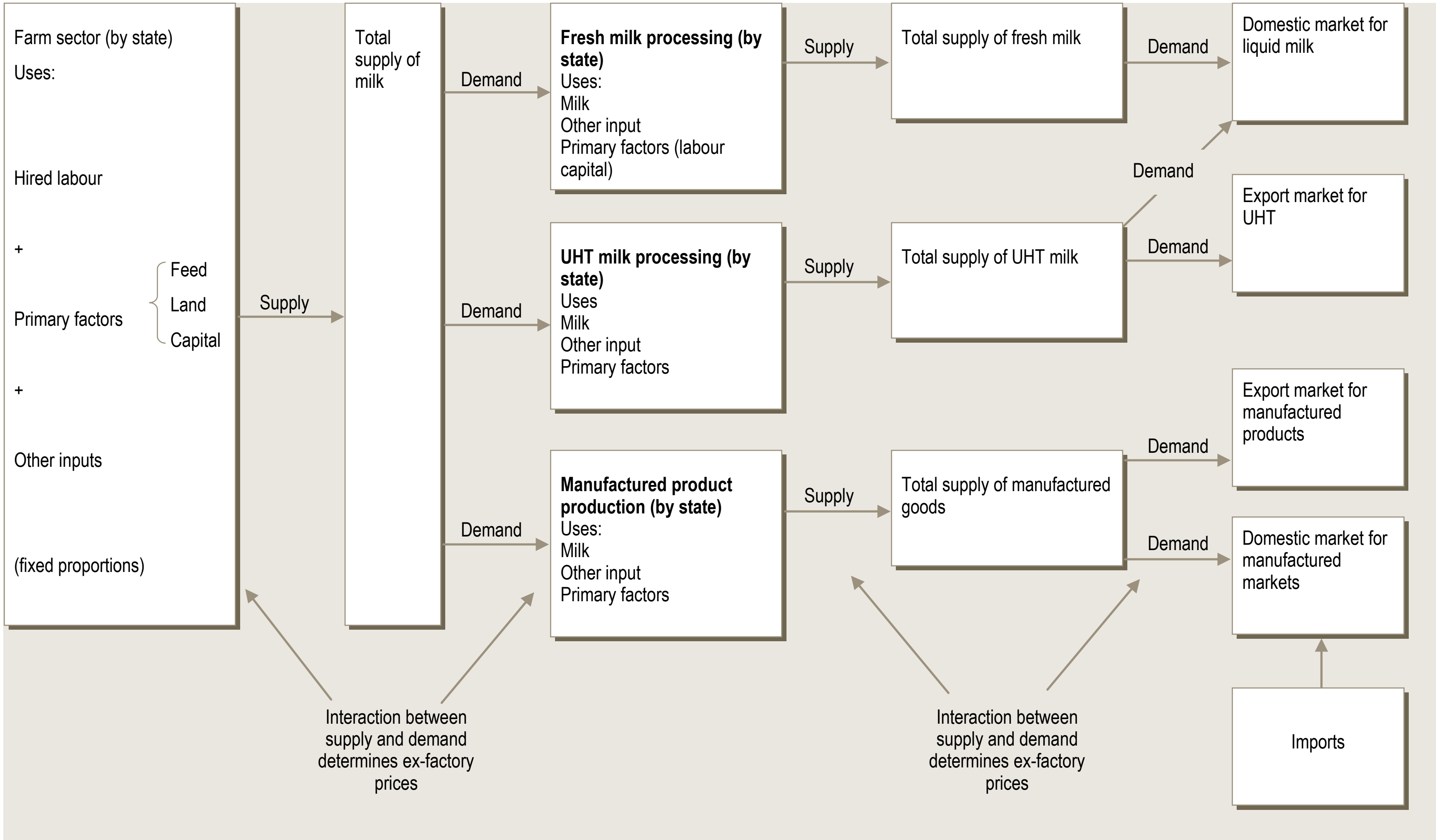
The value chain in the database is augmented with a number of equations which specify how each of the various participants in the industry react as various changes are imposed on the model. These equations describe:

- the production of raw, processed and manufactured milk products
- domestic, export and import demands for these products
- world export markets
- pricing relationships
- market clearing conditions
- greenhouse gas emissions.
- Production–supply relationships

Production-supply relationships

Chart 5.9 illustrates the supply chains of dairy production, which consists of two parts: farm level milk production and downstream processing.

