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Dairy Productivity - FINAL REPORT

A Marsden Jacob Report

Prepared for Dairy Australia
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Acronyms and abbreviations

DA	Dairy Australia
DFMP	Dairy Farm Monitor Project
QDAS	Queensland Department of Agriculture Services
TFP	Total factor productivity
DEA	Data Envelopment Analysis
SFA	Stochastic Frontier Analysis

Acknowledgments

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1. Executive overview

Key Points

- Productivity growth is essential to maintaining the long term competitiveness of the industry
- Dairy productivity growth has been weak over the last two decades.
- Research, Development and Extension (RD&E) are key drivers of productivity performance. Given that most farmers are technically efficient, it is vital that new RD&E deliver improved productivity outcomes in the future. This will require continued and improved investment in Dairy Australia's RD&E portfolio.
- A decomposition of this growth using sophisticated statistical techniques reveals that while technical progress and technical efficiency have been stagnant, most farmers are already highly technically efficient in terms of using existing technologies. While new technology is being adopted on farms it is not translating over time into improvements industry productivity.
- Constant return to scale means that productivity is being shaped mostly by farmers changing their mix of inputs and outputs in response to changing circumstances.
- There are indications that farmers are incrementally adapting over time to weather and climate variability.
- Over the period of analysis, changes in dairy profitability have been driven by changes in the terms of trade (ratio of output prices to input prices) rather than changes in productivity and, when terms of trade have weakened, productivity change has not compensated for that weakness.

Recommendations

- Dairy Australia maintain the productivity model and database that has been constructed
- Dairy Australia update the data annually – this will maintain data integrity of Dairy Australia skill base
- Model be rerun and analysis updated every three years – this is sufficient time for useful trend analysis and reduces the risk of inappropriate conclusions from analysing year to year trends
- Further work be undertaken to disaggregate and understand underpinning relationships between productivity performance and farm system characteristics.
- Further work be undertaken to understand the quality and level of RD&E delivered by Dairy Australia and its impact on dairy industry productivity performance

Key conclusions – concepts, data and tools

Productivity measures the relationship between physical inputs and physical outputs. Understanding how productivity performance has changed over time is important toward understanding the dairy industry's future competitive position. Over time, weak productivity performance can (other things equal) translate into a weaker competitive position. Often weak productivity is offset by other competitive factors such as prices received for products and price paid for inputs.

However, this is not always the case. RD&E is an essential driver of productivity performance and one variable that can be controlled by the industry. Enhancing the level of RD&E undertaken and its quality are key routes to enhancing productivity and long term competitiveness.

New productivity measurement techniques using proper index methods provide an opportunity for the industry to better understand its productivity performance and the composition of that performance. These new techniques can be applied to many years of consistent dairy farm monitor data. This annual farm performance data can be converted to physical measures of farm inputs and outputs that can then be analysed in a robust and comparable way.

Key conclusions – index calculation and analysis

Annual dairy farm monitor data was converted to an annual time series database of individual farm physical inputs and physical outputs. A set of proper productivity indexes were calculated from this data to estimate the annual level and change in productivity at different industry spatial groupings. Two key productivity techniques were applied – data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Each approach has advantages and disadvantages but taken together can provide robust overview of productivity performance.

Overall dairy industry productivity has been relatively weak. Overall relative levels of productivity across regions reflected general levels of comparative advantage in farms between regions. While farmers are highly technical efficient, there has been very limited growth in the overall level of technical efficiency. Scale of the farms had little impact on farm productivity performance. The analysis also showed that productivity performance has been remarkably resilient to climate variability.

The impacts on profitability of weak productivity can be offset by terms of trade. However, the analysis found that this was not always the experience of the dairy industry. Sometimes, weak productivity also corresponded with periods of weak terms of trade. Generally, it was found that most of the dairy industry trends in profitability could be explained by shifts in the terms of trade rather changes productivity.

Key conclusions – economy wide insights

The importance of RD&E and productivity to industry competitiveness can be demonstrated through the analysis of whole of the economy and industry economic modelling (using the The Enormous Regional Model or TERM). The TERM model enables complex dynamics between the dairy industry and regional economies and the national economy to be understood.

At a national level, the productivity performance of the dairy industry has relatively minor impacts – this is because the industry is a small share of the national economy. However, at regional scales, these outcomes are more significant where the industry is a more important share of those economies. This is the case in the major dairy regions in parts of Victoria and Tasmania.

In those economies, the long- term impact of productivity can have three important consequences:

- better productivity performance boosts farm household income and manufacturing output. This improves regional economic outcomes.
- the gains can be reduced where rising productivity simultaneously weakens the farm services sector as less labour and few inputs are required.

- the net effect of benefits to the region from improved productivity against the loss of income from the region in the form of RD&E expenditure. This is particularly important when the performance of productivity does not offset losses from weak terms of trade. In those circumstances regional, economies can be worse off, but there is insufficient incentive to farmers to invest more in RD&E to address this problem. This may create a case for additional government investment in dairy RD&E.

Discussion

Dairy productivity growth has been weak since the early 2000s. Some key differences across states are:

- Victorian productivity appears to have declined slightly after an initial recovery from drought in the early 2000s (the decline in recent years is mainly attributable to the northern Victorian region which has experienced some hot, dry periods and low irrigation water availability)
- Tasmanian productivity has strengthened slightly in recent years
- New South Wales and Queensland have experienced slight rises and falls since the early 2000s and ended up at similar levels of performance to that at their starting points
- South Australian performance has been volatile and rising but caution is required with the small number of farms in the data set and the significant variation in operating conditions and differences in the farm systems
- Productivity in Western Australia has been reasonably stagnant since the data was first collected in 2013/14.

Productivity growth can occur from: technical change or progress (as a result of implementing new technologies); improvements in technical efficiency (as a result of farmers becoming more efficient using existing technologies); changing the scale of operations to capture any benefits of larger operations; and changing the mix of inputs used to produce outputs.

The contribution of technical change or progress to productivity growth has been weak. The technical change component of total factor productivity (TFP) growth has virtually flatlined over the six-year period 2013/14 to 2018/19. This is not to say new technology has not been adopted on farms — it has, the challenge is it is not resulting over the longer term into productivity improvements.

With the given technologies in dairy farming, a very high percentage of dairy farms are technically efficient at maximising outputs with given inputs. Technical efficiency has fallen slightly but 75 per cent of farm are at least 91 to 92 per cent efficient across Australia. Just on 25 per cent of farms have an efficiency of greater that 94.5 per cent. The technical efficiency component of productivity was relatively similar across states.

Scale and mix efficiency has also fallen slightly in more recent years (since 2006/07). The estimates of productivity indicate that dairy farms on the whole exhibit constant returns to scale – that is productivity levels not driven by the size of the farm and larger farmers do not have higher rates of productivity. However, further work is required to disaggregate this relationship for a range of farm sizes. Estimates indicate that for every 1 per cent increases in input use there is very close to a corresponding 1 percent increase in output. Given this relationship, estimates of scale and mix efficiency suggest that most of the productivity improvements have come from changes in the mix of inputs. Scale and mix efficiency estimates are relatively similar across Australia.

Changes in environmental variables and their impacts on annual productivity performance was investigated. The results were mixed and further disaggregation and analysis is being undertaken but, may be limited by the annual nature of the farm performance data used – including the fact that timing and sequencing of weather events are critical to the efficiency of dairy production systems.

Several variables were found to be important in examining the role of the environment on productivity performance - including:

- annual rainfall
- a constructed temperature and humidity index (THI) and
- the coefficient of variation[1] of THI for a grouping of months within and around the winter and also the remainder of the year.

However, taken together, changes in the level of rainfall and the level and variability of THI were not found to have had a significant effect on the level of productivity growth. On first blush, this suggests that dairy farmers have been successfully incrementally adapting to weather and climate variation. However, while productivity might not have been significantly affected, the change input mix and their prices would have nonetheless affected the terms of trade and profitability.

