Estimating the Regional Economic Impacts of the 2017 to 2019 Drought on NSW and the Rest of Australia

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Glyn Wittwer
Centre of Policy Studies,
Victoria University

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Glyn Wittwer,
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Abstract

Much of New South Wales and southern Queensland suffered from extreme drought conditions from 2017 to 2019. In 2017, rainfall anomalies over 12 months were not extreme, but maximum temperatures across northern New South Wales and southern Queensland were far above normal. There was also a marked deficit in winter rainfall so that there were severe shortfalls in effective rainfall.

The drought worsened in 2018 through a combination of marked winter rainfall deficits and continuing temperatures far above average. Regions which in the past have rarely experienced drought, notably the Liverpool Plains in New South Wales, were in throes of extreme drought. Conditions only worsened in 2019, the hottest and driest year recorded in Australia.

This study models the marginal impacts of drought on the regional NSW and national economies of Australia using VU-TERM, a multi-regional, dynamic model of the regions of Australia. It does not include losses arises from the catastrophic bushfires which started in Queensland in September 2019 and flared in all states and territories in the following months.

From the national perspective, prolonged drought had substantial impacts on national productivity. It was sufficient to force real GDP to more than 1.0% below base in 2018-19 and 2019-20. The marginal contribution of drought to national real wages growth was as much as minus 1%.

Modelling results indicate that NSW real GDP fell relative to forecast by 0.7% or $2.6 billion in 2017-18, and more than 1.3% or $5.5 billion in 2018-19 and 2019-20. These impacts reflect a severe diminution of farm output, given that agriculture accounts for around 1.6% and downstream processing for around 3.5% of NSW's income.

NSW job losses due to drought were around 0.55% or 17,500 FTE jobs in 2017-18 and more than 1.0% or 34,000 jobs in 2018-19. The state-wide jobs outcome in 2019-20 was slightly better due to real wages falling further relative to base.

At the regional level, relatively farm-intensive parts of the state suffer proportionally greater drought-induced losses. All inland regions were affected severely by drought. The worst affected region was New England–North West, in which real GDP in both 2018-19 and 2019-20 fell almost 15% below forecast, with an accompanying drop in employment of more than 5.0%. Other hard-hit regions include Far West-Orana, in which 2018-19 and 2019-20 real GDP fell 12% and employment fell 4.0% below forecast.

The economic losses spread into regions not directly affected by drought. In the composite coastal region spanning Wollongong, Sydney and Newcastle, real GDP fell 0.6% below forecast and employment as much as 0.8% below forecast. Jobs in the coastal region which accounts for 78% of baseline state-wide employment fall by more than 21,000 FTE, with jobs in other regions falling by around 13,000 FTE in 2018-19 relative to base.

In this scenario, we assume that there is a full recovery in seasonal conditions in 2020 which impacts on 2020-21 economic outcomes. However, prolonged drought depletes farm capital through two mechanisms. First, reduced farm income depresses investment during drought years. Second, prolonged drought leads to a depletion of herd numbers. This extends beyond additional slaughtering to culling. Consequently, drought depletes the income earning capacity of farms in recovery relative to no drought. At the sectoral level, there are some farm output losses in the recovery phase relative to forecast due to the depleted capital base following drought.

The drought diminishes national welfare. Lost productivity depresses income in drought. Even with NSW and national employment rising above forecast in recovery, real GDP remains slightly below base in recovery and does not compensate for drought-induced losses. The net present value of national welfare is $43 billion, equivalent to a loss in annualised terms of $1300 million at a 3% discount rate. The NSW welfare loss is around $690 million annualised, equivalent to permanent annual welfare loss of $89 per NSW resident.

A modelled compensation package consists of direct transfers to households in drought-affected regions. This results in a slight increase in welfare in NSW. This is because compensation stimulates consumption, which in turn stimulates employment slightly, thereby reducing drought-induced job losses relative to no compensation.

JEL: Q11, Q15, C68
Keywords: regional drought impacts; welfare; seasonal recovery

Contents

1. Introduction

This section shows the rainfall and temperature anomalies for each of 2017 to 2019, which impacted most severely in New South Wales and southern Queensland.

2017 rainfall and temperature anomalies in Australia

The annual rainfall declines for 2017 do not indicate anything other than moderate drought over much of New South Wales and southern Queensland (figure 1). However, winter rainfall was in the decile 1 range over a substantial area of New South Wales key farming regions (figure 2).

Figure 1: Rainfall deciles, 2017

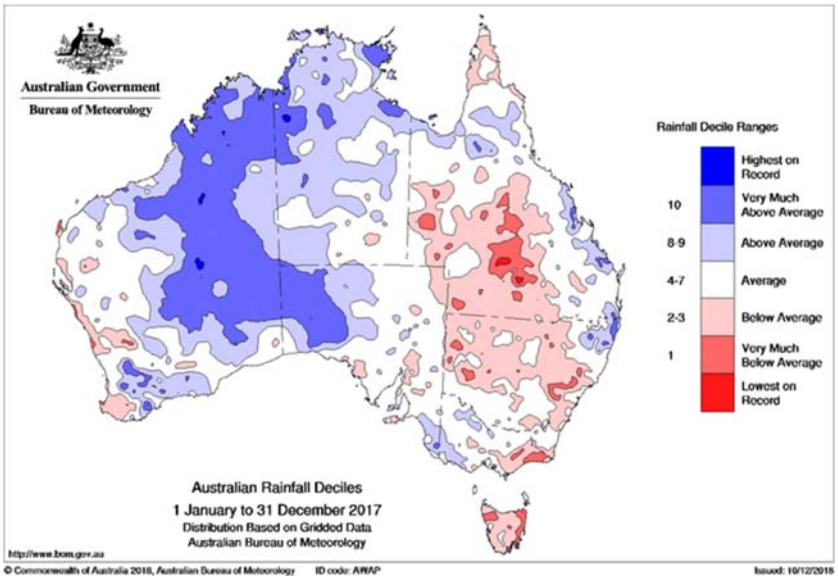
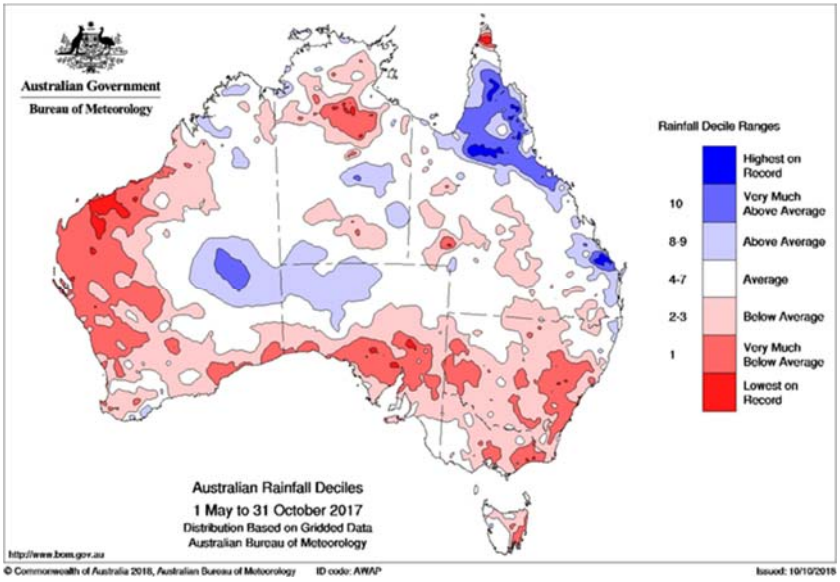
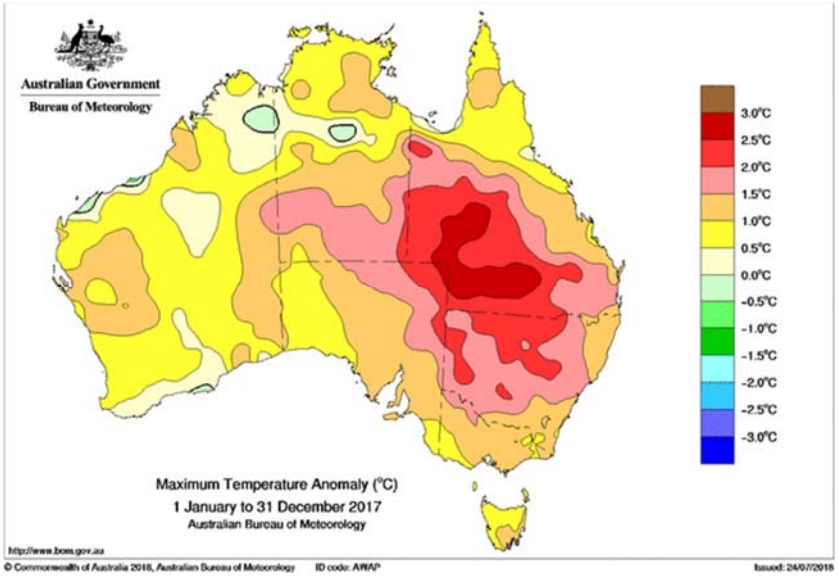


Figure 2: Winter rainfall deciles, 2017



In addition, much of northern New South Wales and southern Queensland had average maximum temperatures 1.5C to 2.5C above average (figure 3). On this basis, northern New South Wales and southern Queensland experienced at least moderate and possibly severe drought conditions in 2017.

Figure 3: Maximum temperature anomaly, 2017



2018 rainfall and temperature anomalies in Australia

In 2018, northern New South Wales and southern Queensland descended further into drought conditions. Annual rainfall deficiencies were less severe than winter rainfall deficiencies, when recorded rainfall is more effective. Figure 5 shows that much of New South Wales and southern Queensland had decile 1 or worse winter rainfall in 2018.

Figure 4: Rainfall deciles, 2018

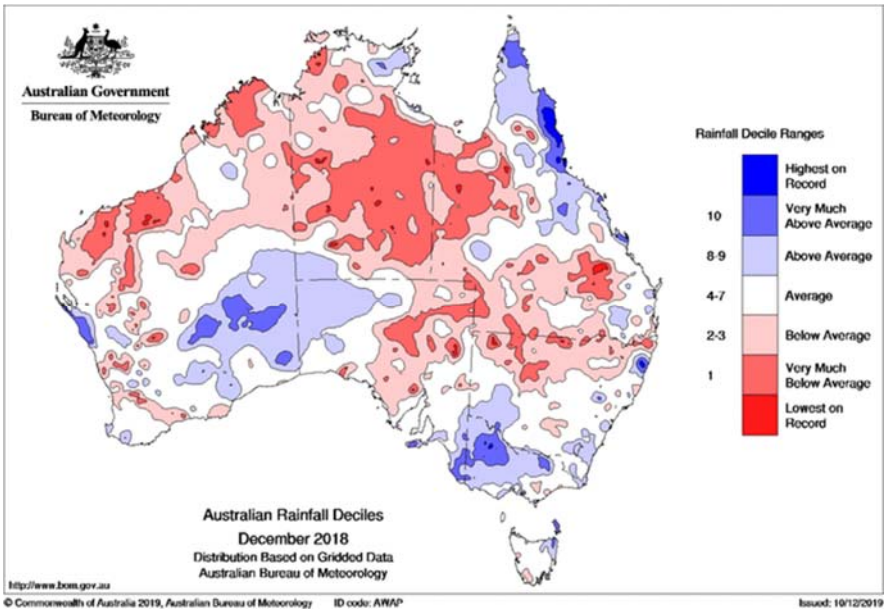
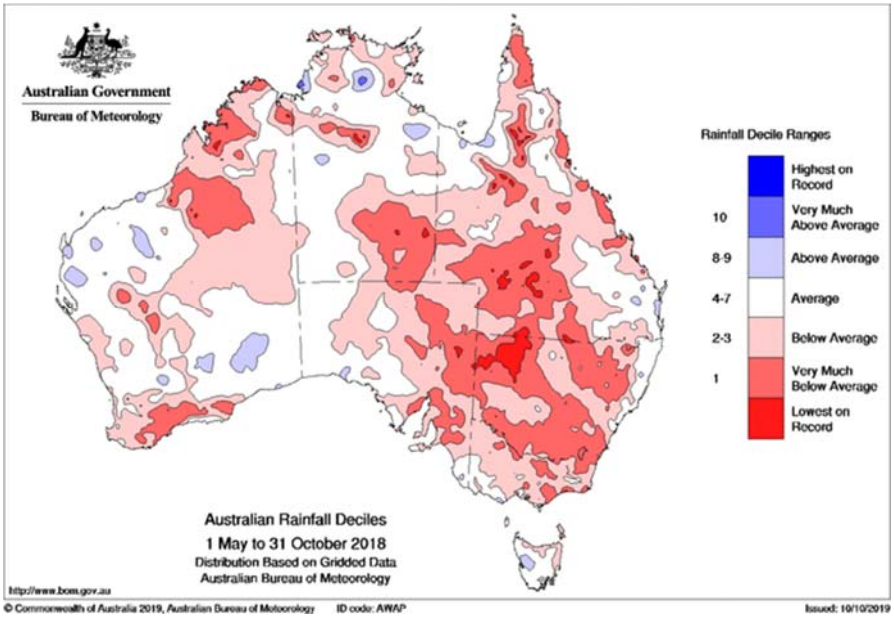
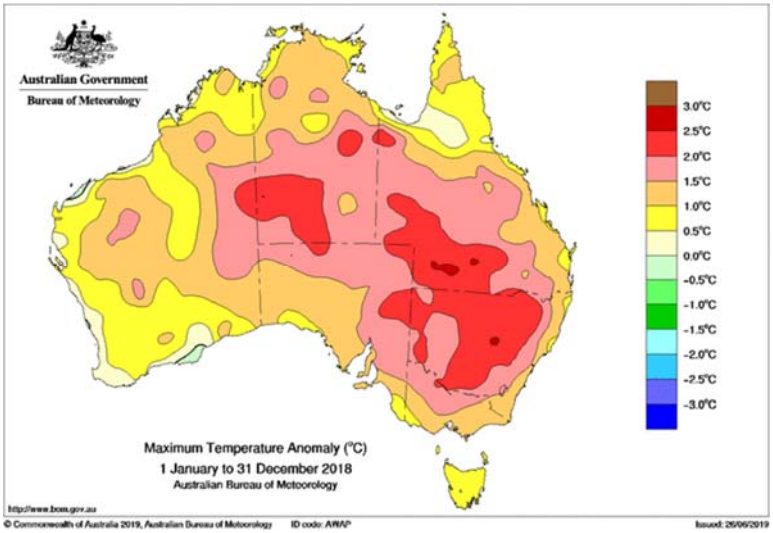


Figure 5: Winter rainfall deciles, 2018



Drought spread to virtually the entire state in 2018. Maximum temperature anomalies for a substantial part of the state exceeded 2 degrees (figure 6).