5.9 **Milk supply flow chart**



Farm level

Farmers combine feed, primary factors and other inputs in a fixed proportion to produce two types of milk — market and manufacturing. They are assumed to be able to substitute feed for the generic fixed factor representing the farms' land and capital stock. The ability of the farmer to substitute feed for the fixed factor in part determines the extent to which the farm is able to respond to changes in the farm gate price. The parameter affecting this rate of substitution (elasticity of substitution) is calibrated to yield a farm supply elasticity of 0.5.

Downstream processing

Milk processors combine market milk, primary factors (labour and capital) and other inputs in a fixed proportion to produce fresh and UHT milk. Manufactures purchases manufacturing milk to produce manufactured products for sale on domestic and overseas markets. UHT milk is also assumed to be exported. A supply elasticity of 1.5 is assumed for all downstream processing industries.

Demand relationships

Consumers worldwide are assumed to have very inelastic demands for milk products. The price elasticity of demand for fresh and UHT milk is assumed to be -0.15 while manufactured products are assumed to have an elasticity of demand of -0.25. The overseas demands for Australian exports are assumed to be very elastic with an elasticity of -10. It is assumed that the income elasticity of demand for milk products for consumers in Australia and other developed countries (USA, EU and New Zealand) is zero, while the income elasticity of demand are 1 and 2, respectively, for UHT milk and manufactured milk products for consumers in the rest of the world.

Consumers of liquid milk are able to choose between fresh and UHT milk, but they do not distinguish the source of the supply of these milks. Consumers are assumed to choose their total demand for liquid milk and then allocate their demands across fresh and UHT milk. The rate at which consumers are willing to substitute between UHT and fresh milk is relatively low (an elasticity of substitution of 0.5).

Consumers of manufactured products can satisfy their demands from domestic (with no distinction between states) and imported sources. An elasticity of substitution between domestic and imported products of 0.5 is assumed. Consumers then further allocate their demands for imported manufactured products across products from different regions with an elasticity of substitution of 4.4, which is drawn from the GTAP Database 5.

World export market

The current version of the model includes a cluster of equations describing the supply and demand of dairy exports in the world market. In addition to Australia, New Zealand, EU, USA and the rest of the world (ROW) produce UHT milk and manufactured dairy products according to the price of the products with a price elasticity of supply varying from 0.1 to 0.42.

The export supply from each of these regions is the difference of the production and its domestic consumption. Domestic demand for dairy products in these regions is modelled in a way similar to that in Australia. It is determined by the price of product, population and income growth. The domestic demand is then further allocated to demand for domestic and imported products with an elasticity of substitution of 0.5. Like Australian consumers, consumers in these regions then further allocate their demands for imported dairy products across products from different regions with an elasticity of substitution of 4.4, which is drawn from the GTAP Database 6.

Pricing relationships

The model contains a number of pricing relationships that specify how the price varies from the point of production to the point of sale.

Market clearing conditions

The model solves for a set of equilibrium prices that clear all markets (that is, the supply of a commodity matches the demand for it). A single national market (and equilibrium price) is assumed for each of the farm milk and processing products.

Labour is assumed to be supplied without limit at a fixed wage rate. Feed is also assumed to be supplied without limit at the price derived form the GRAIN model. In the case of the fixed factor, its price varies to ration demand for it.

Greenhouse gas emissions

Greenhouse gas emissions are a function of the number of dairy cattle, which is in turn determined by milk output and technological progress in milk production.

Reference

ABARE 2010, *Australian Commodity Statistics 2009*, Australian Bureau of Agricultural and Resource Economics, Canberra.

ABARE-BRS 2010a, *Environmentally sustainable diversion limits in the Murray-Darling Basin: Socioeconomic analysis*, ABRE-BRS client report for the Murray-Darling Basin Authority, Australian Bureau of Agricultural and Resource Economics-Bureau of Rural Science, Canberra

ABARE-BRS 2010b, *Assessing the regional impact of the Murray-Darling Basin Plan and the Australian Government's Water for the Future Program in the Murray-Darling Basin*, ABRE-BRS client report for the Department of Sustainability, Environment, Water, Population and Communities, Australian Bureau of Agricultural and Resource Economics-Bureau of Rural Science, Canberra

IMF 2010, *World Economic Outlook*, International Monetary Fund, Washington, D.C., available at http://www.imf.org/external/pubs/ft/weo/2010/01/index.htm

Nassol and *et al* 2009, 'Productivity movements in Australian agriculture', *Australian Commodities*, March quarter, 16(1), p. 206-216.

UNPD 2009, *World Population Prospects: The 2008 Revision*, United Nations Population Division, New York.

USDA 2010, Long-term Agricultural Projection to 2019, Table 38 Prices received by farmers, selected food commodities, long-term projections, United States Department of Agriculture, Washington, D.C., available at http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/94005/./2010/index.html