In examining productivity performance, some interesting relationships were found. First, this study found a very weak negative relationship between production and rainfall. Care is required interpreting this given the performance data are annual and the analysis preliminary. When rainfall weakens this is offset by the use of other inputs including stored feed, imported feed and concentrates and irrigation water, and when rainfall increases there can be a softening of production as these inputs are reduced and grown pasture is consumed in greater quantities – all with consequent effects on productivity. Moreover, under very wet conditions pasture growth can be negatively impacted along with herd health. Additionally, the study found that high levels of THI were found to be negatively correlated with production levels – as

[1] The ratio of the standard deviation to the mean and shows the extent of variation in relation to the mean.

temperature variability rose, production fell, indicating there are greater the limits in dairy farm systems to managing heat stress/hot periods than there are to managing rainfall variability.

Profitability change was decomposed into the product of the productivity index and the terms of trade index. Analysis indicates that in Victoria and Queensland profitability changes have been largely driven by changes in terms of trade. In contrast to earlier historical periods, over the last two decades dairy productivity has not risen to offset the recent periods of weak and declining terms of trade.

While improving productivity is important to the growth of the dairy industry, the performance relative to other competitors for resources, such as land and water, is also important. A computable general equilibrium model was used to understand the national and regional impacts of a range of future RDE expenditure, productivity and terms of trade scenarios. Key insights were:

- A small increase in R&D investments may not be sufficient to counter adverse terms-of-trade movements faced by the sector.
- A larger increase may counter such movements with consequent national welfare gains, despite demand adversity.
- Productivity gains in dairy cattle production (milk and livestock) benefit domestic and overseas consumers.
- Productivity gains that more than offset terms-of-trade losses may raise national welfare, but not stop output declines in the dairy sectors.

The modelling also demonstrated a key issue is the distribution of gains between the dairy sector and rest of the economy. Productivity gains in dairy cattle production benefit domestic and overseas consumers. Productivity gains that more than offset terms-of-trade losses may raise farm profit but, will also benefit the wider economy, and will not necessarily stop declines in total amount of milk produced in Australia. Such an outcome underlines a justification for the rest of the economy to contribute to R&D expenditures concerning dairy productivity.

2. Part 2

A relatively new productivity index calculation method is introduced which enables the underlying economic components of productivity to be identified and measured. This provides a richer understanding of the drivers of long-term changes in dairy industry profitability and the role key drivers of productivity play.

Long term profitability is a central concern of the dairy industry. In the long term, changes in profitability are driven by underlying changes in the productivity and the terms of trade. A proper index approach[2] can be used to decompose the underlying components of productivity as well as understand the relative influence they and the terms of trade play in long term industry competitiveness. This can enable comparisons between dairy regions and states of the relative performance and significance of each factor. This cutting-edge approach has had limited application internationally and so comparative analysis of international performance needs to be undertaken with care.

2.1 Background – why long run productivity performance is important

The approach used in this study differs to other approaches used in the past and more recently in calculating and measuring productivity, in that the method applied here analyses the link between farm business productivity and farm business profit. The value of this method is that it highlights the determining factors of productivity (i.e. technical efficiency and technical change) and consequently profitability, instead of the consequences of profitability (i.e. return on assets or return on capital employed). This makes the method useful in assisting in the development of industry strategy and directing investment in key areas to support long -term profitability.

Productivity is the relationship between the quantities of farm inputs used and farm outputs produced. Moreover, productivity is an index measure that describes how much inputs are used to produce outputs relative to other farms. Productivity, therefore, reflects the ability of farm businesses to increase their physical outputs relative to their use of physical inputs. The focus of this study is long term trends in productivity and its consequences for industry competitiveness.

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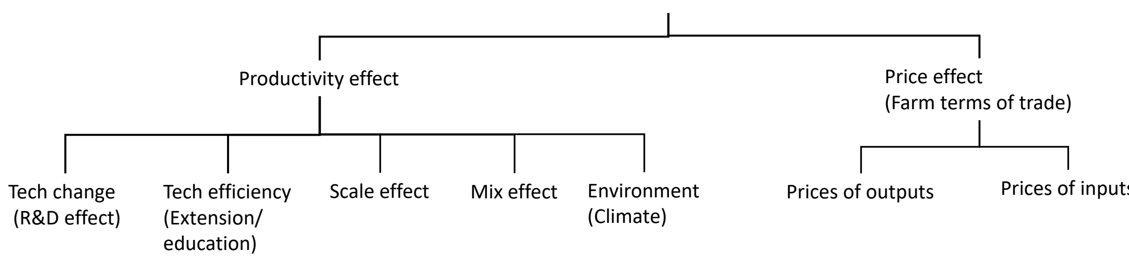
2 O'Donnell 2016 summarises the features of a proper index. He observes a proper index satisfies important common notions and axioms from index number and economic theory -for example they are non negative, non decreasing, linear homogenous scalar valued aggregator function and satisfies the transivity axiom. In doing so a proper productivity index can be decomposed into the underlying components of productivity including technical efficiency and measures of efficiency change.

In this study, productivity is measured using all factors of production in a dairy business. This should not be confused with other measures of productivity that are promoted from time to time such as full time equivalent (FTE) units of labour per cow or total litres of milk produced per cow. These are partial productivity measures. When used in isolation, partial measures may provide a misleading indication of overall productivity and no single partial measure can be explicitly linked to profitability.

In the short and medium term, variations in farm productivity do not provide an acceptable guide as to the underlying impact of a more productive farm on profit or indeed profitability. We make an important distinction here between profitability and profit. Our concern with productivity is its influence over long term profitability with the focus on how it helps shape changes in the *ratio* of revenue to costs. Change in profit on the other hand is change in revenue minus change in costs. Productivity can vary within a year and from year to year due to a wide range of factors beyond the control of the farmer. In the long term, the profitability of dairy farms across the industry is underpinned by their productivity growth and their terms of trade (Figure 1)) and this is something the industry can collectively help shape. Terms of trade is an index of the ratio of the prices paid for those inputs and outputs.

Figure 1: The relationship of productivity to long run farm profitability



Productivity has been the focus of industry efforts to improve long term industry competitiveness. This is because industry has the capacity to influence productivity trends by investing in research, development and extension and farmers choosing to implement new technologies and ways of doing things in their businesses. In contrast, the dairy industry has limited capacity to influence the terms of trade because the prices for industry outputs such as milk and livestock are determined factors outside of the control of farmers. For example, international milk prices shape domestic price outcomes and livestock prices are shaped by the circumstances facing the beef cattle industry. Similarly, this is also the case for input prices which are shaped by the availability of the inputs and the domestic competition between dairy farmers and other farmers for them, as well as by those internationally.

Productivity growth is essential for improving long term competitiveness. Competitiveness is the ability of farmers to compete in markets (both for their produce but also for inputs into the farming system). Rising productivity in the long run contributes to rising profitability (relative increase in the rate of change of profit) which can then provide the means to fund inputs and compete where input prices are rising. Rising productivity also reduces the relative amount of inputs required for a given level of output and can enable output to be sold profitably when real output prices are flat or falling.

Long term profitability is enhanced if productivity increases and when the terms of trade are neutral or rising over time (Figure 2). That is, farm business produces more output with fewer inputs *and* the relative prices of those outputs are rising at least faster than those inputs — such that there is a change in the ratios of revenue to costs. Historically, it has been common for productivity to be either positive or negative but offset by a countervailing terms of trade position - as was the case from the 1970s through to the 1990s. Long term profitability is undermined if productivity weakens over the longer term and there is also a weakening of the terms of trade position— under this scenario, farmers use more inputs to produce a given level of output *and* the costs of the inputs are rising faster than the outputs.

Figure 2: Effects of productivity and terms of trade outcomes on long run profitability

Change in Productivity	Change in Terms of Trade	Impact on Profitability
+ve	+ve	✓
+ve	-ve	Unclear
-ve	+ve	Unclear
-ve	-ve	X

In this report, we use detailed farm financial and operational data from the Dairy Farm Monitor Project (DFMP) and Queensland Dairy Accounting Scheme (QDAS) to examine the drivers of productivity growth. As shown later in this report, a concerning insight from our productivity analysis of the DFMP and QDAS data is that both terms of trade and productivity have not been growing, and productivity has been declining in some regions in recent years. The long-term competitive position of the industry will be further impacted if this continues. Given there is very little that can be done about the terms of trade, it is important that the industries long term productivity performance is improved.