Figure 6: Maximum temperature anomaly, 2018



2019 rainfall and temperature anomalies in Australia

After two years of worsening drought across New South Wales and southern Queensland, the Indian Ocean Dipole in 2019 was the strongest positive value ever recorded (see http://www.bom.gov.au/climate/iod/). A substantial part of the regions already drought affected in the previous two years suffered their driest and hottest year on record (figures 7 and 9). Record winter rainfall deficits were also recorded in some areas in the third consecutive year of drought (figure 8).

Figure 7: Rainfall deciles, 2019

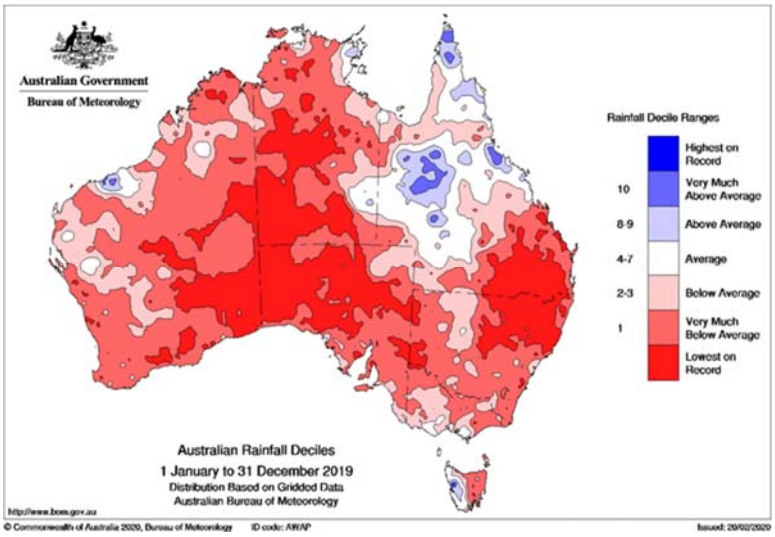


Figure 8: Winter rainfall deciles, 2019

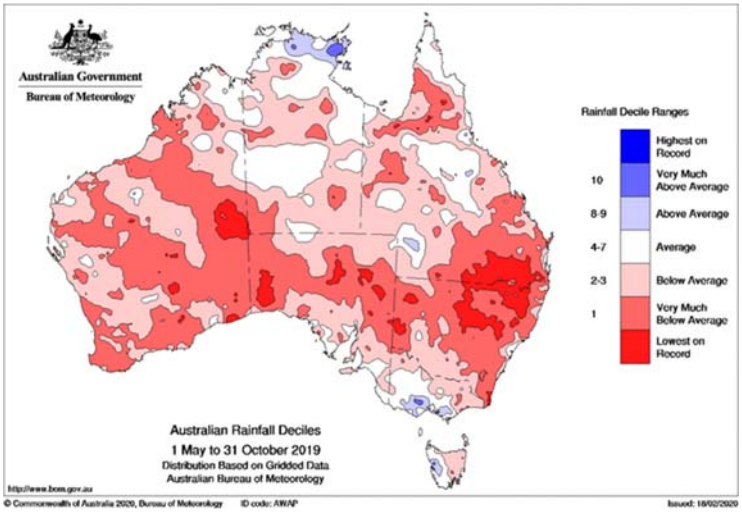
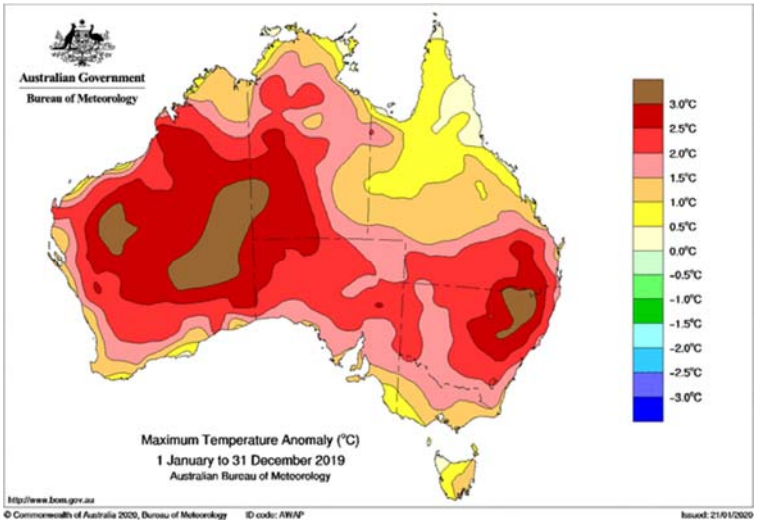


Figure 9: Maximum temperature anomaly, 2019



Recovery in 2020

In substantial parts of eastern Australia, rainfall in the first 10 weeks of 2020 has already exceeded annual totals for 2019.

Within the modelling reported in this study, we assume that there is a full seasonal recovery reflected across Australia. The Bureau of Meteorology, as of 5 March 2020, projected average or above average rainfall in most of the regions worst affected by drought (see http://www.bom.gov.au/climate/outlooks/#/overview/summary). In regions with substantial bushfire damage, recovery will be slower. This study does not take account of bushfire impacts nor their slowing of recovery.

2. Statewide results

Ascribing shocks to VU-TERM

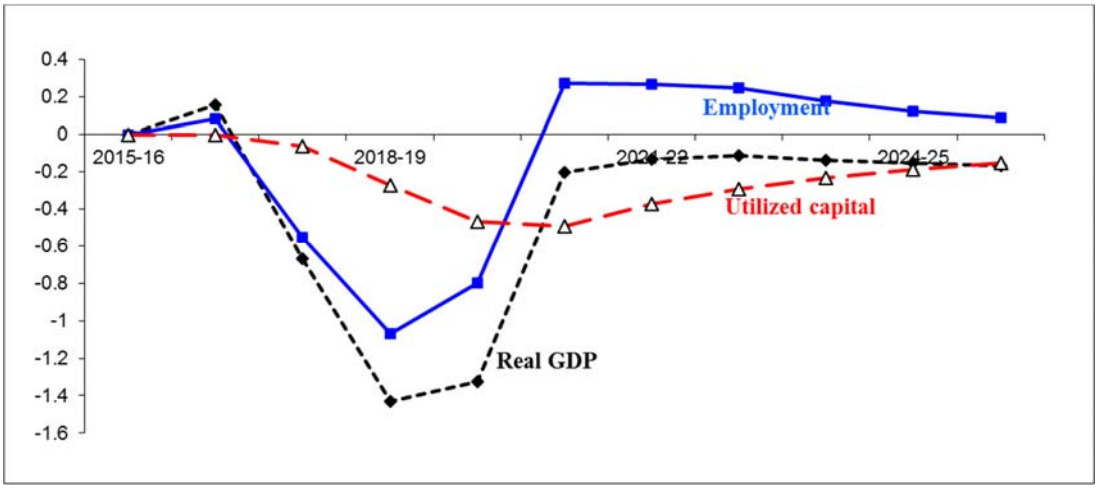
There are two types of shocks in this simulation. Crop outputs for 2016-17 to 2018-19 were based on observations. The corresponding outputs for 2019-20 are based on projections (ABARES Crop Reports).

Livestock output within the model is depicted via land productivity shocks. The reason for choosing land productivity instead of total factor productivity is that within the modified theory of VU-TERM, land is substitutable with hay & fodder within the production function of the livestock sectors. Once pastures fail due to drought, farmers turn to hay & fodder to feed their livestock.

To put the present drought into context, the simulation starts at 2015-16. The following year 2016-17 is depicted as a better than average year for agriculture. The following year 2017-18 is depicted as a moderate drought in northern NSW, with crop data indicating a poorer season elsewhere. In 2018-19 and 2019-20, modelling depicts a worsening drought that has spread state-wide except in the northern coastal region.

The state-wide macro results reflect the shocks to the model. We explain GDP as a function of primary factors and underlying technology: GDP=f(Land, Labour, Capital, Technology). The impact of changes in income-side factors and technology is shown in figure 10.

Figure 10: NSW GDP, income side
(% deviations from base)



During drought, we observe that on-farm and contractor machinery may be idle due to reduced plantings. This effect is captured mostly by exogenously assuming a reduction in utilized capital. With a return to normal seasons in 2020-21, capital returns to full utilization. However, capital remains below base in recovery years due to a drought-induced decline in investment (figures 10 and 12).

Drought reduces the output that farms can produce from given inputs, implying a technological deterioration. This is evident in figure 10. Real GDP is a macro measure of output, and from 2017-18 to 2019-20, the percentage fall in real GDP is larger than the percentage fall in labour or utilized capital, with technological deterioration explaining most of the loss.

Drought weakens the labour market in NSW, with both employment and real wages falling below forecast (figure 11). Employment falls more than 0.25% or 7,800 FTE jobs below forecast in 2017-18 and 0.55% or 17,600 FTE jobs below base in 2018-19. By assumption, real wages adjust sluggishly at the regional level.

In the recovery year (2020-21), employment rises to 0.28% or around 9,000 jobs above forecast in NSW. With a strengthening of the labour market due to a return to normal seasonal conditions, real wages persist below forecast due to sluggish adjustment. As long as labour demand exceeds labour supply, there is upward pressure on wages. By 2025-26, labour supply, employment and real wages are moving towards base.

Figure 11: NSW labour market
(% deviations from base)

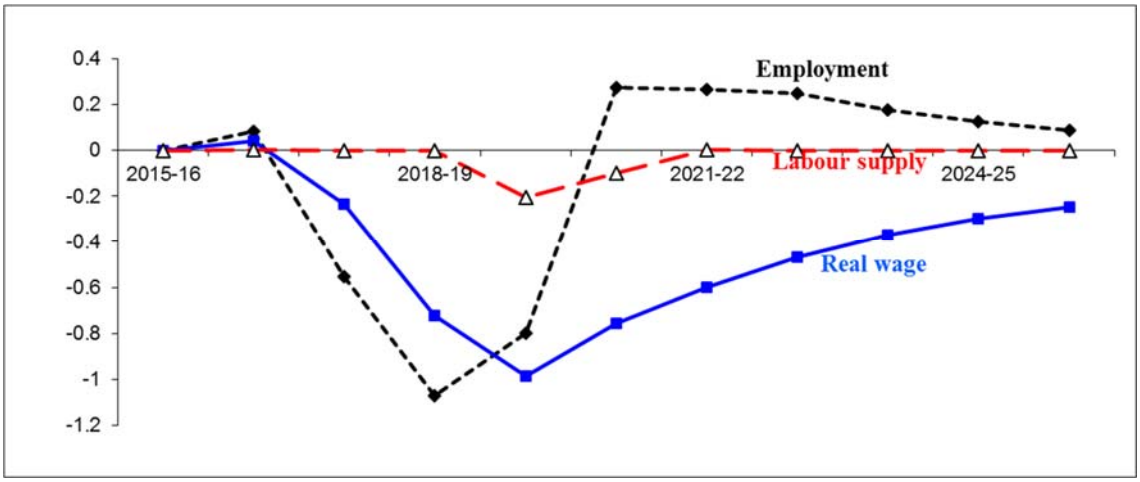
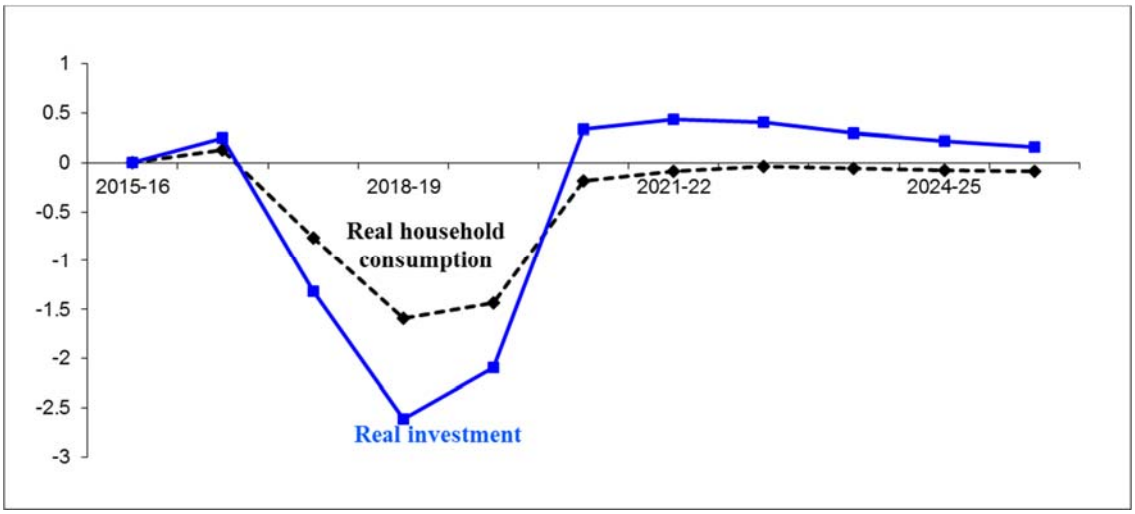


Figure 12: NSW expenditure side
(% deviations from base)



Fluctuations in farm investment in response to changing seasonal conditions drive fluctuations in NSW macro investment relative to forecast (figure 12). In the relatively good season of 2016-17 and in recovery in 2020-21, state-wide investment rises above forecast. In the dry years of 2017-18 to 2019-20, investment falls below forecast.