2.2 Historical Productivity and Terms of trade trends

Overview

Care is required comparing absolute levels and rates and change productivity. Total factor productivity is the standard measure of industry productivity when considering trends in long term competitiveness. However, there can be significant difference in the levels of TFP between countries because of differences in calculation methods and data used. Nonetheless, the general directions and timings of the rates of growth are instructive and improve our understanding of long-term industry competitiveness with other countries.

In Australia, ABARES estimated that dairy productivity has declined since 2010 after rising over the previous decade.[3] International studies on dairy productivity indicate some improvement in productivity growth:

- Several studies indicate the productivity performance of the US dairy sector has improved since the early 2000s after an extended period of weak performance. One study of Wisconsin dairy farms, which used a proper index approach, found a sustained improvement in productivity due to improvements in technological change and technical efficiency.
- The productivity performance of Irish dairy farms increased significantly over the last decade in response to changes in key EU policy setting affecting the industry.
- Evidence on the recent performance of New Zealand dairy productivity is sparse, but recent analysis found the performance for all New Zealand agriculture has been relatively weak.

However, these studies show mixed evidence on the impacts of scale efficiency on TFP performance. A range of historical studies on Europe and US dairy farms found either constant or declining returns to scale.

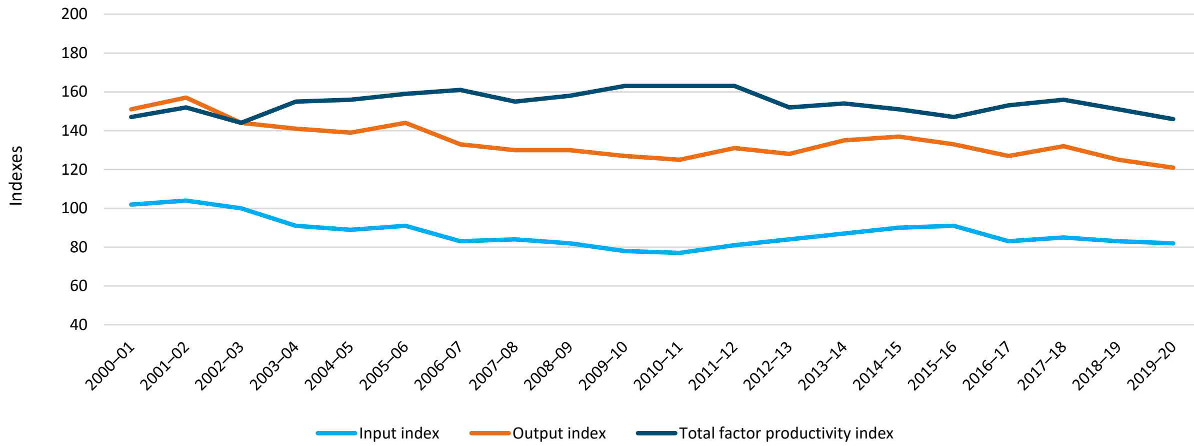
ABARES estimates

ABARES has previously estimated that dairy productivity has declined since 2010 after rising over the previous decade (Figure 3: ABARES dairy industry total factor productivity

). Total factor productivity is now at similar levels to the early 2000s. This is generally consistent with the findings from this study. Both the index of the outputs produced, and inputs used has fallen across the board since the early 2000s.

[3] https://www.agriculture.gov.au/abares/research-topics/productivity/agricultural-productivity-estimates

Figure 3: ABARES dairy industry total factor productivity

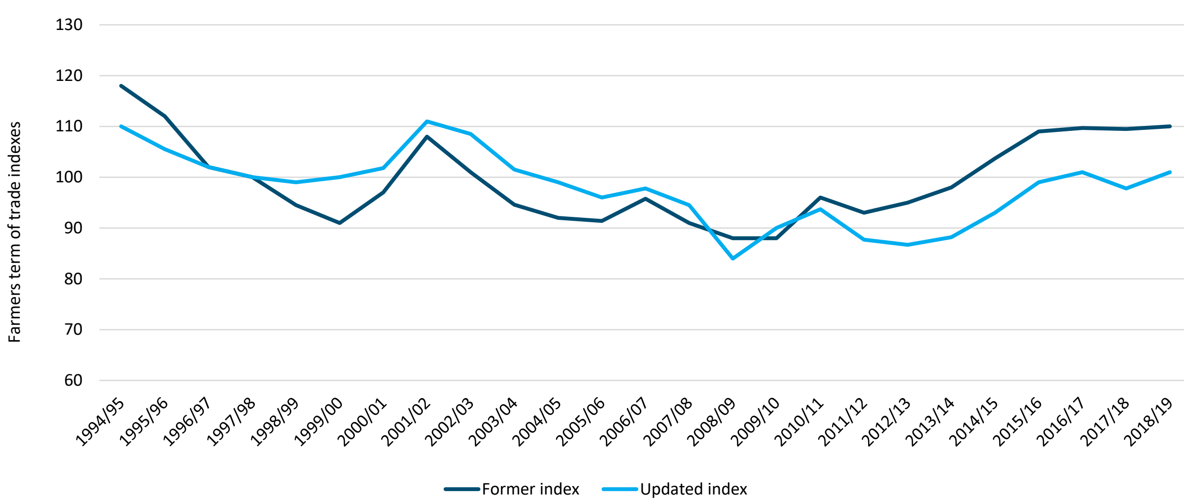


Source: ABARES (2020), Australian Agricultural Productivity, 2019–20 data dashboard

ABARES reports a general terms of trade for agriculture (Figure 4: Terms of Trade Australian agriculture

) but has not recently reported a terms of trade index for the dairy industry. ABARES recently modified the way in which the terms of trade is calculated with the updated index resulting in lowering of the level of the index year to year compared to the previous method. Based on the new index, the terms of trade for agriculture generally rose since 2010. This is unlikely to be representative of the terms of trade for dairy given the general recent weakness and volatility in milk prices.

Figure 4: Terms of Trade Australian agriculture



Source: Source: ABARES (2020), https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1029961/

Caution is required when comparing ABARES TFP and terms of trade estimates and results for this study. There are other significant calculation method and data differences that limit comparisons with this analysis.

For example, the ABARES productivity estimation method uses a Fisher index which limits the scope to which the estimates can be decomposed to understand the underlying drivers and building blocks of TFP in same manner as the proper index approaches applied in this study. O'Donnell (2010)[4] provides a detailed explanation on the limitations of a Fisher Index. In this study for the purposes of comparison, a Fisher index was also calculated alongside the Lowe Index. In all cases, using the same DFMP and QDAS data, the Lowe Index was consistently lower in absolute growth to the Fisher index. This suggests that using the Fisher index overestimates the recent weakness in TFP performance and, therefore, the negative trends observed in the Fisher TFP index are not as severe as has been previously estimated.

Nonetheless, a countervailing consideration is a potentially positive bias potentially with in the DFMP and QDAS data – that is the DFMP and QDAS arguably may have a higher proportion of high performing farms in terms of TFP than the ABARES data set. This is because ABARES uses a random sample approach and, therefore, is likely to include more farmers with poorer general management than those in the DFMP and QDAS programs. Arguably, the DFMP and QDAS data has some bias in that generally farms with average to above average management are included. However, the analysis of DFMP and QDAS data indicates that there is significant variation in the types of farms and the relative levels of farm performance overtime and, therefore, provides useful insight into industry TFP performance.

The ABARES Fisher Index and Lowe index estimates from this study are both complementary to improving our understanding of TFP performance. However, the methods are different and this can lead to differences in the absolute levels of TFP and rates of growth. However, the direction and scale of growth or deceleration are useful points of comparison. The composition and drivers of these changes in TFP are not necessarily well understood in some studies because of the methods of calculation. General insights into competitive settings and their influence on TFP can be informative.

International studies

Ireland

The Irish dairy industry has reported results from a national TFP study in 2019 and found that relative to 2010, TFP increased by 14% by 2016. However, in one production year, 2014-2015, the year when milk quota was removed, the TFP measure increased by 10%.[5] The TFP index for dairy farms then

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[4] O'Donnell C. 2010, Measuring and decomposing agricultural productivity and profitability change.