Table 1 summarises the deviations in macro variables and employment for forecast from a base with business-as-usual or average seasonal conditions.

Table 1: NSW macro outcomes
($m real or jobs FTE relative to base)

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Real GDP ($m)	832	-3762	-8281	-7924	-1251	-842	-732	-917	-1062	-1177
Household consumption ($m)	414	-2610	-5631	-5234	-717	-337	-148	-255	-324	-370
Real investment ($m)	315	-1708	-3460	-2822	461	618	579	436	325	238
Employment (FTE)	2608	-17598	-34356	-25864	8976	8752	8191	5852	4173	2962

Table 2: NSW industry outputs
(% change in outputs relative to base)

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Sheep	0.1	-11.0	-22.0	-22.5	-8.3	-4.0	-3.3	-2.4	-1.7	-1.1
BeefCattle	0.1	-11.4	-20.9	-21.5	-8.8	-2.0	-1.5	-0.9	-0.3	0.3
DairyCattle	0.3	-8.7	-14.5	-13.9	-3.0	2.1	2.6	3.2	3.7	4.1
OthLivstock	-0.3	-0.3	-5.0	-4.4	-3.4	-3.1	-3.0	-2.8	-2.7	-2.5
Wheat	42.3	-43.3	-65.9	-66.1	-8.7	-5.0	-5.0	-4.8	-4.6	-4.4
OthBrdAcrCrp	18.6	-43.3	-59.0	-58.6	-2.9	-0.7	-0.9	-0.8	-0.8	-0.7
Horticulture	-0.1	-0.1	-0.9	-12.9	-0.8	-0.8	-0.9	-0.9	-0.9	-0.9
Rice	-0.2	-30.0	-64.9	-65.6	-56.9	-34.8	-2.9	-3.0	-3.1	-3.2
Cotton	0.0	-20.0	-48.0	-47.8	-13.7	-0.5	5.9	5.6	5.3	5.0
HayCerealFod	12.8	-17.8	-51.2	-49.7	8.8	6.7	6.2	5.9	5.6	5.4
ForestFish	-0.1	-0.3	-1.2	-1.3	-0.7	-0.6	-0.6	-0.5	-0.6	-0.6
GinnedCotton	0.2	-17.1	-38.2	-37.5	-25.2	-11.9	3.5	3.0	2.6	2.2
AgriSrvces	2.8	-9.8	-19.7	-19.5	-3.6	-1.2	-0.2	-0.2	-0.2	-0.2
Mining	-0.2	1.0	2.1	2.1	0.9	0.6	0.5	0.5	0.5	0.4
MeatProds	-0.2	-1.8	-7.2	-6.8	-1.9	-1.4	-1.5	-1.3	-1.2	-1.1
Seafood	-0.1	0.4	0.9	0.8	0.5	0.3	0.2	0.2	0.2	0.2
DairyProds	0.5	-1.6	-4.0	-4.0	-0.4	-0.4	-0.4	-0.3	-0.2	-0.1
OtherFood	0.4	-1.5	-3.2	-3.5	-0.3	-0.4	-0.4	-0.3	-0.2	-0.1
TCFs	-0.2	0.6	0.6	0.6	0.3	0.1	-0.1	-0.1	-0.2	-0.2
OthManuf	-0.1	0.6	1.3	1.5	0.8	0.6	0.5	0.4	0.4	0.3
Utilities	0.1	-0.4	-0.9	-0.8	-0.1	0.0	0.0	-0.1	-0.1	-0.1
Constructn	0.1	-1.0	-2.0	-1.6	0.1	0.2	0.2	0.2	0.1	0.1
Trade	0.2	-0.8	-1.7	-1.5	0.0	0.0	0.1	0.0	0.0	0.0
HotelsCafes	0.1	-0.6	-1.6	-1.4	-0.2	-0.1	-0.2	-0.2	-0.2	-0.2
RoadFreight	0.5	-1.3	-2.6	-2.5	-0.4	-0.2	-0.2	-0.2	-0.2	-0.2
OthTransport	0.1	-0.5	-1.2	-1.1	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3
OthService	0.0	-0.2	-0.4	-0.3	0.2	0.1	0.1	0.1	0.1	0.1
OwnerDwellng	0.0	0.0	-0.1	-0.2	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2
GovAdmDefOrd	0.1	-0.6	-1.4	-1.2	-0.1	-0.1	0.0	-0.1	-0.1	-0.1
EduHealth	0.0	0.0	0.0	0.2	0.4	0.3	0.2	0.2	0.1	0.1

Table 3: NSW industry outputs
($m change in outputs relative to base, 2018 dollars)

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Sheep	1	-70	-136	-137	-50	-24	-20	-15	-10	-7
BeefCattle	1	-95	-174	-178	-73	-17	-13	-7	-2	2
DairyCattle	0	-10	-16	-15	-3	2	3	4	4	5
OthLivstock	-2	-2	-27	-22	-17	-15	-14	-13	-13	-12
Wheat	375	-379	-561	-552	-72	-41	-41	-39	-37	-35
OthBrdAcrCrp	195	-451	-601	-588	-29	-7	-8	-8	-7	-7
Horticulture	-1	-1	-5	-75	-5	-5	-5	-5	-5	-6
Rice	0	-34	-85	-97	-94	-64	-6	-6	-7	-8
Cotton	0	-184	-443	-442	-127	-5	55	52	50	47
HayCerealFod	30	-40	-114	-109	19	14	13	13	12	12
ForestFish	0	-1	-7	-7	-4	-3	-3	-3	-3	-4
GinnedCotton	2	-159	-366	-367	-253	-122	36	32	28	25
AgriSrvces	12	-43	-90	-91	-17	-6	-1	-1	-1	-1
Mining	-12	67	150	153	64	46	37	35	34	33
MeatProds	-5	-43	-173	-166	-47	-35	-37	-33	-30	-28
Seafood	0	0	1	1	0	0	0	0	0	0
DairyProds	3	-9	-22	-22	-2	-2	-2	-2	-1	-1
OtherFood	25	-91	-197	-215	-16	-27	-23	-16	-11	-7
TCFs	-1	5	5	5	2	1	-1	-1	-1	-2
OthManuf	-25	132	296	334	190	138	109	97	87	87
Utilities	5	-36	-73	-67	-7	-4	-4	-5	-6	-7
Constructn	41	-291	-620	-524	46	79	80	62	46	32
Trade	70	-327	-694	-650	-17	20	29	13	1	-8
HotelsCafes	7	-93	-228	-216	-25	-22	-28	-33	-38	-41
RoadFreight	29	-84	-167	-168	-26	-16	-15	-16	-17	-19
OthTransport	8	-76	-191	-184	-37	-35	-44	-50	-55	-61
OthService	56	-447	-851	-628	368	317	273	213	172	143
OwnerDwellng	0	6	-26	-93	-150	-149	-141	-130	-120	-112
GovAdmDefOrd	16	-180	-395	-371	-40	-17	-13	-22	-29	-34
EduHealth	-4	-14	20	94	215	162	126	99	81	68

Note: the sum of real value-added does not exactly equal real GDP, as the latter includes indirect taxes.

The welfare of drought calculated from a national perspective, based on the net present value of the deviation in real private plus public consumption from base, minus the change in net foreign liabilities in the final year of the simulation. The welfare impact of the drought is $43 billion, or an annualised loss of $1,300 million based on a 3% discount rate. If we apply the same calculation to NSW deviations, the annualised loss is $690 million or $89 per person.

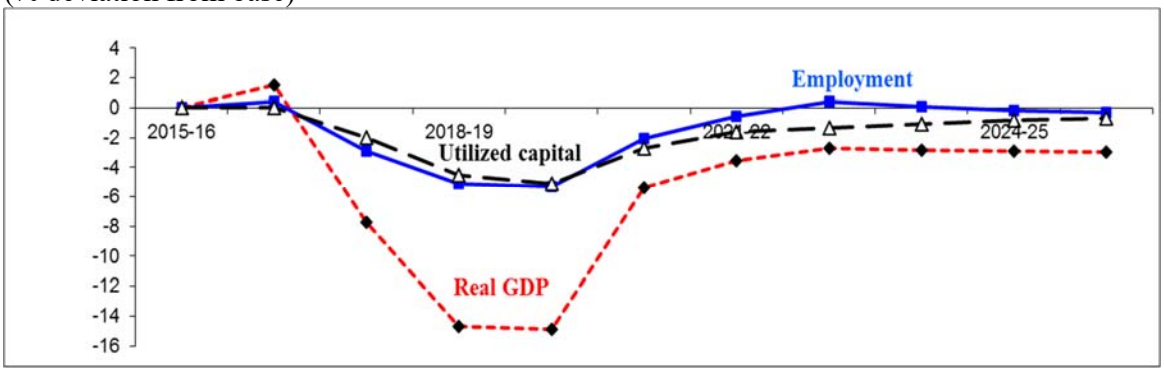
3. Sub-state impacts

New England-North West

New England-North West (an SA4 region) has the largest drought-induced productivity losses of any region in the scenario. Real GDP and employment rose relative to forecast in 2016-17 due to a seasonal recovery, then slumped in 2017-18 due to drought. Worsening drought in 2018-19 drove employment to more than 5% below base. Idle farm capital due to

drought was largely responsible for a fall in utilized capital to 4% below forecast in this year. Real GDP in 2018-19 and 2019-20 was almost 15% below base, reflecting reduced employment, capital utilization and drought-induced productivity losses (figure 13). In the base year, farming and downstream processing accounts for around 24% of regional income.

Figure 13: New England-North West GDP income side
(% deviation from base)



Drought weakens the labour market in New England-North West, with the fall of employment of 5% or around 3600 jobs in 2018-19 and 2019-20 being accompanied by a fall in real wages of 3.0% relative to forecast (figure 14).

Figure 14: New England-North West labour market
(% deviation from base)

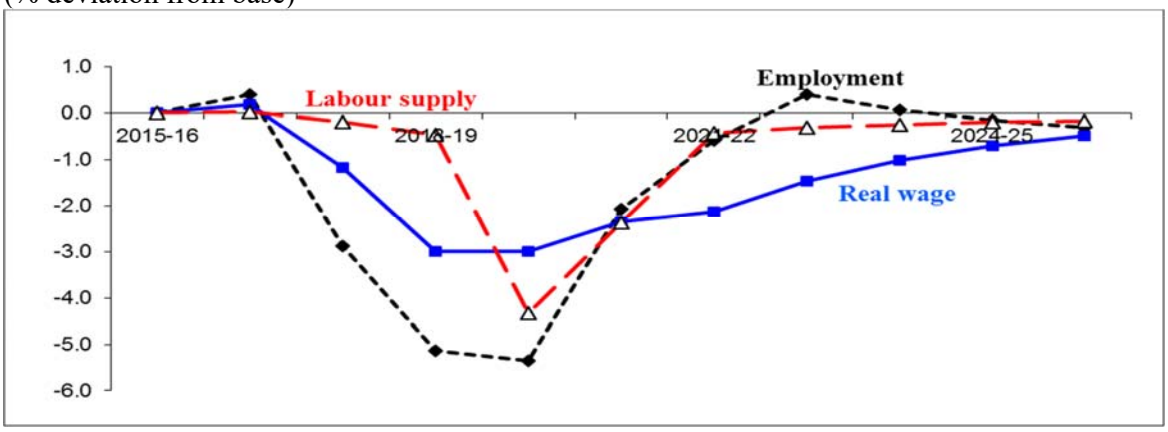
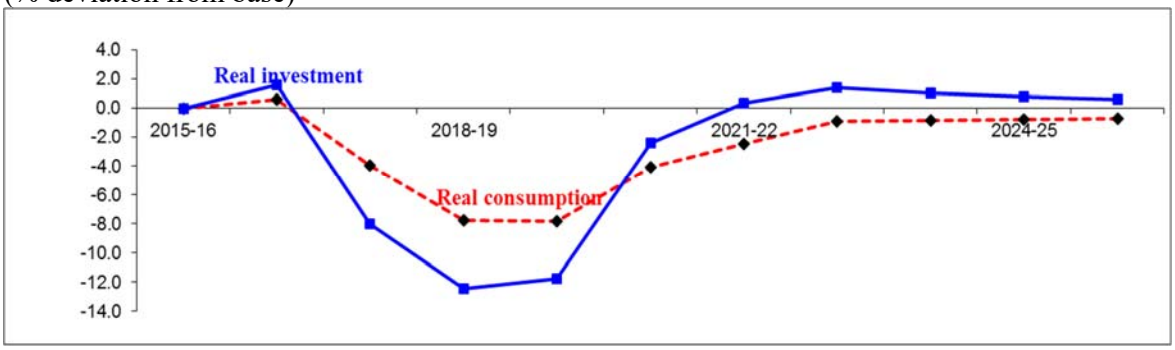


Figure 15: New England-North West real consumption and investment
(% deviation from base)



Drought induces a sharp fall in investment in New England-North West, as shown for 2017-18 to 2019-20. Recovery induces a rise relative to base in investment in 2020-21 (figure 15).

Table 4: SA2 level macro outcomes within New England-North West
(% change from base)

Real GDP	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Armidale	0.3	-1.0	-1.1	-1.5	0.2	0.2	-0.2	-0.4	-0.5	-0.6
Armidale Region - North	0.3	-3.4	-6.1	-6.4	-2.1	-0.9	-1.4	-1.3	-1.3	-1.2
Armidale Region - South	0.2	-1.6	-2.8	-3.2	-0.7	-0.3	-0.7	-0.8	-0.8	-0.8
Walcha	0.7	-4.7	-8.1	-8.5	-2.6	-1.3	-1.8	-1.7	-1.6	-1.5
Glen Innes	0.5	-3.2	-5.2	-5.5	-1.5	-0.8	-1.2	-1.2	-1.2	-1.2
Inverell	0.3	-1.6	-3.2	-3.5	-0.5	-0.3	-0.8	-0.8	-0.9	-0.9
Inverell Region - East	1.1	-7.3	-14.1	-14.4	-4.8	-3.3	-3.7	-3.6	-3.5	-3.5
Inverell Region - West	3.2	-13.3	-18.1	-18.5	-4.7	-3.5	-4.0	-4.0	-3.9	-3.9
Tenterfield	0.6	-3.3	-5.2	-5.5	-1.5	-0.9	-1.4	-1.4	-1.4	-1.4
Moree	1.6	-10.9	-21.9	-21.9	-9.5	-5.7	-2.2	-2.5	-2.7	-2.8
Moree Region	10.1	-33.6	-52.3	-52.3	-14.7	-9.5	-6.5	-6.6	-6.7	-6.7
Narrabri	1.0	-7.8	-19.0	-19.1	-8.0	-5.1	-2.7	-2.9	-3.0	-3.1
Narrabri Region	4.3	-22.3	-42.6	-42.5	-16.1	-9.0	-2.8	-3.1	-3.3	-3.5
Gunnedah	0.3	-2.0	-4.8	-4.9	-1.6	-1.0	-0.8	-1.0	-1.1	-1.2
Gunnedah Region	2.9	-15.8	-31.4	-31.5	-11.3	-7.6	-5.1	-5.2	-5.3	-5.4
Quirindi	2.9	-11.1	-17.7	-17.9	-4.8	-3.9	-4.2	-4.2	-4.3	-4.3
Tamworth - East	0.3	-1.1	-2.0	-2.3	-0.2	0.0	-0.4	-0.5	-0.6	-0.6
Tamworth - North	0.3	-1.2	-1.9	-2.2	-0.1	-0.1	-0.5	-0.6	-0.7	-0.8
Tamworth - West	0.2	-0.9	-2.3	-2.6	-0.3	-0.3	-0.9	-0.9	-1.0	-1.0
Tamworth Region	0.7	-3.1	-4.8	-5.1	-1.1	-0.6	-1.0	-1.1	-1.1	-1.2
Employment										
Armidale	0.2	-0.6	-0.4	-0.6	1.1	1.1	0.6	0.2	-0.1	-0.2
Armidale Region - North	0.4	-2.3	-3.2	-3.4	0.4	1.0	0.6	0.2	0.0	-0.1
Armidale Region - South	0.4	-1.5	-1.9	-2.1	0.7	1.1	0.6	0.2	0.0	-0.2
Walcha	0.6	-3.0	-4.2	-4.5	0.1	1.1	0.5	0.3	0.1	0.0
Glen Innes	0.5	-2.0	-2.6	-2.7	0.5	1.0	0.5	0.2	0.0	-0.2
Inverell	0.2	-1.6	-3.3	-3.2	0.6	0.9	0.3	0.0	-0.2	-0.4
Inverell Region - East	0.3	-1.9	-2.6	-3.0	-0.3	0.5	0.1	-0.2	-0.3	-0.4
Inverell Region - West	0.6	-3.2	-4.2	-4.5	0.0	1.0	0.4	0.1	-0.1	-0.2
Tenterfield	0.5	-1.7	-1.9	-2.1	0.7	1.1	0.5	0.2	0.0	-0.2
Moree	0.5	-6.7	-14.0	-14.0	-8.0	-3.6	1.0	0.6	0.3	0.1
Moree Region	0.9	-8.5	-14.6	-15.8	-10.8	-5.5	-1.0	-1.2	-1.2	-1.2
Narrabri	0.4	-4.5	-9.1	-9.4	-5.9	-2.8	0.5	0.2	-0.1	-0.3
Narrabri Region	0.4	-9.6	-20.6	-21.1	-15.4	-7.9	0.5	0.1	-0.1	-0.3
Gunnedah	0.1	-1.0	-1.5	-1.8	-0.3	0.3	0.6	0.3	0.0	-0.2
Gunnedah Region	0.4	-4.1	-7.6	-8.6	-7.3	-4.0	-0.3	-0.6	-0.7	-0.8
Quirindi	0.6	-2.3	-2.8	-3.1	0.0	0.6	0.1	-0.2	-0.4	-0.5
Tamworth - East	0.4	-1.4	-2.3	-2.3	0.7	0.9	0.4	0.1	-0.2	-0.3
Tamworth - North	0.3	-1.1	-1.5	-1.6	0.9	1.0	0.4	0.1	-0.1	-0.3
Tamworth - West	0.4	-1.8	-3.4	-3.3	0.6	0.9	0.3	0.0	-0.3	-0.4
Tamworth Region	0.4	-1.5	-1.9	-2.1	0.8	1.0	0.5	0.1	-0.1	-0.2

New England-North West includes economic activities that are not directly affected by drought, including education, health and other services. At the SA2 level, in which some regions are far more reliant on farming, losses are more substantial.

For example, the Moree Region suffers a loss in real GDP of more than half relative to base in 2018-19, with an accompanying fall in employment of 16% (table 4). In general, SA2 regions that cover towns tend to suffer losses that are smaller than SA2s that are cover out-of-town regions. This reflects the industry composition of the SA2 economy, with services accounting for a larger share of within-town income.

Far West-Orana

Far West-Orana is aonther SA4 region severely affected by three years of drought. Figures 16 to 18 show the macro outcomes.

Figure 16: Far West-Orana real GDP income side
(% deviation from base)

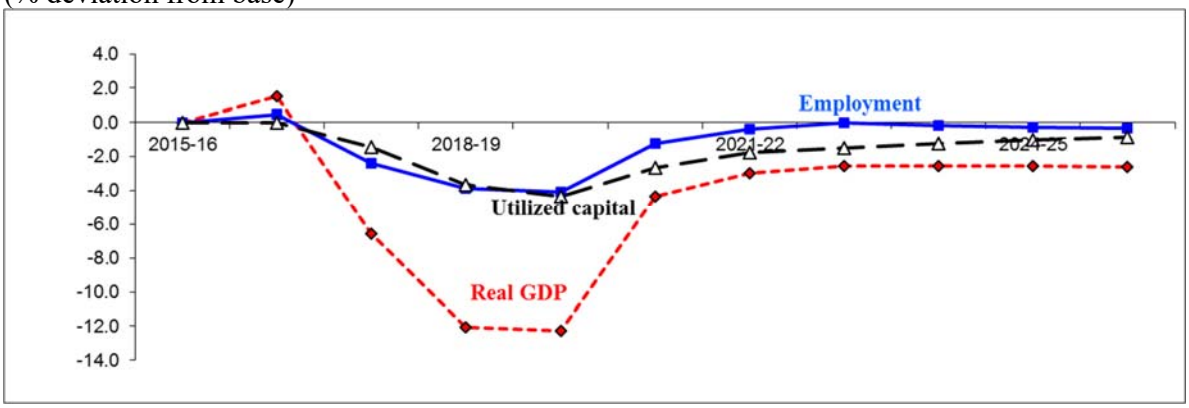


Figure 17: Far West-Orana labour market
(% deviation from base)

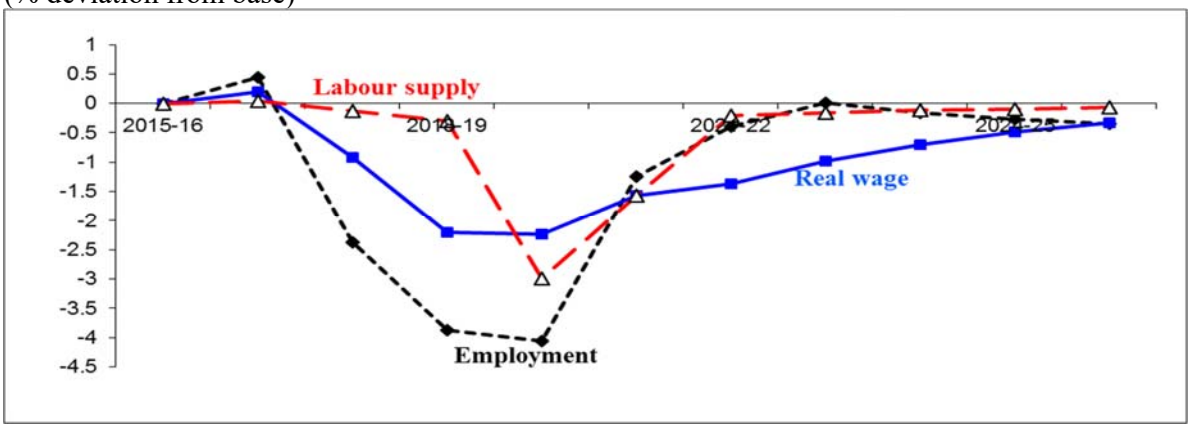


Figure 18: Far West-Orana real consumption and investment
(% deviation from base)

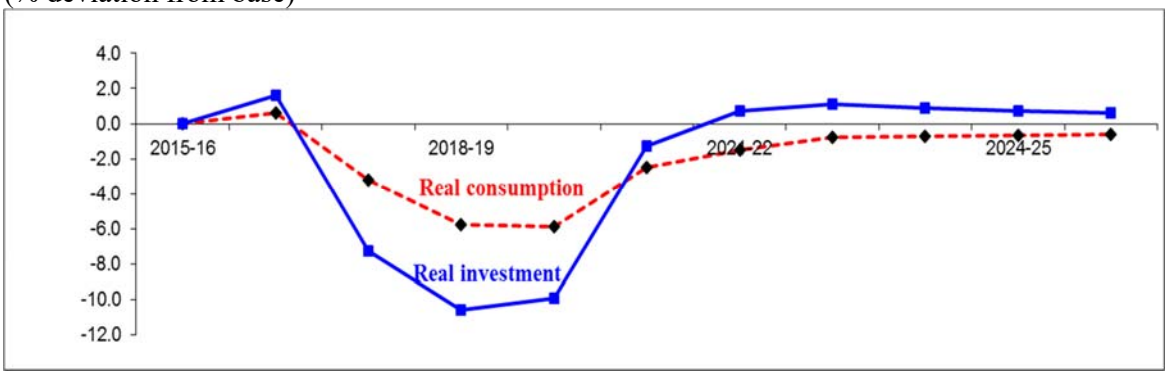


Table 5: SA2 level macro outcomes within Far West-Orana
(% change from base)

Real GDP	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Bourke – Brewarrina	0.6	-6.7	-17.4	-17.5	-7.7	-5.1	-3.5	-3.5	-3.5	-3.5
Cobar	0.7	-2.2	-2.8	-3.0	-0.6	-0.5	-0.8	-0.8	-0.8	-0.8
Coonamble	7.1	-20.5	-30.7	-31.0	-8.8	-6.7	-6.5	-6.4	-6.3	-6.2
Nyngan – Warren	2.8	-15.8	-35.6	-35.7	-12.9	-8.4	-6.0	-6.0	-6.1	-6.1
Walgett - Lightning Ridge	5.2	-18.7	-30.1	-30.3	-10.0	-7.2	-5.6	-5.6	-5.6	-5.6
Broken Hill	0.1	-0.3	-0.4	-0.7	0.1	0.1	-0.1	-0.1	-0.2	-0.2
Far West	0.0	-5.8	-10.8	-11.0	-4.4	-2.2	-2.3	-2.1	-1.9	-1.7
Coonabarabran	2.3	-7.9	-11.7	-11.9	-3.3	-2.3	-2.4	-2.4	-2.3	-2.3
Dubbo – East	0.4	-1.4	-2.5	-2.8	-0.6	-0.4	-0.5	-0.6	-0.6	-0.6
Dubbo – South	0.4	-1.6	-2.7	-3.0	-0.6	-0.4	-0.5	-0.6	-0.6	-0.6
Dubbo – West	0.4	-1.5	-2.6	-2.9	-0.6	-0.4	-0.6	-0.6	-0.7	-0.7
Dubbo Region	1.5	-5.8	-8.6	-8.9	-2.4	-1.7	-1.8	-1.8	-1.8	-1.8
Gilgandra	5.0	-15.8	-21.4	-21.7	-5.5	-4.5	-4.6	-4.5	-4.5	-4.4
Narromine	3.6	-16.7	-29.8	-30.0	-11.3	-7.6	-4.5	-4.6	-4.7	-4.7
Wellington	1.6	-5.9	-8.9	-9.1	-2.4	-1.7	-1.8	-1.8	-1.8	-1.8
Employment										
Bourke – Brewarrina	0.5	-3.4	-6.2	-6.6	-4.2	-2.2	-0.2	-0.4	-0.4	-0.5
Cobar	-0.1	0.5	1.6	1.2	1.0	0.9	0.4	0.2	0.1	0.0
Coonamble	0.8	-5.0	-6.9	-7.3	-2.3	-0.5	-0.4	-0.5	-0.5	-0.5
Nyngan – Warren	0.7	-3.0	-4.5	-6.1	-7.2	-4.9	-1.9	-1.9	-1.8	-1.7
Walgett - Lightning Ridge	0.6	-5.3	-9.1	-9.5	-5.1	-2.3	-0.2	-0.3	-0.4	-0.4
Broken Hill	0.2	-0.5	-0.4	-0.6	0.7	0.6	0.3	0.1	-0.1	-0.2
Far West	0.0	-2.8	-3.7	-4.0	-0.7	0.5	0.2	0.2	0.2	0.2
Coonabarabran	0.5	-2.6	-3.9	-4.0	-0.4	0.3	0.1	0.0	-0.1	-0.2
Dubbo – East	0.4	-1.8	-3.0	-3.0	0.1	0.3	0.1	-0.1	-0.2	-0.3
Dubbo – South	0.4	-1.7	-2.9	-2.9	0.1	0.3	0.1	-0.1	-0.2	-0.3
Dubbo – West	0.4	-1.8	-3.0	-3.0	0.1	0.3	0.1	-0.1	-0.2	-0.3
Dubbo Region	0.6	-2.6	-4.0	-4.0	-0.2	0.3	0.1	0.0	-0.2	-0.2
Gilgandra	0.8	-4.4	-6.6	-6.7	-1.0	0.2	0.0	-0.1	-0.2	-0.3
Narromine	0.8	-6.9	-13.1	-13.4	-8.2	-4.3	0.0	-0.2	-0.3	-0.4
Wellington	0.5	-2.4	-3.7	-3.8	-0.2	0.3	0.2	0.0	-0.1	-0.2