[5] McCormack M, Thorne F, and Hanrahan K, 2018, Measuring Total factor productivity on Irish dairy farms and Fisher Index approach to using farm level data, 92nd Annual Conference, April 16-18, 2018, Warwick University, Coventry, UK 273479, Agricultural Economics Societyhttps://ideas.repec.org/p/ags/aesc18/273479.html

grew by 3% in the production year 2015-2016.The most significant finding was that the removal of milk quotas in 2015 has led to an increase of over 30% in dairy cow numbers since 2010, and although Suckler cow numbers have dropped slightly, the total number of cows in Ireland has reached an all-time high of over 2.5 million head.

United States of America

Several productivity studies have been undertaken on the US dairy industry. The most relevant was a panel data set of Wisconsin farms using similar farm level data and TFP calculation methods to this study.[6] The study estimated annual productivity growth for 17 years between 1996 and 2012 to be 2.16 per cent. The majority of this growth was attributed to technical progress. Growth in technical efficiency was weak at 0.05 per cent, and scale and mix of inputs efficiency of 0.13 per cent. Climate adaptation efforts were found to have negatively impacted on productivity by 0.31 per cent.

New Zealand

Information on the recent TFP performance of the New Zealand dairy industry is scarce. The OECD recently reported that over the period 2007-16 the New Zealand agriculture as a whole experienced relatively low productivity growth if 0.7 per cent.[7] This was well below the TFP growth experienced in the 1990s. Given the relative size of dairy industry output to other agriculture industries, the TFP performance of the dairy industry is likely to be a significant contributor to this trend.

2.3 Overview of general approach and method (see appendices for further detail)

A proper index approach

This study uses the proper TFP index approach developed by O'Donnell[8].

The proper index approach of O'Donnell has a number of advantages over the traditional Fisher index estimation procedures. First, the approach ensures that the indices created have all the characteristics of a proper index and, therefore, give greater confidence that the estimates are a true representation of farm performance. Further, the approach enables a robust decomposition of the key economic components of productivity including technological change, technical efficiency, scale efficiency, mix of inputs, as well as appropriately accounting for the impact of environmental factors such as rainfall temperature, soils and topography.

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[6] Njuki, E., Bravo-Ureta, B., and Cabrera, V. 2020, Climatic effects and total factor productivity: econometric evidence for Wisconsin dairy farms*, European Review of Agricultural Economics,* Vol 47(3) pp12176-1301

[7] OECD, 2020, https://www.oecd-ilibrary.org/sites/a5eaae99-en/index.html?itemId=/content/component/a5eaae99-en

[8] O'Donnell C. (2018), Productivity and Efficiency Analysis, An Economic Approach to Measuring and Explaining Managerial Performance

DFMP and QDAS data

This study uses financial year DFMP and QDAS data between 2000-01 and 2019-20 to estimate productivity performance using the TFP Lowe index which is then decomposed into several component parts.

The decomposed productivity indices are estimated for both balanced and unbalanced data:

- Unbalanced data uses all available data. This means that that for some farms there is no data in some years. Additionally, this means that for different regions there are different periods of time over which productivity is calculated. For example, QDAS data commences in 2000-01, Victoria 2006-07 and Tasmania 2014-15.
- Balanced data sets only include farms where there is a complete set of annual data for each farm for a given period of time. This means that consistent time periods of productivity data are created and compared.

The graphs in this report use unbalanced data unless otherwise stated.

Given that annual productivity estimates vary from year to year, there can be differences in the estimates of productivity growth depending on which periods used to estimate productivity and which farms are included.

Overall, the quality of the DFMP and QDAS data is high and consistent in its definition, gathering and estimation methods. However, there are some differences in the level and detail and quality of some data over time as the definition and inclusion of variables evolved to a nationally consistent approach over time.

In order to undertake this study, we have worked carefully with DA, DFMP and QDAS staff to ensure that a consistent and accurate data set is used in this productivity analysis.

Creation of output and input quantities and prices series

A significant step in this process has been the conversion of annual farm financial data, which contains numerous variables, to a data set of output and input quantities and output and input prices.

Decomposition of TFP

Two computational methods are used to decompose total factor productivity the O'Donnell proper index method.

- Data Envelopment Analysis (DEA), which is a linear programming method of estimating TFP where the data determines the modelled relationships and not predetermined by the modeller; and
- Stochastic frontier analysis (SFA) uses a Bayesian estimation approach to determine the productivity estimates and their relationships. This approach uses Bayesian estimation for a production function and then uses this to decompose total factor productivity into different

components.

The R mathematical program tool, as customised by O'Donnell, was applied to each method and summary reports from R were customised using Excel. Under both approaches, TFP is calculated using the Lowe Index which is a proper index.

In addition, a terms of trade (output prices to input prices) index is also created at various groupings of farms over different time periods.

Under the DEA approach, TFP is decomposed using the following formula:

- Total Factor Productivity Index (TFPI) = Environment and technology index (ETI) x Output-orientated technical efficiency index (OTEI) x Output-orientated scale efficiency index (OSEI) x Residual mix efficiency index (RMEI).
- This can be shortened to: TFPI = ETI × OTEI × OSEI x RMEI.

Under the stochastic frontier approach:

- Total Factor Productivity Index (Lowe Index) = Output-orientated technology index (OTI) × Output-orientated environmental index (OEI) × Output-orientated technical efficiency index (OTEI) × Output-orientated scale and mix efficiency index (OSMEI) × Statistical noise index (SNI).
- This can be shortened to: TFPI = OTI x OEI x OTEI x OSMEI x SNI.

Each of the indexes used under the DEA and stochastic frontier approach is described in more detail in Table 1.

Table 1: Definitions of TFP decomposition measures

Measure	Relevant in this report to:	Definition
Total factor productivity index (TFPI)	• Data Envelopment Analysis • Stochastic Frontier Analysis	TFPI is a measure of total output change divided by a measure of total input change (i.e., an output index divided by an input index). TFPI is a proper index. TFPI compares the TFP of one firm to another across time periods. TFPI = ETI × OTEI × OSEI x RMEI.
Environment and technology index (ETI)	• Data Envelopment Analysis	ETI is a combined measure of environmental and technical/technological progress change. Technical change is a shift in the production function due to the discovery of new technologies. Environment change indicates the extent to which environmental factors are influencing TFPI.
Output-oriented technical efficiency index (OTEI)	• Data Envelopment Analysis	OTEI is a measure of technical efficiency. Technical efficiency is a measure of movements

Measure	Relevant in this report to:	Definition
	• Stochastic Frontier Analysis	towards or away from the production frontier due to the use of different existing technologies.
Output-orientated scale efficiency index (OSEI)	• Data Envelopment Analysis	OSEI is a measure of scale efficiency.
Residual mix efficiency index (RMEI)	• Data Envelopment Analysis	RMEI is a residual component that remains after accounting for pure technical and scale efficiency effects. RMEI essentially reflects a change in mix of inputs but may also involve a change in scale.
Output-orientated technology index (OTI)	• Stochastic Frontier Analysis	OTI is a measure of technical or technological progress. Technical change is a shift in the production function due to the discovery of new technologies.
Output-orientated environmental index (OEI)	• Stochastic Frontier Analysis	OEI is a measure of changes in characteristics of the environment (e.g., weather).
Output-orientated scale and mix efficiency index (OSMEI)	• Stochastic Frontier Analysis	OSMEI is a measure of both scale efficiency and the efficiency of the mix of inputs.
Statistical noise index	• Stochastic Frontier Analysis	OSEI is a measure of changes in characteristics of the environment (e.g., topography) and weather. OSEI

Source: *Builds on information contained in O'Donnell C. (2018), Productivity and Efficiency Analysis, An Economic Approach to Measuring and Explaining Managerial Performance, and other similar sources.*

Outputs and inputs used in modelling

Using the DEA and stochastic frontier analysis approaches requires defining:

- A set of output variables
- A set of input variables
- A set of environment variables

The modelling uses 2 output variables, 12 input variables and 8 environment variables (although only two environment variables are used in the DEA analysis).

The farm outputs used for the modelling include:

- Milk production
- Livestock sales

The farm inputs used for the modelling include:

- Herd health and replacement
- Capital
- Land
- Labour
- Metabolisable energy (ME) (Grain/concentrates/fodder/agistment)
- Fuel and oil
- Irrigation water
- Fertiliser
- Overhead
- Repairs and Maintenance
- Pasture improvement
- Number of cows

The environment variables used for modelling include:

- Annual rainfall
- Annual average Temperature Humidity Index (THI)
- Coefficient of variation of rainfall (summer grouping)
- Coefficient of variation of rainfall (winter grouping)
- Coefficient of variation of THI (summer grouping)
- State of Australia
- Dairy Australia region

Note that only the first two environment variables (annual rainfall and annual THI) are used in the DEA analysis while all eight are used in the stochastic frontier analysis.

The data sources and calculation of the quantities and prices the output, input and environment variables are described in Appendix 1.

Time periods for modelling

The time periods modelled in this report varies by state due to limitations in the DFMP and QDAS data. The time periods use for modelling are:

- Victoria: 2006/07 to 2018/19
- Tasmania: 2013/14 to 2018/19

- New South Wales: 2011/12 to 2019/20 and 2000/01 to 2006/07.
- Queensland: 2000/01 to 2018/19
- South Australia: 2012/13 to 2018/19
- Western Australia: 2013/14 to 2019/20.

Most of the graphs in this report are limited to 2006/07 to 2018/19 which contains most of the data.

2.4 Conclusion

Productivity measures the relationship between physical inputs and physical outputs. Understanding how productivity performance has changed over time is important toward understanding the dairy industry's future competitive position. Over time weak productivity performance can (other things equal) translate into a weaker competitive position.

Often weak productivity is offset by other competitive factors such as prices received for products and price paid for inputs. However, this is not always the case. RDE is an essential driver of productivity performance and one variable that can be controlled by the industry. Enhancing the level of RDE undertaken and its quality are key routes to enhancing productivity and long-term competitiveness.

New productivity measurement techniques using proper index methods provide an opportunity for the industry to better understand its productivity performance and the composition of that performance. These new techniques can be applied to many years of consistent dairy farm monitor data. This annual farm performance data can be converted to physical measures of farm inputs and outputs that can then be analysed in a robust and comparable way.

3. Part 3

Dairy productivity has flatlined over most of the last two decades. While a large number of farmers are highly efficient there have been no discernible gains from technological change. Productivity is being mostly maintained by altering input mixes. Long term profitability is being driven by the terms of trade and productivity is not lifting when terms have deteriorated.

National dairy productivity remained flat over the last decade and this is repeated experience of almost all states. While technical progress and technical efficiency have been stagnant, farmers are already highly technically efficient using existing technologies. Generally constant return to scale means that productivity is being shaped mostly by farmers changing their mix of inputs and outputs in response to changing circumstances. There is some evidence that productivity is resilient to changes in environmental conditions suggesting farmers are incrementally adapting to environmental variability. Changes in profitability have been determined by the shifts in the terms of trade and productivity growth has not helped offset periods of weak terms of trade.

3.1 National, State and Regional Performance - DEA

3.1.1 National

The data in Figure 5 shows little change in Total Factor Productivity for the Australian dairy industry since 2013/14. There is some difference between states with Tasmania and SA showing a slight increase in TFP over that period while the other states showed little change over that period. The size of the dairy industry in Tasmania and SA was not large enough to have a marked impact on the overall trend for the Australian dairy industry. (The small sample size and diversity in farm operating conditions for the SA industry mean that the results for SA need to be treated with a level of caution).

Data was available for Victoria and Queensland from 2006/07 and there also appeared to be little change in TFP over this extended period except, for a small increase in Victoria following the severe drought conditions in 2006/07. The environmental/climatic conditions would seem to be the key explanation for the increase in the Environment and Technology Index between 2006/07 and 2008/09 in Victoria (Figure 7). The increase in TFP for Tasmania in recent years appeared to come mainly from the Environment and Technology component whereas the increase in TFP for SA was not clearly attributable to any individual component.

There appeared to be little change in Scale Efficiency across the study period for all States or regions (Figure 8).

The Residual Mix Efficiency component did show some variation over the study period but, no clear trends were apparent (Figure 9). Overall, for the Australian dairy industry, there appeared little change in how efficiently inputs were combined over time.

The Technical Efficiency component did show some variation over the study period but, this was mainly in SA and no clear trends were apparent (Figure 10) for the Australian dairy industry.

The data presented in Figure 6 using the Fisher Index shows a similar pattern in terms of the general flat TFP of the Australian dairy industry over the period studied but, the Index is consistently lower than the Lowe Index in Figure 5.

Note that all of the graphs in this report only show the consolidated Australian picture from 2013/14 to 2018/19 as this time period contains data from each of the six states.

Figure 5: National: Total Factor Productivity Index (Lowe Index)

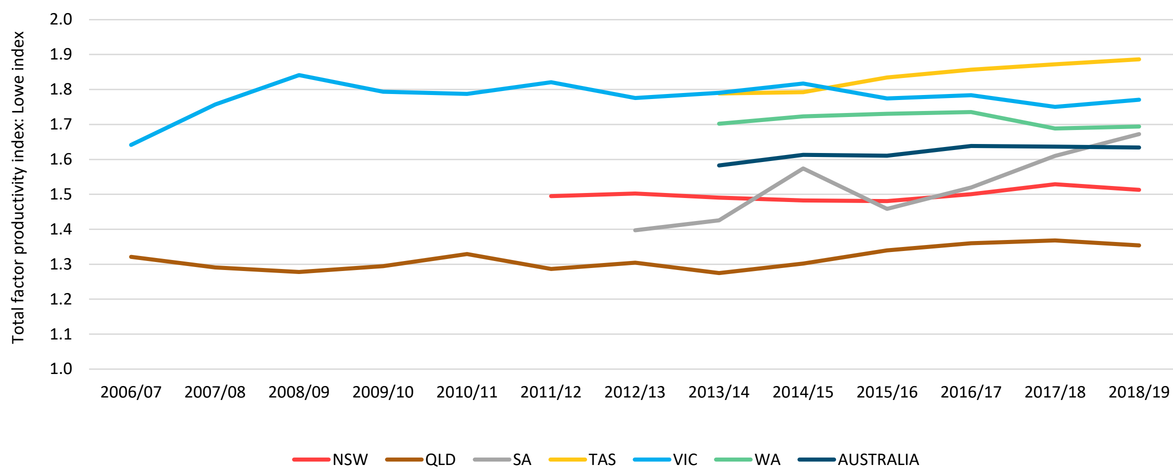


Figure 6: National: Fisher Index (FI)

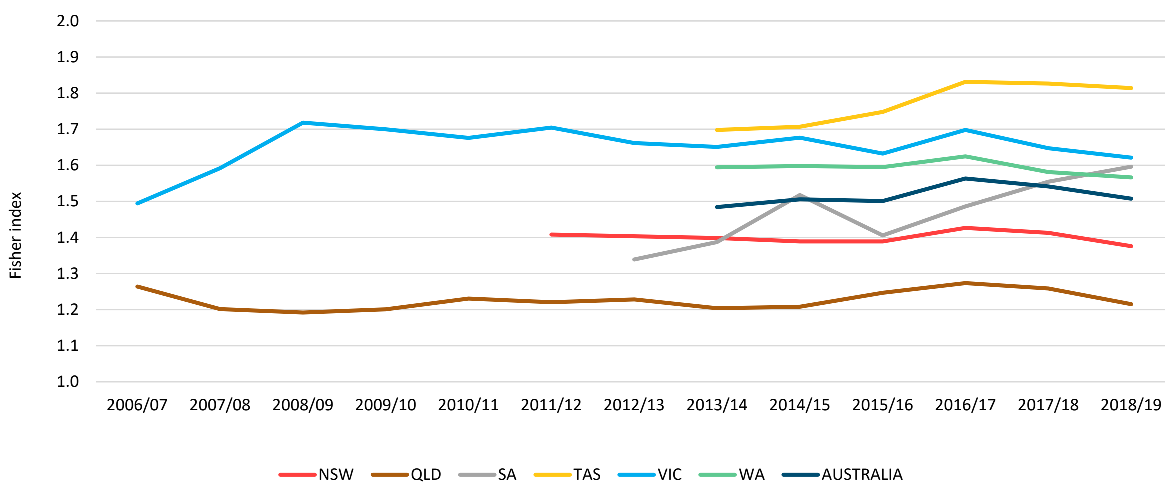


Figure 7: National: Environment and technology index (ETI)