Other SA4 regions

Drought-induced income losses in Murray SA4 are moderated by irrigation activity. Perennial producers purchase water off annual irrigators, particularly rice and cotton, in this scenario. Although low security water allocations have been cut severely, higher security water cuts were not as severe in the southern basin.[1]

Figure 16: Murray real GDP income side
(% deviation from base)

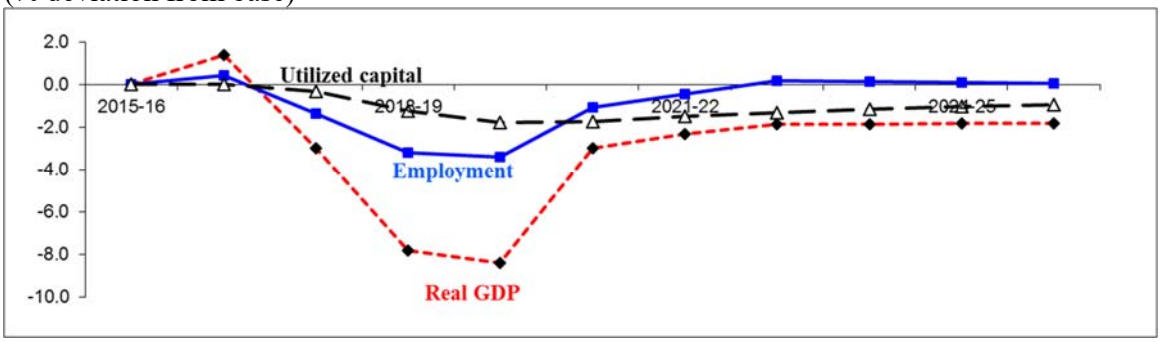


Figure 17: Murray labour market
(% deviation from base)

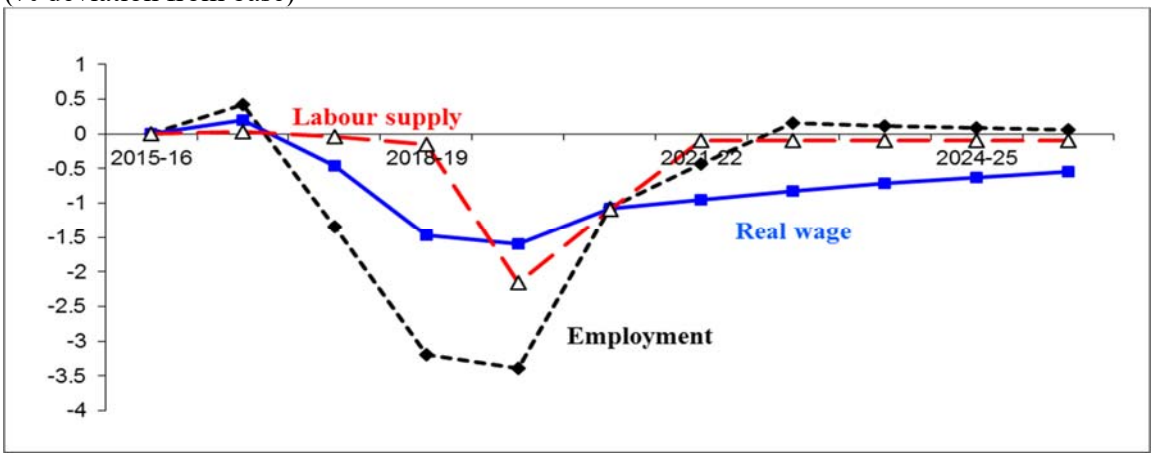
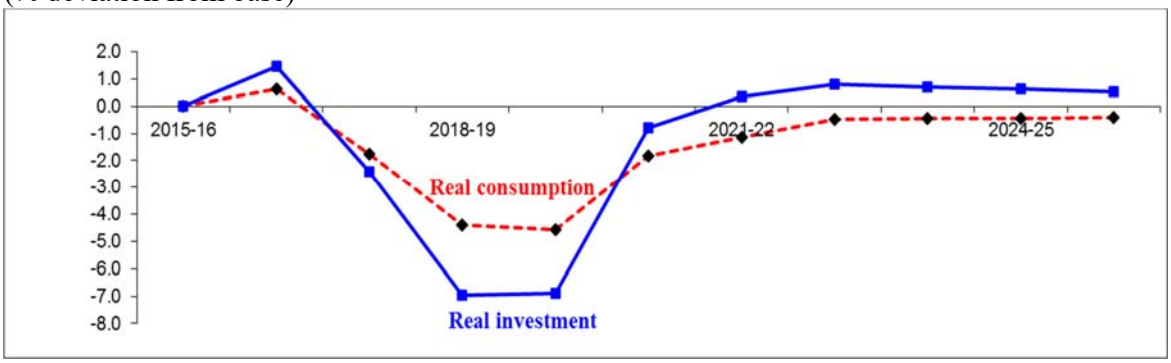


Figure 18: Murray real consumption and investment
(% deviation from base)



[1] See https://nvrm.net.au/seasonal-determinations/history/seasonal-determination-17-september-2018.html.

Table 6: SA2 level macro outcomes within Murray
(% change from base)

Real GDP	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Albury – East	0.2	-0.7	-1.7	-2.0	-0.6	-0.6	-0.5	-0.5	-0.5	-0.6
Albury – North	0.2	-0.8	-2.2	-2.4	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Albury – South	0.1	-0.7	-2.1	-2.3	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Albury Region	1.7	-3.0	-8.5	-8.8	-2.5	-2.1	-2.0	-2.0	-2.0	-1.9
Lavington	0.2	-0.8	-1.9	-2.2	-0.8	-0.8	-0.7	-0.7	-0.7	-0.7
Hay	0.5	-11.5	-23.8	-23.9	-14.4	-7.7	-0.3	-0.3	-0.4	-0.5
Wentworth – Buronga	0.5	-1.3	-3.6	-7.2	-1.9	-1.8	-1.8	-1.8	-1.8	-1.8
Wentworth-Balranald Reg.	3.6	-5.0	-12.9	-16.7	-4.5	-3.8	-3.7	-3.6	-3.5	-3.5
Corowa	0.4	-1.6	-5.9	-6.0	-3.0	-2.9	-2.8	-2.7	-2.7	-2.6
Corowa Region	5.0	-6.8	-17.0	-17.3	-4.7	-4.0	-4.0	-3.9	-3.8	-3.8
Deniliquin	0.9	-2.1	-6.0	-6.2	-2.2	-2.0	-1.9	-1.8	-1.8	-1.8
Deniliquin Region	5.9	-8.0	-22.2	-22.5	-5.4	-4.5	-4.3	-4.2	-4.1	-4.1
Moama	0.9	-1.9	-5.4	-5.8	-2.3	-2.2	-2.1	-2.1	-2.1	-2.0
Tocumwal - Finley – Jerilderie	3.5	-5.7	-15.1	-15.8	-4.1	-3.4	-3.3	-3.2	-3.2	-3.1
Employment										
Albury – East	0.2	-0.8	-1.6	-1.7	0.1	0.2	0.2	0.1	0.1	0.1
Albury – North	0.3	-0.9	-2.0	-2.1	0.0	0.0	0.1	0.1	0.0	0.0
Albury – South	0.2	-0.8	-1.5	-1.7	0.0	0.1	0.1	0.1	0.1	0.0
Albury Region	0.4	-0.7	-1.9	-2.2	-0.2	0.1	0.2	0.2	0.2	0.1
Lavington	0.3	-0.9	-1.8	-2.0	0.1	0.1	0.2	0.1	0.1	0.0
Hay	0.3	-10.1	-19.3	-19.5	-15.6	-8.5	0.7	0.7	0.7	0.6
Wentworth – Buronga	0.5	-1.2	-2.8	-3.2	-0.3	-0.2	0.0	-0.1	-0.1	-0.2
Wentworth-Balranald Reg.	0.6	-1.2	-4.0	-4.6	-1.5	-0.5	-0.1	-0.1	-0.1	-0.1
Corowa	0.3	-1.0	-2.9	-3.0	-0.8	-0.6	-0.3	-0.3	-0.3	-0.3
Corowa Region	0.7	-0.7	-3.3	-3.5	-1.0	-0.1	0.1	0.1	0.0	0.0
Deniliquin	0.5	-1.4	-3.5	-3.6	-0.4	-0.1	0.1	0.0	0.0	0.0
Deniliquin Region	0.8	0.1	-2.5	-3.0	-1.1	0.1	0.3	0.3	0.3	0.3
Moama	0.5	-1.2	-3.0	-3.2	-0.4	-0.2	0.1	0.0	0.0	-0.1
Tocumwal - Finley – Jerilderie	0.8	-1.0	-3.6	-3.9	-0.7	0.0	0.2	0.2	0.2	0.1

Riverina's Horticulture sector similarly copes with drought via water trading. Macro losses at the regional level are slightly larger in Riverina than Murray.

Figure 19: Riverina real GDP income side
(% deviation from base)

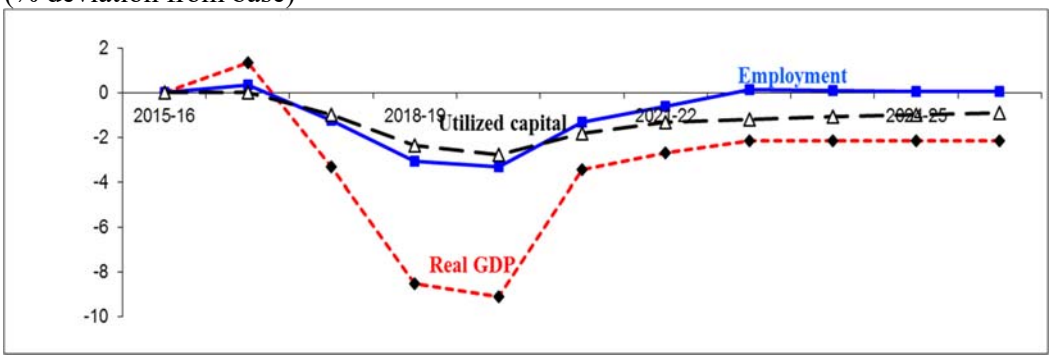


Figure 20: Riverina labour market
(% deviation from base)

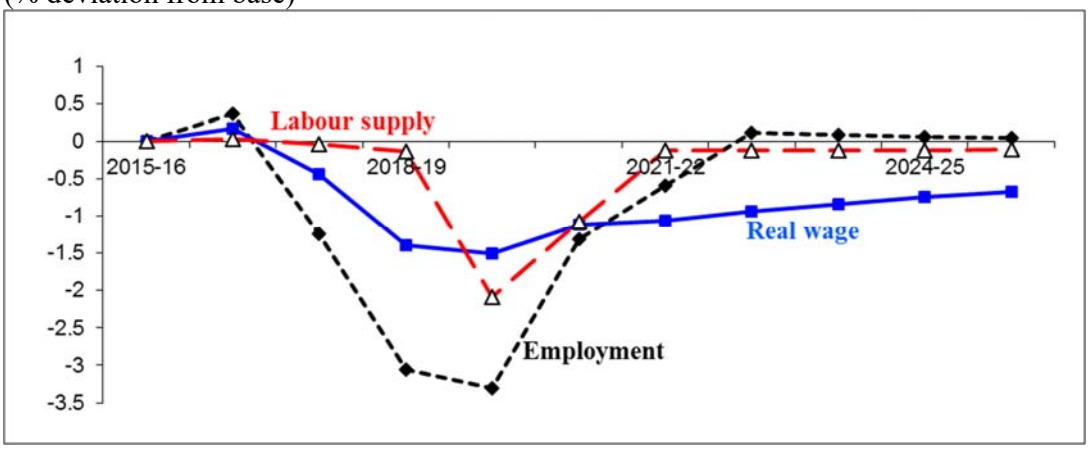


Figure 21: Riverina real consumption and investment
(% deviation from base)

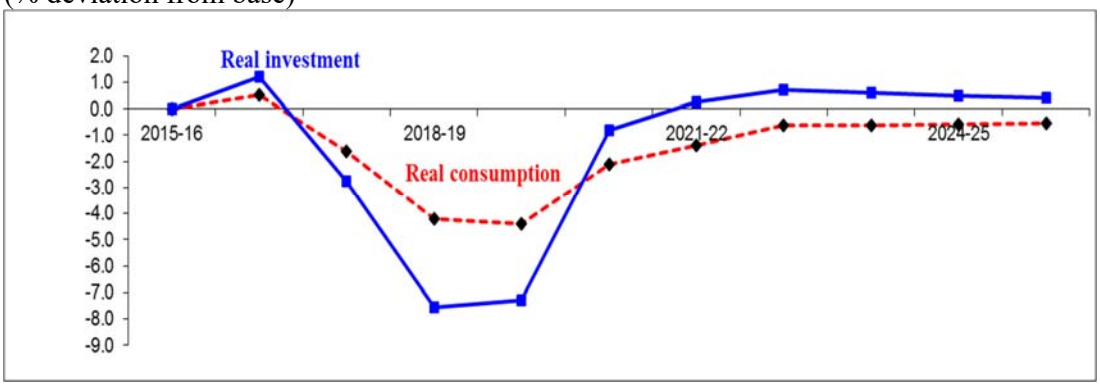


Table 7: SA2 level macro outcomes within Riverina
(% change from base)

Real GDP	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Griffith (NSW)	0.6	-2.2	-5.9	-7.0	-2.2	-1.8	-1.5	-1.5	-1.5	-1.5
Griffith Region	2.8	-9.4	-20.9	-22.5	-8.0	-4.5	-1.6	-1.6	-1.6	-1.7
Leeton	0.7	-2.2	-6.4	-7.6	-2.7	-2.3	-2.1	-2.1	-2.1	-2.1
Narrandera	5.3	-6.2	-16.1	-16.5	-5.4	-4.7	-4.4	-4.3	-4.3	-4.3
Tumbarumba	0.1	-1.7	-5.5	-6.0	-3.6	-3.3	-3.0	-3.0	-3.0	-3.0
Tumut	0.1	-0.9	-2.8	-3.1	-2.1	-2.1	-1.9	-1.9	-2.0	-2.0
Tumut Region	0.1	-1.5	-4.2	-5.0	-3.0	-2.8	-2.5	-2.5	-2.5	-2.5
Cootamundra	1.4	-2.9	-8.3	-8.5	-3.5	-3.2	-3.0	-2.9	-2.9	-2.9
Gundagai	0.5	-2.9	-9.1	-9.4	-5.5	-5.0	-4.5	-4.4	-4.4	-4.3
Junee	2.3	-4.0	-10.7	-10.9	-4.3	-3.9	-3.7	-3.6	-3.6	-3.6
Temora	5.5	-8.0	-19.5	-19.8	-6.1	-5.4	-5.1	-5.0	-5.0	-5.0
Wagga Wagga - East	0.3	-1.1	-2.8	-3.1	-1.2	-1.0	-0.9	-0.9	-0.9	-0.9
Wagga Wagga - North	0.5	-1.8	-5.8	-6.0	-3.5	-3.4	-3.1	-3.1	-3.1	-3.1
Wagga Wagga - South	0.3	-0.9	-2.8	-3.0	-1.0	-0.9	-0.8	-0.8	-0.8	-0.8
Wagga Wagga - West	0.3	-1.0	-3.0	-3.2	-1.4	-1.3	-1.2	-1.2	-1.2	-1.3
Wagga Wagga Region	3.6	-5.7	-14.3	-14.5	-4.1	-3.3	-3.0	-3.0	-3.0	-3.0
Employment										
Griffith (NSW)	0.4	-1.4	-3.6	-3.8	-0.6	-0.3	0.0	0.0	0.0	0.0
Griffith Region	0.6	-4.1	-8.1	-9.0	-7.9	-4.5	-0.3	-0.2	-0.2	-0.1
Leeton	0.4	-0.9	-2.5	-2.9	-0.4	-0.3	0.0	-0.1	-0.1	-0.1
Narrandera	0.5	-0.8	-3.7	-3.9	-1.5	-0.4	0.0	0.0	0.0	-0.1
Tumbarumba	0.2	-0.3	-0.8	-1.2	-0.8	-0.5	0.1	0.1	0.0	0.0
Tumut	0.2	-0.5	-1.0	-1.3	-0.3	-0.1	0.2	0.2	0.1	0.1
Tumut Region	0.2	-0.5	-1.1	-1.5	-0.7	-0.4	0.1	0.1	0.0	0.0
Cootamundra	0.4	-1.1	-3.2	-3.3	-0.8	-0.3	0.0	0.0	0.0	-0.1
Gundagai	0.2	-0.8	-2.9	-3.2	-1.6	-1.1	-0.2	-0.2	-0.2	-0.2
Junee	0.3	-0.9	-3.2	-3.2	-1.0	-0.4	-0.1	-0.1	-0.1	-0.1
Temora	0.7	-0.6	-3.7	-4.0	-1.7	-0.5	0.1	0.0	0.0	0.0
Wagga Wagga - East	0.3	-0.9	-2.0	-2.1	0.0	0.2	0.3	0.2	0.2	0.2
Wagga Wagga - North	0.3	-0.7	-2.1	-2.3	-0.8	-0.5	0.0	0.0	-0.1	-0.1
Wagga Wagga - South	0.3	-0.8	-1.8	-2.0	0.1	0.2	0.3	0.3	0.2	0.2
Wagga Wagga - West	0.2	-0.7	-1.7	-1.7	0.0	0.1	0.2	0.2	0.1	0.1
Wagga Wagga Region	0.4	-0.8	-2.8	-3.0	-0.9	-0.1	0.4	0.4	0.3	0.3

Figure 22: Central West real GDP income side
(% deviation from base)

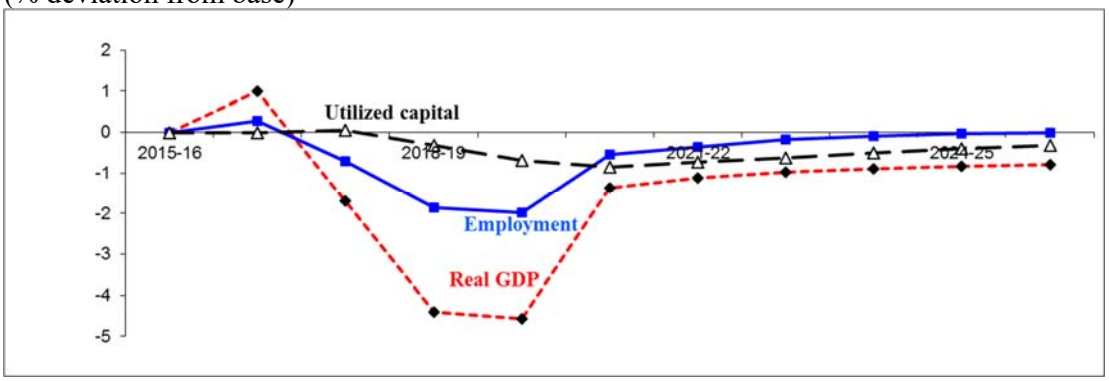


Figure 23: Central West labour market
(% deviation from base)

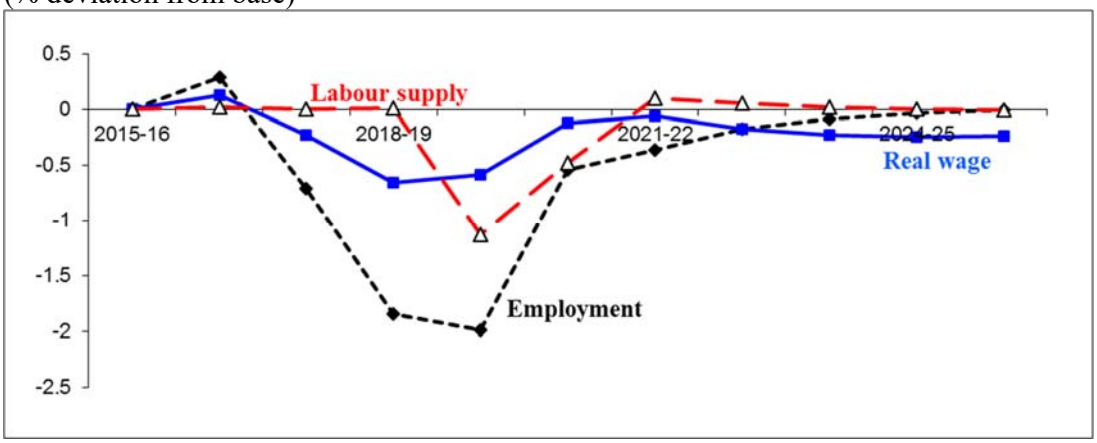


Figure 24: Central West real consumption and investment
(% deviation from base)

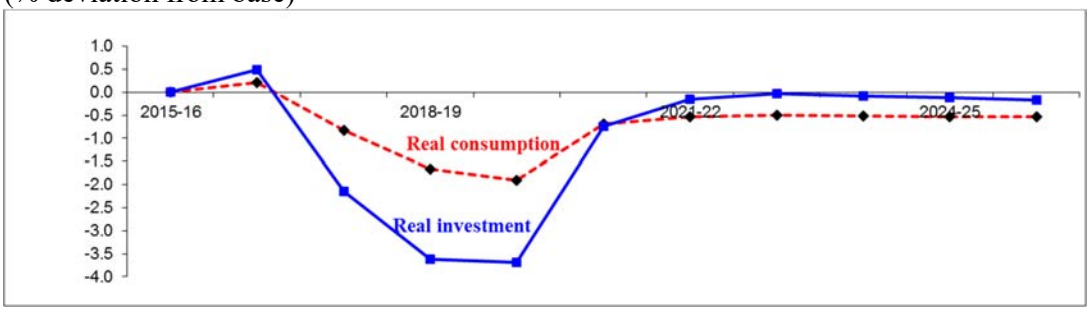


Table 8: SA2 level macro outcomes within Central West
(% change from base)

Real GDP	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Bathurst	0.2	-0.7	-1.7	-1.8	-0.6	-0.6	-0.4	-0.3	-0.3	-0.2
Bathurst - East	0.2	-0.7	-1.9	-2.1	-0.7	-0.6	-0.5	-0.4	-0.3	-0.3
Bathurst Region	0.3	-1.1	-2.7	-2.9	-1.0	-0.8	-0.6	-0.5	-0.5	-0.4
Oberon	0.1	-0.7	-1.5	-1.7	-0.8	-0.6	-0.5	-0.4	-0.3	-0.3
Condobolin	6.6	-8.8	-21.4	-21.5	-5.5	-4.3	-4.0	-3.8	-3.7	-3.6
Cowra	0.8	-1.6	-4.6	-4.7	-1.4	-1.2	-1.1	-1.0	-0.9	-0.8
Cowra Region	2.9	-3.9	-13.1	-13.0	-3.3	-2.7	-2.6	-2.4	-2.3	-2.3
Forbes	2.5	-3.5	-10.3	-10.3	-2.7	-2.3	-2.1	-2.0	-1.9	-1.9
Grenfell	7.5	-8.9	-21.8	-21.9	-5.6	-4.4	-4.2	-4.0	-3.9	-3.8
Parkes (NSW)	0.6	-1.2	-2.8	-2.9	-0.9	-0.8	-0.7	-0.6	-0.6	-0.5
Parkes Region	6.8	-8.4	-19.8	-20.0	-5.2	-4.2	-4.0	-3.9	-3.8	-3.7
West Wyalong	6.3	-8.0	-18.5	-18.7	-4.7	-3.9	-3.8	-3.6	-3.5	-3.5
Lithgow	0.1	-0.3	-0.7	-0.8	-0.3	-0.4	-0.2	-0.2	-0.1	-0.1
Lithgow Region	0.1	-0.5	-1.0	-1.1	-0.5	-0.4	-0.3	-0.2	-0.2	-0.2
Mudgee	0.1	-0.2	-0.8	-1.0	-0.3	-0.4	-0.3	-0.2	-0.1	-0.1
Mudgee Region - East	0.0	-0.6	-1.1	-1.4	-0.6	-0.5	-0.4	-0.3	-0.3	-0.2
Mudgee Region - West	0.3	-1.0	-3.0	-3.2	-1.0	-0.8	-0.7	-0.6	-0.5	-0.4
Blayney	0.2	-0.9	-2.1	-2.3	-0.8	-0.7	-0.5	-0.4	-0.4	-0.3
Orange	0.1	-0.5	-1.2	-1.4	-0.5	-0.5	-0.3	-0.2	-0.2	-0.2
Orange North	0.1	-0.4	-1.1	-1.3	-0.5	-0.4	-0.3	-0.2	-0.2	-0.1
Orange Region	0.5	-1.4	-3.5	-3.7	-1.2	-1.0	-0.8	-0.7	-0.6	-0.5
Employment										
Bathurst	0.2	-1.0	-2.2	-2.3	-0.5	-0.4	-0.2	-0.1	-0.1	-0.1
Bathurst - East	0.3	-1.0	-2.2	-2.3	-0.5	-0.4	-0.2	-0.1	-0.1	-0.1
Bathurst Region	0.3	-1.0	-2.1	-2.2	-0.5	-0.4	-0.2	-0.1	0.0	0.0
Oberon	0.2	-0.8	-1.5	-1.7	-0.5	-0.4	-0.2	-0.1	0.0	0.0
Condobolin	0.8	-0.3	-3.0	-3.4	-2.0	-0.8	-0.4	-0.2	-0.1	0.0
Cowra	0.4	-1.0	-2.7	-2.7	-0.7	-0.4	-0.2	-0.2	-0.1	-0.1
Cowra Region	0.6	-0.1	-2.0	-2.2	-0.8	-0.3	0.0	0.1	0.2	0.2
Forbes	0.5	-0.6	-2.3	-2.5	-0.8	-0.3	-0.1	0.0	0.0	0.1
Grenfell	1.0	-0.7	-4.8	-5.0	-2.1	-0.4	-0.2	0.0	0.1	0.2
Parkes (NSW)	0.3	-0.8	-1.9	-2.0	-0.5	-0.4	-0.2	-0.1	-0.1	-0.1
Parkes Region	0.8	-0.4	-3.8	-4.1	-1.9	-0.4	-0.2	0.0	0.1	0.1
West Wyalong	0.7	-0.5	-3.5	-3.7	-1.7	-0.5	-0.3	-0.1	0.0	0.0
Lithgow	0.1	-0.6	-1.2	-1.3	-0.3	-0.3	-0.1	-0.1	0.0	0.0
Lithgow Region	0.2	-0.7	-1.3	-1.4	-0.3	-0.3	-0.1	0.0	0.0	0.0
Mudgee	0.1	-0.3	-0.6	-0.8	-0.1	-0.2	-0.1	0.0	0.0	0.1
Mudgee Region - East	0.2	-0.7	-1.2	-1.4	-0.4	-0.3	-0.1	0.0	0.1	0.1
Mudgee Region - West	0.2	-0.4	-1.0	-1.2	-0.3	-0.2	-0.1	0.0	0.1	0.1
Blayney	0.2	-0.7	-1.5	-1.7	-0.4	-0.3	-0.1	0.0	0.0	0.0
Orange	0.2	-0.8	-1.6	-1.7	-0.4	-0.4	-0.2	-0.1	-0.1	0.0
Orange North	0.2	-0.6	-1.3	-1.4	-0.3	-0.3	-0.2	-0.1	0.0	0.0
Orange Region	0.3	-1.0	-2.2	-2.3	-0.5	-0.4	-0.2	-0.1	0.0	0.0