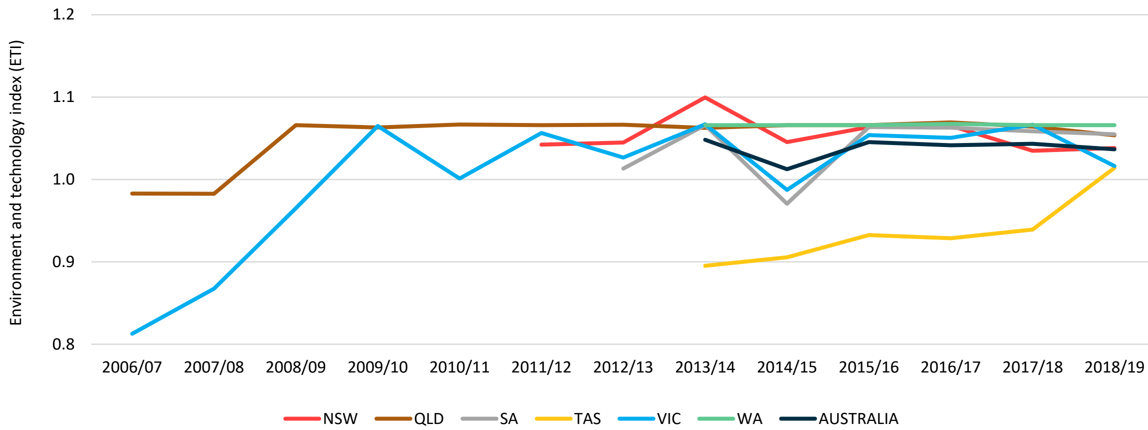


Figure 8: National: Output-oriented scale efficiency index (OSEI)

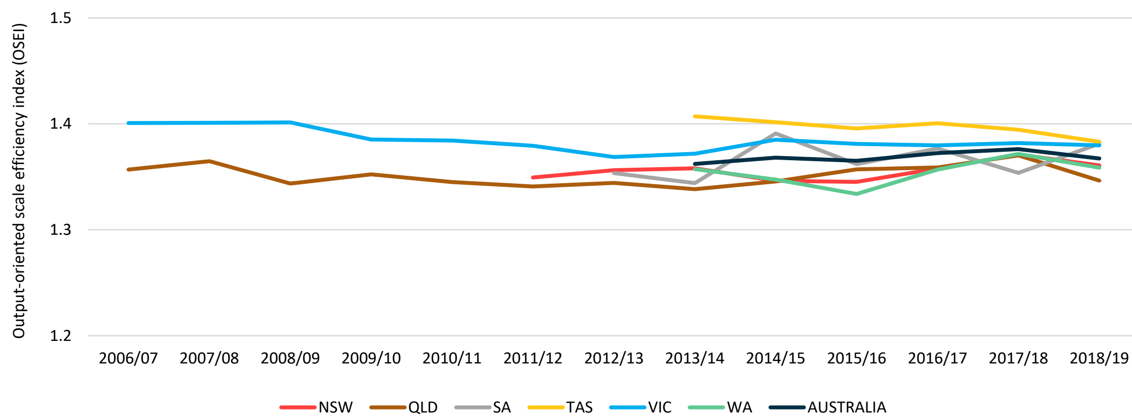


Figure 9: National: Residual mix efficiency index (RMEI)

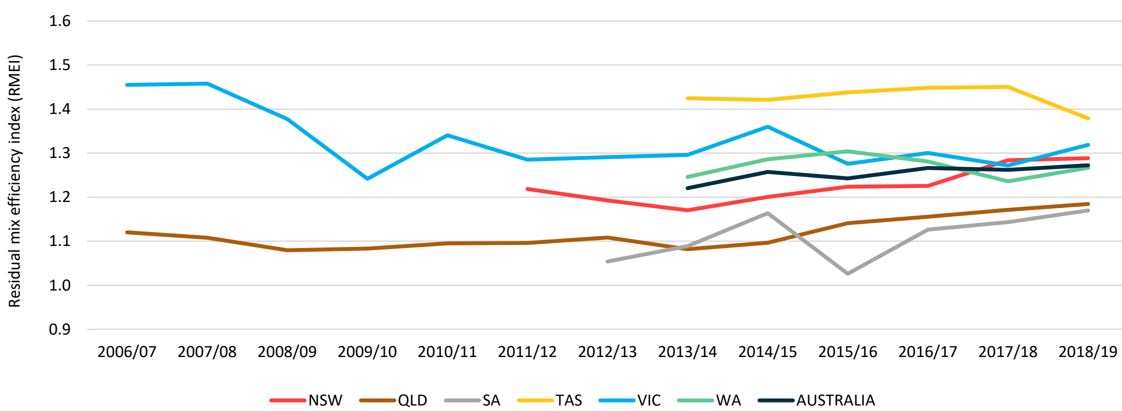
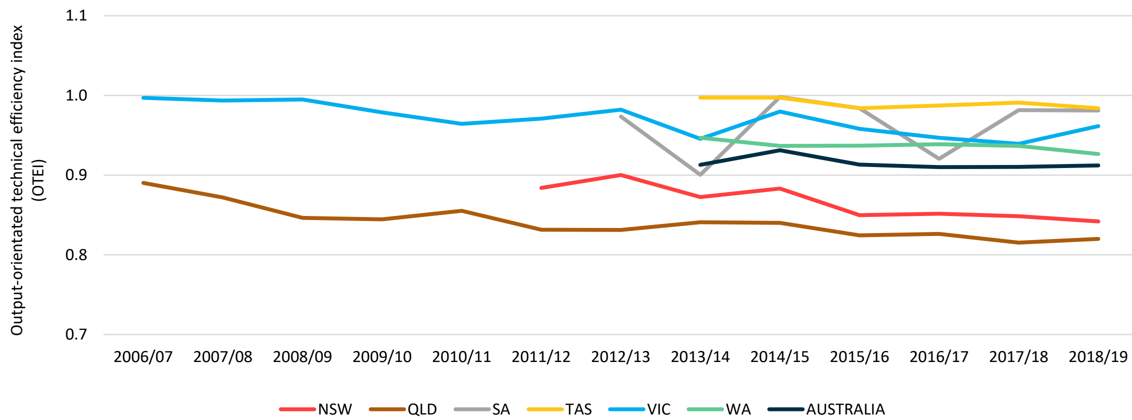


Figure 10: National: Output-orientated technical efficiency index (OTEI)



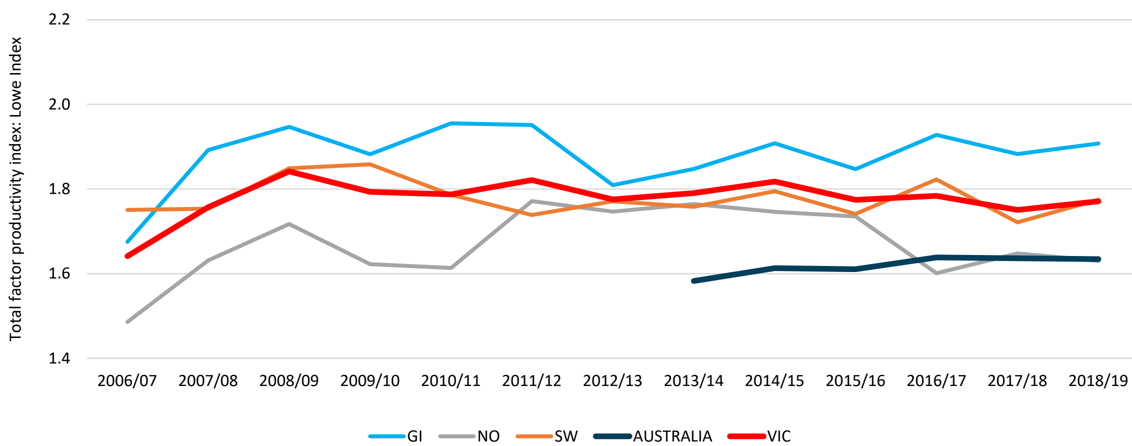
3.1.2 Victoria

While the general trend for TFP over the study period has been relatively flat, the data in Figure 11 shows some differences between the 3 dairy regions in Victoria. TFP for South-West Victoria has generally been relatively flat. Northern Victoria has had more variation and appeared to have a downward trend in the last 3 years of the study period which is likely to be associated with relatively hot, dry conditions and low irrigation water availability. The data for Gippsland was also somewhat variable – it shows an overall increase between 2006/07, although much of the increase occurred immediately after the severe drought of 2006/07.