Figure 25: Southern Highlands-Shoalhaven real GDP income side
(% deviation from base)

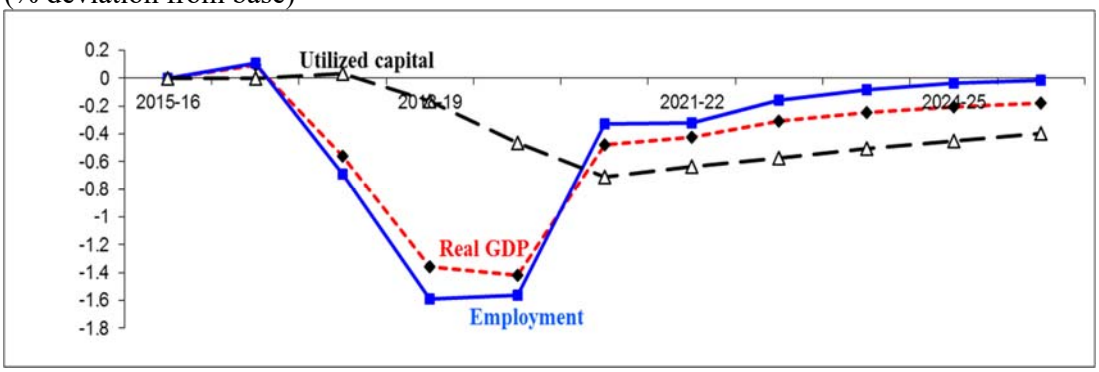


Figure 26: Southern Highlands-Shoalhaven labour market
(% deviation from base)

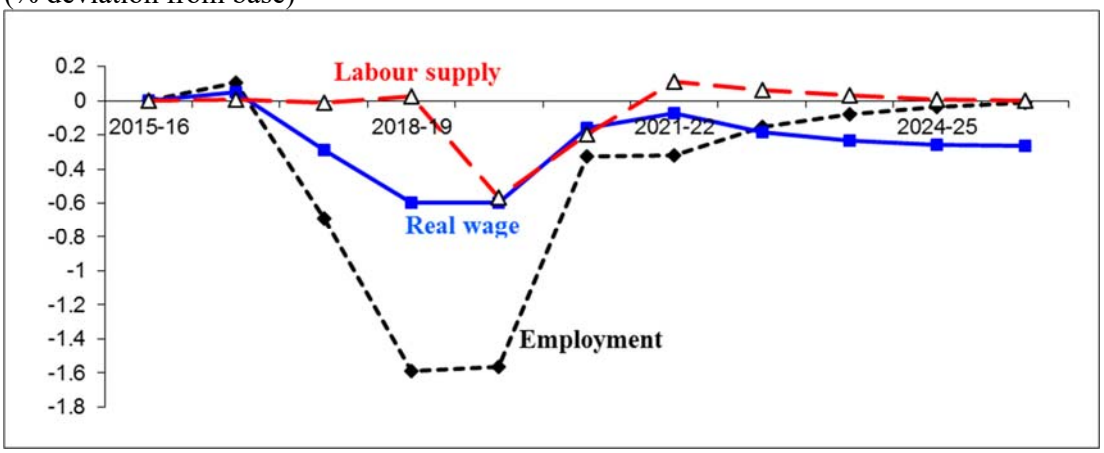


Figure 27: Southern Highlands-Shoalhaven real consumption and investment
(% deviation from base)

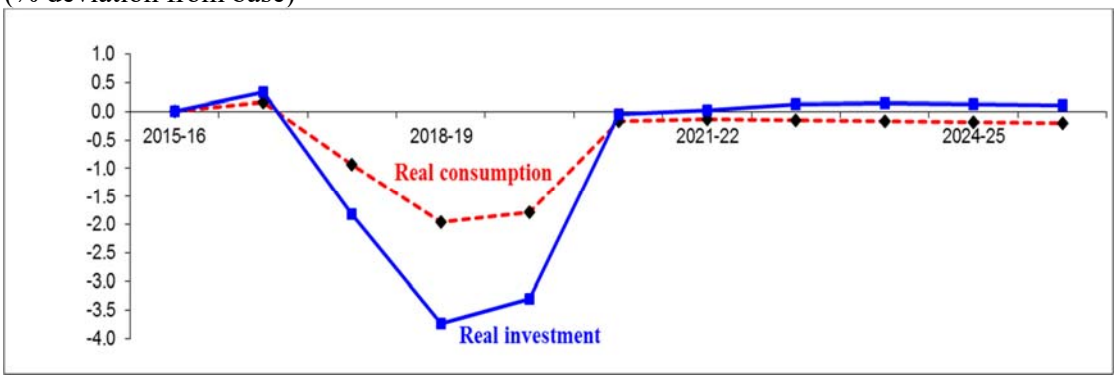


Figure 28: Hunter exc. Newcastle real GDP income side
(% deviation from base)

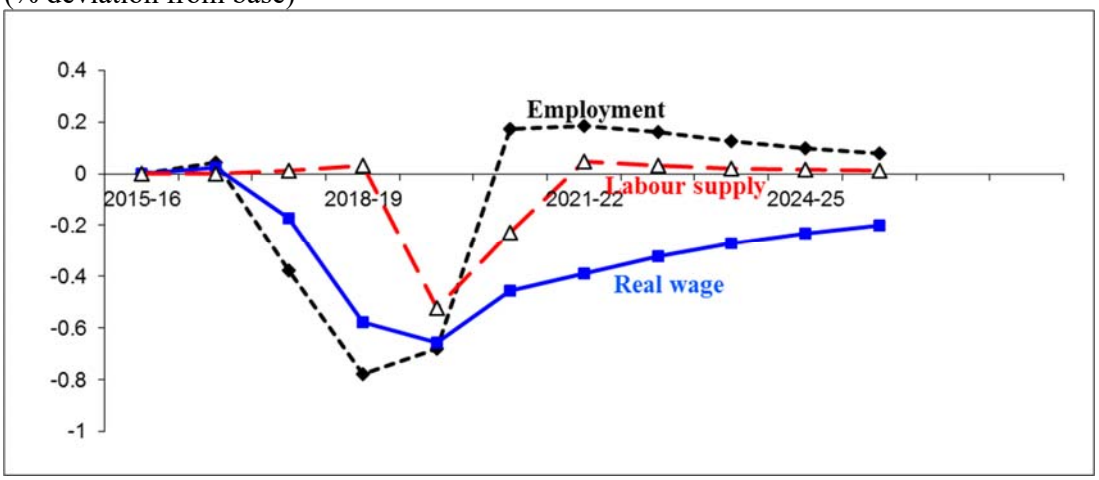


Figure 29: Hunter exc. Newcastle labour market
(% deviation from base)

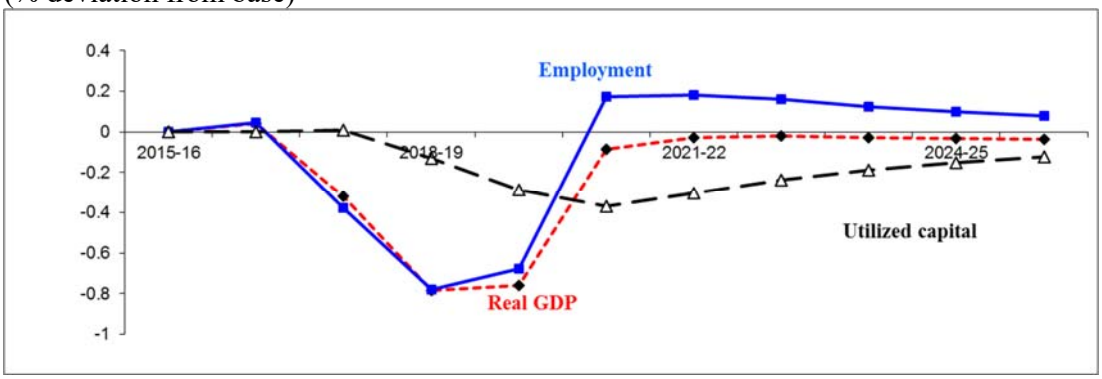
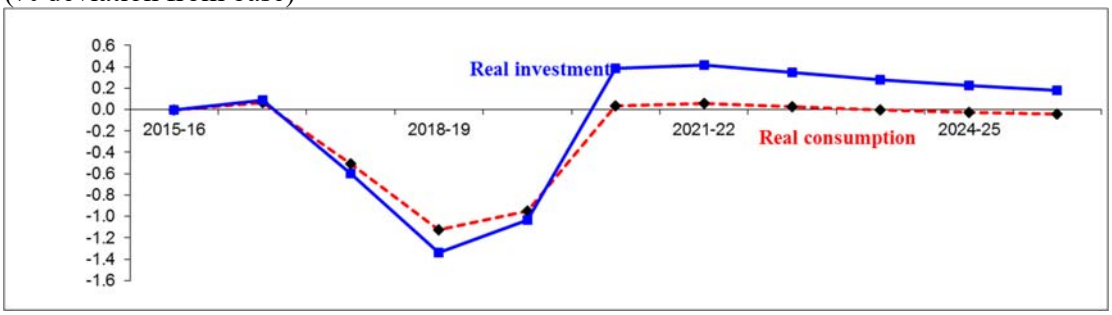


Figure 30: Hunter exc. Newcastle real consumption and investment
(% deviation from base)



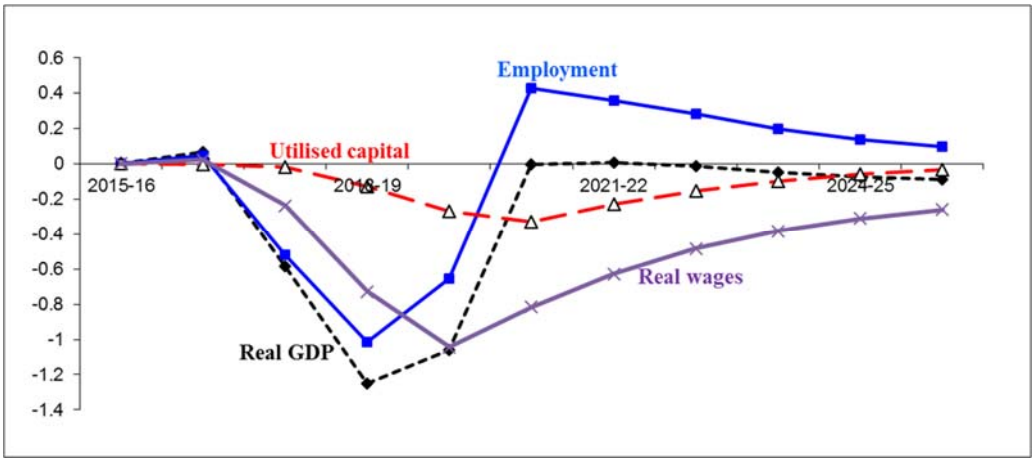
4. National impacts

Based on VU-TERM modelling, real GDP fell by at least 1% in 2018-19 and 2019-20 relative to base (figure 31). The marginal impact depends to some extent on our labour market assumptions. In this modelling, regional real wages follow a theory of sticky wages adjustment combined with exogenous inward labour supply shifts in the most severely affected regions, offset by labour supply increases in less affected regions.

Much economic commentary in the past few years has focused on slow wages growth. This has been attributed to low productivity growth. This study concludes that a significant part of national low productivity growth arose due to drought-induced negative productivity in agriculture. Real wages in this scenario at the national level are slowed for a number of years due to the three- year drought. Indeed, we could surmise that the marginal impact on drought on national employment has been smaller, and the marginal impact on wages growth larger than modelled. If this were the case, it would subdue drought-induced national real GDP and welfare losses to some extent.

It follows that in recovery, agriculture can contribute to stronger national wages growth.

Figure 31: National GDP, income side
(% deviations from base)



5. Modelling of a drought relief measure

A scenario variant was to supplement household incomes in drought-affected regions via direct transfers. This results in a slight improvement in both national and state welfare relative to drought with no transfer to households. The reason for this is that drought weakens the labour market, resulting in job losses. Compensation to households enables increased household spending relative to no compensation results in a small increase in employment relative to no compensation in drought years.

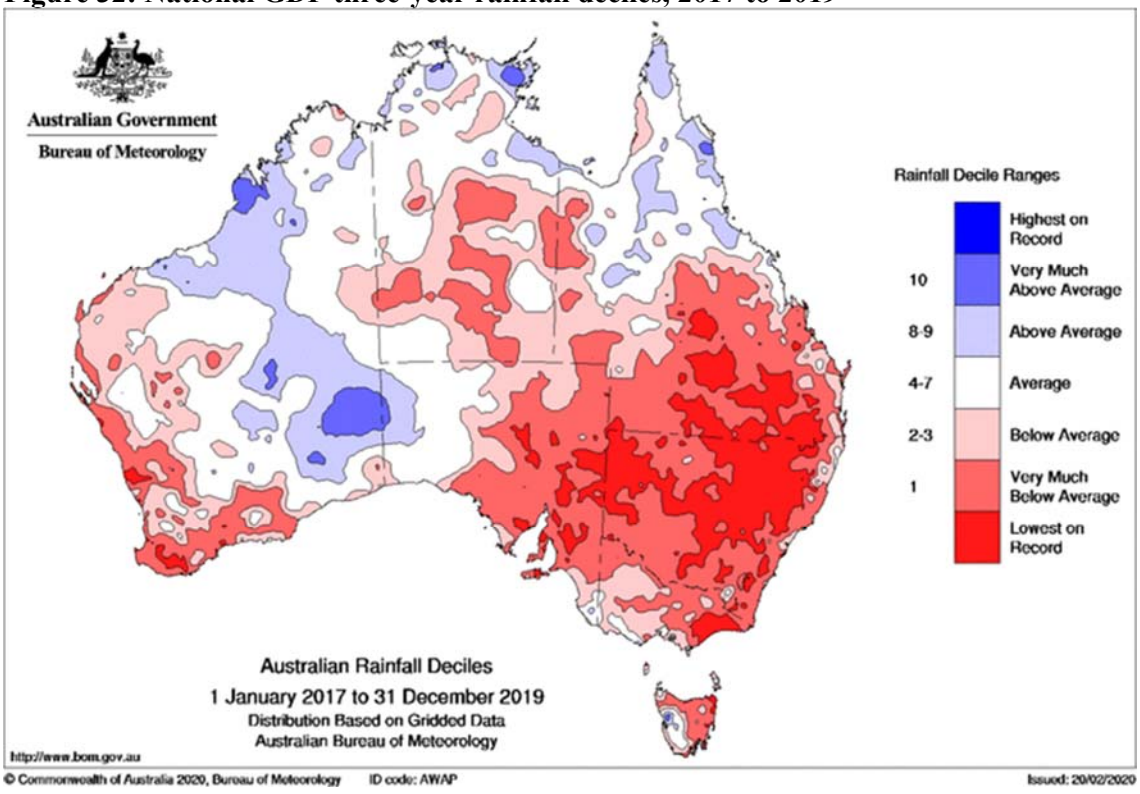
The welfare impact is small though positive. This implies that transfers to households in drought-affected regions are economically justifiable.