The majority of the variation for the Victorian regions appeared to come from the Environment and Technology component and this is most likely a reflection of the variation in climatic conditions (Figure 15).

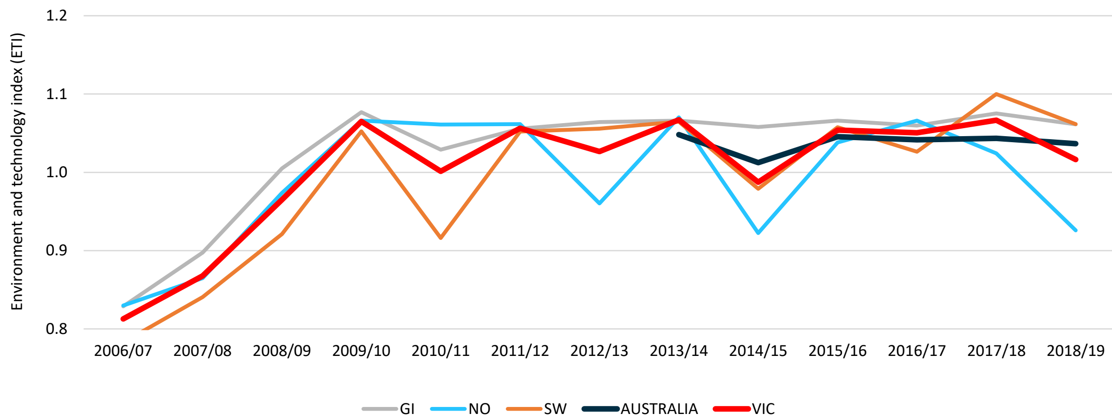
Scale efficiency appeared to have a slight downward trend over the study period for Victoria (Figure 16).

Figure 11: Victoria: Total Factor Productivity Index: Lowe Index



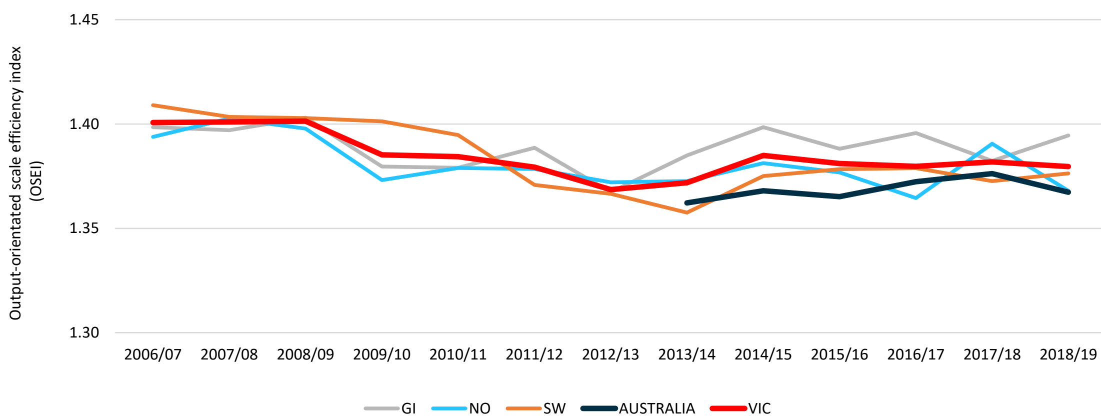
Source: GI refers to Gippsland, NO refers to Northern Victoria and SW refers to South West.

Figure 12: Victoria: Environment and technology index (ETI)



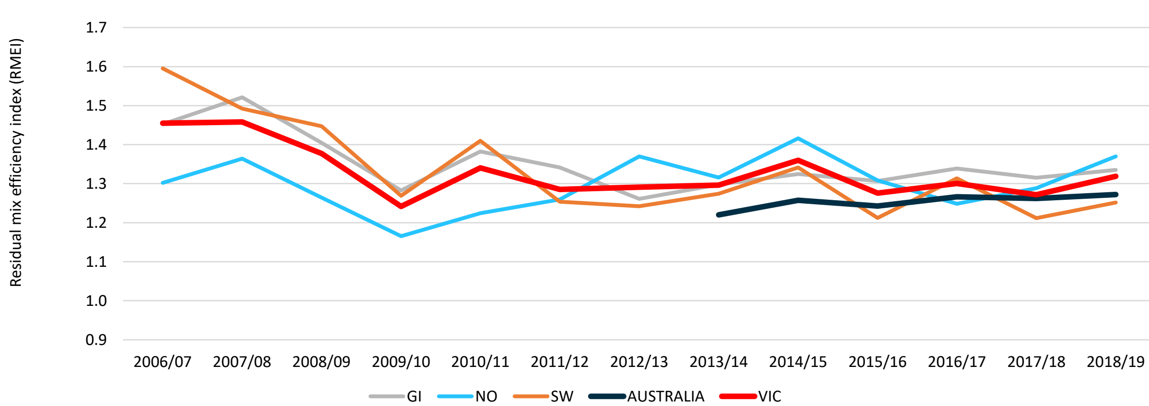
Source: *GI refers to Gippsland, NO refers to Northern Victoria and SW refers to South West.*

Figure 13: Victoria: Output-oriented scale efficiency index (OSEI)



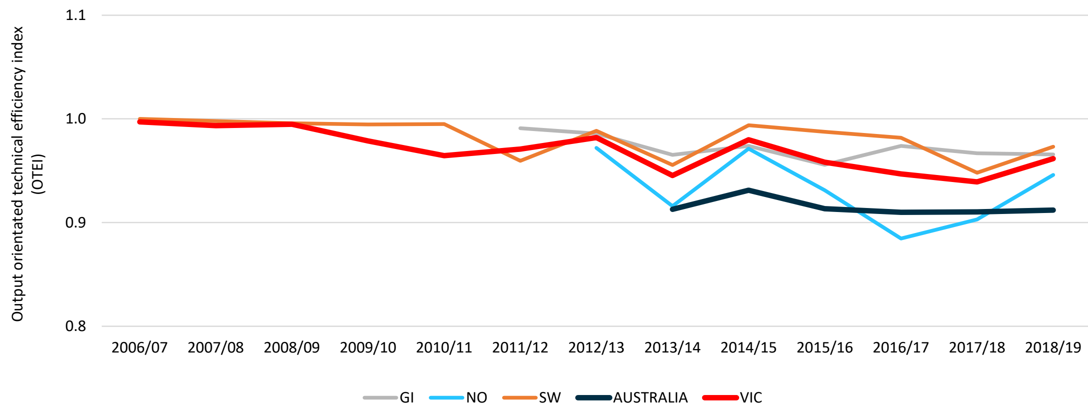
Source: *GI refers to Gippsland, NO refers to Northern Victoria and SW refers to South West.*

Figure 14: Victoria: Residual mix efficiency index (RMEI)



Source: GI refers to Gippsland, NO refers to Northern Victoria and SW refers to South West.

Figure 15: Victoria: Output orientated technical efficiency index (OTEI)



Source: GI refers to Gippsland, NO refers to Northern Victoria and SW refers to South West.

3.1.3 Tasmania

The slight upward trend for the Tasmanian industry appears to come mainly for the Environment and Technology component. The scale efficiency appears to be slightly negative or flat.