6. Conclusion

Although agriculture's share of national income is small, drought still has a significant impact of GDP. In 2016-17, the most recent relatively good agricultural season, the sector's share of GDP was 2.9%. This shrunk to 2.0% in 2019.[2] This magnitude of change aligns with the modelling in this report and is consistent with previous TERM-based modelling of drought (Horridge *et al.*, 2005; Wittwer and Griffith, 2011).

Drought has affected many parts of Australia in the past year or so. A substantial proportion of Australia's significant agricultural areas suffered record rainfall deficits in the three years from 2017 to 2019 (figure 32). Bushfires that started in relatively high rainfall regions along the Great Dividing Range and elsewhere were substantially a consequence of extraordinarily dry conditions and abnormally high temperatures (see figure 9).

Figure 32: National GDP three-year rainfall deciles, 2017 to 2019



This study has concentrated on New South Wales, while ascribing shocks to depict drought in the rest of Australia. A study depicting drought-affected SA4 regions in other states, rather than the "rest of Australia" agricultural shocks ascribed in this study, may result in even larger estimates of income and welfare losses.

From a policy perspective, there is a substantial role for government to play in ensuring that services in drought-affected regions are not run down In particular, the stresses arising from drought warrant an increase in publicly-funded rural counselling services and health services, in addition to temporary transfers to households in drought-affected regions.

[2] Calculated from https://www.abs.gov.au/ausstats/abs@.nsf/mf/5206.0

The aftermath of bushfires does not supersede this. Hardship arising from prolonged drought may have impacts that last for a number of years. Bushfires require various responses to deal with emergency housing, restoration of infrastructure and other restorative actions in addition to drought response measures.

Appendix: VU-TERM version for NSW

What is a computable general equilibrium (CGE) model?

A CGE model can be an economy-wide model. In the context of VU-TERM, it is an economy-wide model that also includes small-region representation. Unlike an input-output model which solves either for quantities or for prices, but not both at once, a CGE model solves for both prices and quantities together.

CGE models can be either comparative static or dynamic. Comparative static models are easier to run than dynamic models. However, comparative static results are in some respects harder to explain. Results are reported as changes from a base case – at some point in the future. The only base case defined in a comparative static model is the initial database.

In dynamic models, we prepare a forecast baseline. This may include forecast increases in macroeconomic variables, technological change and taste changes. For example, agricultural productivity historically has grown by 1 to 2% per annum, so productivity growth of this magnitude is imposed on the forecast baseline.

In this study, we use dynamics to take the timeline of the drought in NSW and rest of Australia. The relatively good year of 2016 was followed by a drought which started in the northern part of the state in 2017, spread state-wide in 2018 and worsened in 2019. Results are presented relatively to a business-as-usual baseline which includes “average” seasonal conditions.

Dynamic CGE modelling

Dynamic models trace the effects of ascribed direct impacts across time periods. The theoretical basis of dynamics is in linkages between investment and capital across time, and the balance of trade and net foreign liabilities. Investment and balance of trade outcomes are flows that a comparative static model includes. Capital and net foreign liabilities are stocks that require a dynamic model.

The importance of these dynamic linkages is evident in project analysis. For example, drought recovery may include a phase of elevated investment and regional aggregate consumption. Investment may be funded by additional borrowing from foreigners, thereby adding to net foreign debt. We need to account for changes in interest payments to foreigners when calculating the spending power of Australian residents arising from a given level of income.

Dynamic VU-TERM combines much of the theory of dynamic national models (see Dixon and Rimmer, 2002) with bottom-up, regional representation. That is, each region in VU-TERM has its own production functions, household demands, input-output database and inter-regional trade matrices. This enables us to model relatively local issues.

Dynamic VU-TERM

TERM was originally developed by Mark Horridge at the Centre of Policy Studies (see http://www.monash.edu.au/policy/term.htm). Since then, Glyn Wittwer has developed a dynamic version of the model, an application of which Wittwer *et al*. (2005) is an example.

In dynamic VU-TERM, we use an underlying forecast. This may be based on the macro forecasts of other agencies. The underlying forecast or baseline gives us a year-by-year "business as usual" case.

Typical variables to be reported in the policy scenario relative to a baseline forecast are regional real GDP, employment and aggregate consumption. Industry level results are also available.

Figure A1: Regions in this application of VU-TERM

Figure A1 shows the bottom-up regions in this study. Essentially, away from a coastal composite that includes Sydney, Wollongong and Newcastle, the bottom-up regions are SA4 regions.

Industry/commodity sectors in master database of VU-TERM

In practice, both the regional and industry/commodity dimensions of the master database of VU-TERM are aggregated so as to reflect the emphasis of a particular project.

The following table contains the full list of 182 sectors in the master database.

Table A1: Industries/commodities in VU-TERM

Sheep	**MeatProds**	**OthManuf (cont.)**	**Trade**	**OthService (cont.)**
BeefCattle	**Seafood**	*IronSteel*	*WholesaleTrd*	*CommuntyHlth*
DairyCattle	**DairyProds**	*Alumina*	*RetailTrade*	*ChildCareSrv*
OthLivestock	**OtherFood**	*Aluminium*	**HotelsCafes**	*LbryMseumArt*
Poultry	*FruitVeg*	*OthNonFeMtl*	*Accomodation*	*SportRecreat*
OthLivestock	*OilsFats*	*ForgedFeStl*	*Restaurant*	*Gambling*
Wheat	*FlourCereals*	*StrucMetlPrd*	**RoadFreight**	*AutoRepairs*
Rice	*Bakery*	*SheetMetlPrd*	**OthTransport**	*OtherRepairs*
Cotton	*SugarConfect*	*FabrcMetlPrd*	*RoadPassngr*	*HrDresBeauty*
HayCerealFod	*OtherFood*	*MVPOthTrnEq*	*RailFreight*	*OthPrsSrv*
OthCrops	*SoftDrinks*	*ShipsBoats*	*UrbanRailway*	*ReligiousOrg*
Barley	*BeerMalt*	*RailwayEquip*	*InterUrbRail*	*IntrstGrpNEC*
Oats	*WineSpirTob*	*Aircraft*	*WaterTrnsprt*	*DomHHService*
OthGrainLegu	**TCFs**	*PhotSciElEqp*	*AirTransport*	*OthService*
SugarCane	*TextileManu*	*ElectriclEqp*	*Pipeline*	**OwnerDwellng**
OtherAgriclt	*LeatherProds*	*HouseholdApp*	*TransprtSrv*	**GovAdmDefOrd**
OthVegetble	*TextileProds*	*OthMachEquip*	*PostCourier*	*FedGovAdmSrv*
Potatoes	*KnittingMill*	*Furniture*	**OthTransport**	*StaGovAdmSrv*
Grapes	*Clothing*	*OtherManufac*	*CommunicSrvc*	*LocGovAdmSrv*
BerriesAll	*Footwear*	**Utilities**	*FilmSndRcrd*	*Defence*
ApplesPears	**OthManuf**	*ElecCoalBlac*	*Broadcasting*	*PoliceCrctnl*
Stonefruit	*SawmillProds*	*ElecCoalBrow*	*Internet*	*OthPublicOrd*
Citrusfruit	*OthWoodProds*	*ElecGas*	*Telecomms*	*Firebrigades*
Olives	*PulpPaper*	*ElecOil*	*LibraryInfo*	**Education**
Bananas	*PaperProds*	*ElecNuclear*	*Finance*	*Preschool*
Orchardfruit	*Printing*	*ElecHydro*	*Insurance*	*PrimSchool*
AlmondMacad	*Petrol*	*ElecBiomass*	*Superannuatn*	*SecdrySchool*
ForestFish	*OthPetrlPrd*	*ElecBiogas*	*FinanceSrvce*	*ArtSptOthEdu*
Aquaculture	*Diesel*	*ElecWind*	**OthService**	*TechVocEduc*
ForestryLogs	*AviationFuel*	*ElecTranDist*	*RentHire*	*TertiaryEdu*
FishingHunt	*RefinedLPG*	*GasSupply*	*OthPrprtySvc*	**Health**
GinnedCotton	*BasicChemicl*	*WaterDrains*	*ArchEngScSvc*	*HospitalNurs*
AgriSrvces	*HumPharmac*	*WasteTmtDsp*	*LegalSrv*	*GPs*
Mining	*OthPharmac*	**Constructn**	*AccountngSrv*	*SpecialistSv*
CoalBlack	*SoapsCosmtc*	*ResidBuildng*	*PrfSrvNEC*	*PathologySvc*
CoalBrown	*PlasticProds*	*NonResBldCns*	*ComputerSrv*	*DentalSrv*
Oil	*RubberProds*	*CvlEngCnstct*	*EmpTrvOthAdm*	*OpmetryOptic*
LNG	*GlassProds*	*ConstrucSrvc*	*SupportSrv*	*OtherHealth*
Gas	*CeramicProds*			*AmbulanceSrv*
IronOres	*CementLime*			
Bauxite	*PlasterEtc*			
NonFeOres	*ONmtlMinProd*			
OtherMining				
MiningSrvces				

** Bold red denotes sectors with a one-to-one mapping from the master database, bold black the aggregated sectors and italicised sectors the master database sectors that are aggregated.*

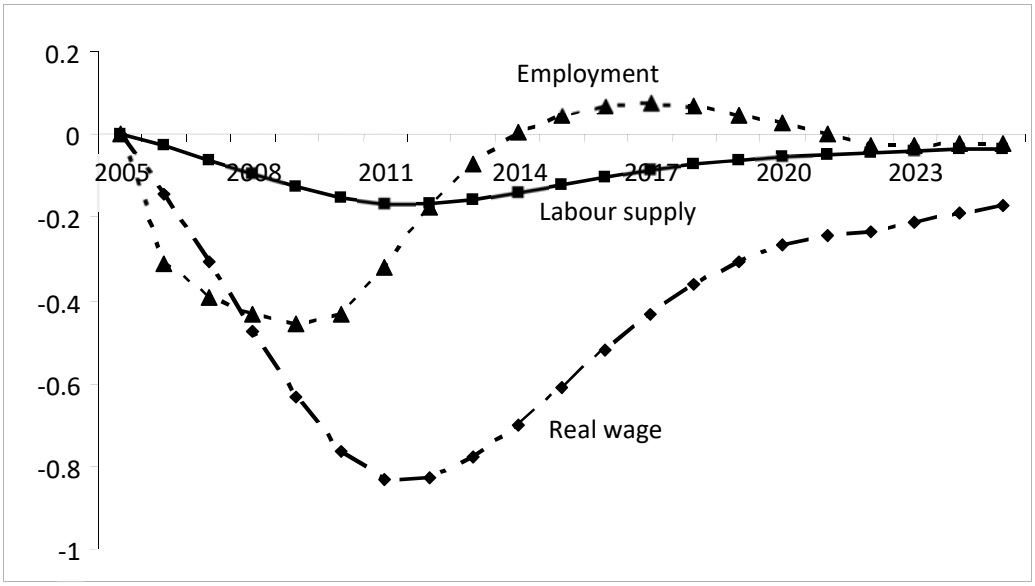
Labour market – forecast v. policy scenario

In the theory of regional labour market adjustment, if regional labour market conditions improve or deteriorate relative to forecast, adjustment occurs in the short term mainly via

changes in employment. Regional wages adjust sluggishly, with gradual adjustment in regional labour market supply (i.e., through migration between regions). Real wages will fall or rise to close the gap between employment and slowly adjusting labour supply. Once the deviation in employment is equal to the deviation in labour supply, real wages reach a turning point (either they bottom out, in the case of a weakening labour market, or peak, in the case of strengthened labour market conditions). Within this theory, adjustment in the longer term occurs via a combination of altered regional labour supply and real wages that deviate relative to those in other regions. Figure A2 shows an example, in which weakened labour market conditions in a region lead to unemployment in the short run and a lower real wage in the region in the long run.

Given the severe weakening of labour markets at the regional level in this study, the usual theory was over-ridden to a small extent. In the worst affected regions, inward labour supply shifts were ascribed temporarily, combined with offsetting shifts in less affected regions. This subdued downward real wage movements in the most drought-affected regions.

Figure A2: An example of a weakened regional labour market with eventual recovery (% change from forecast)



Production technologies

VU-TERM contains variables describing: primary-factor and intermediate-input-saving technical change in current production; input-saving technical change in capital creation; and input-saving technical change in the provision of margin services (e.g. transport and retail trade).

VU-TERM's unique treatment of transport to assess the regional benefits of the project

The supply of margins originating in one region can lower the costs of moving goods between regions further afield. Previous multi-regional models (for example, Naqvi and Peter, 1996) assign the margins supply of a sale either to the origin or destination of the sale.

GEMPACK software

Dynamic VU-TERM uses GEMPACK software for implementation (Harrison, *et al*. 2013; Harrison and Pearson, 1996).

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