Figure 16: Tasmania: Total Factor Productivity Index: Lowe Index

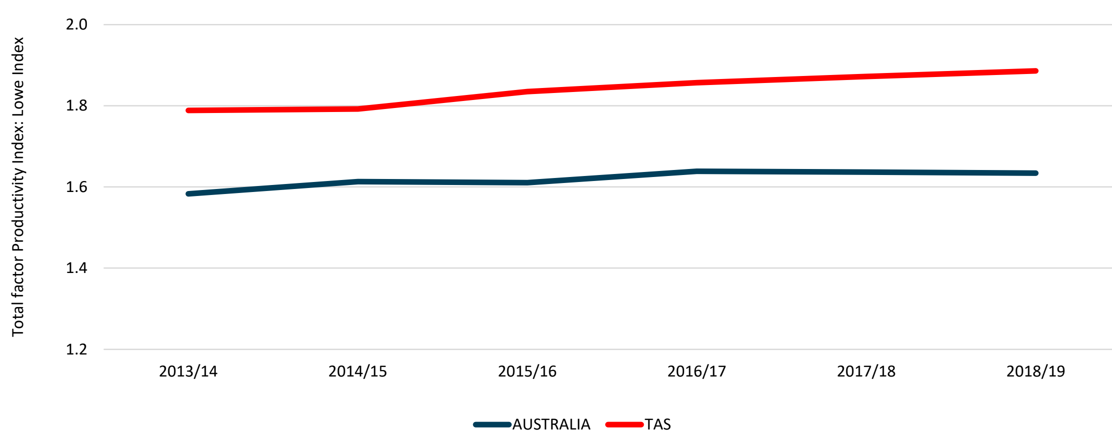


Figure 17: Tasmania: Environment and technology index (ETI)

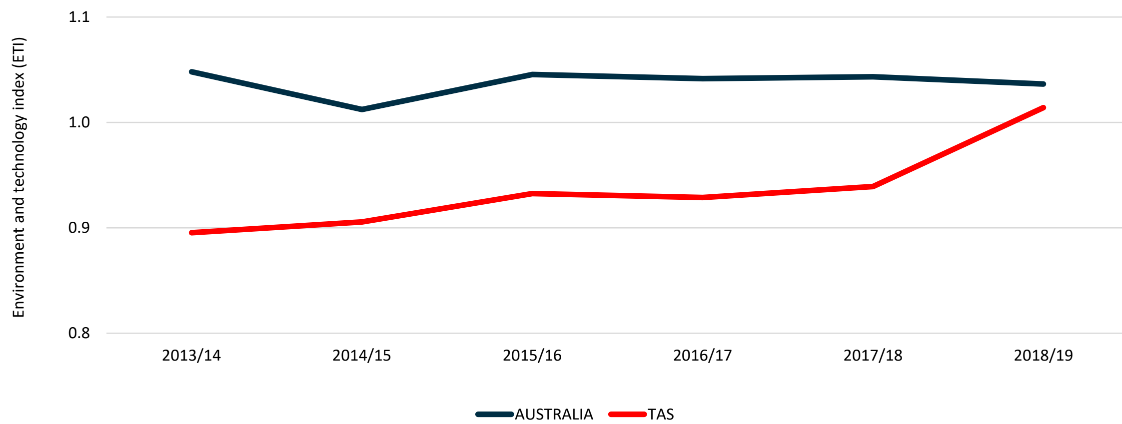


Figure 18: Tasmania: Output-oriented scale efficiency index (OSEI)

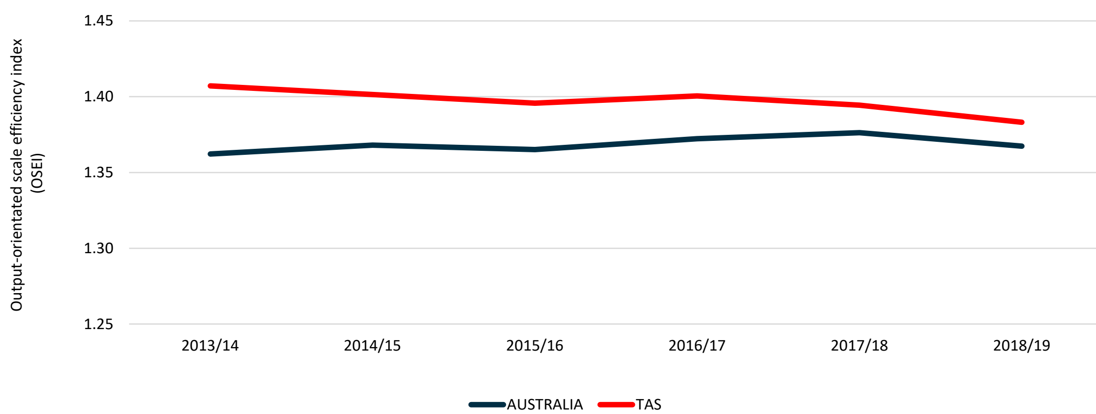


Figure 19: Tasmania: Residual mix efficiency index (RMEI)

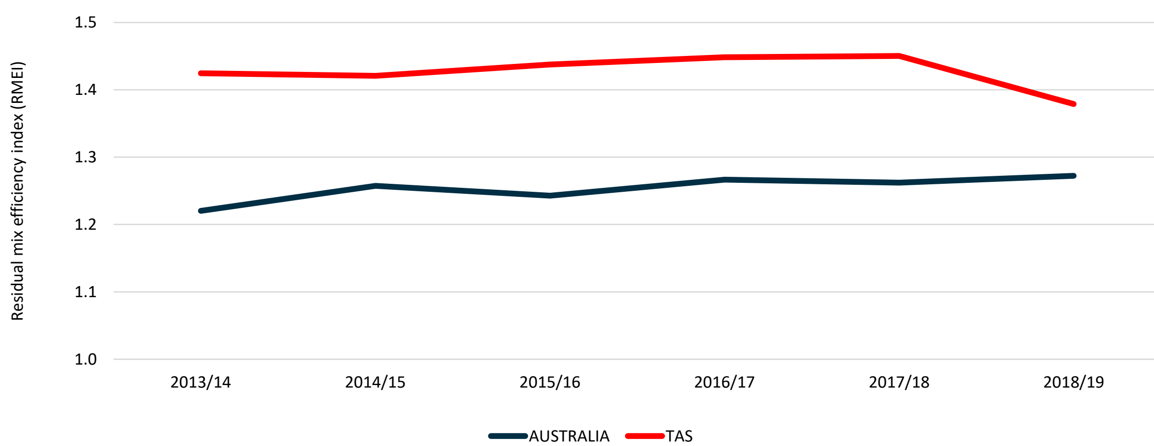
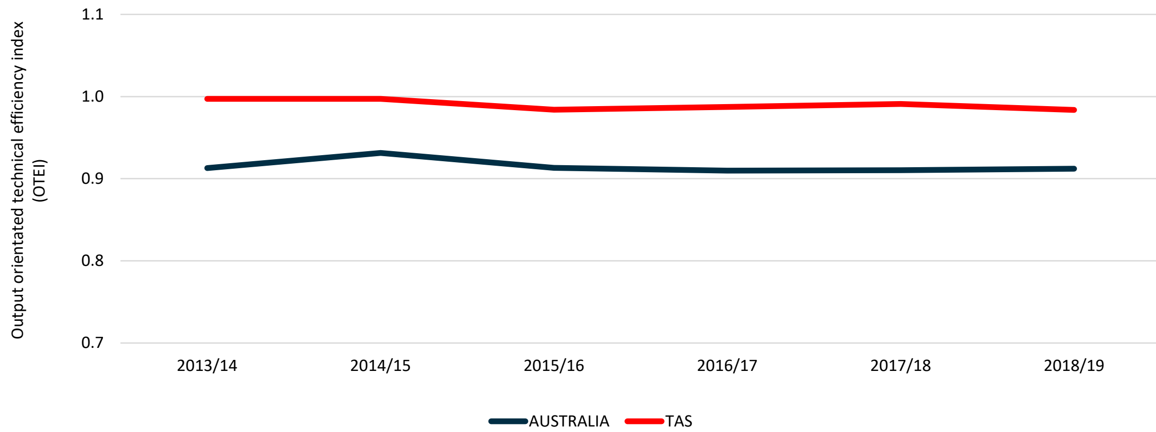


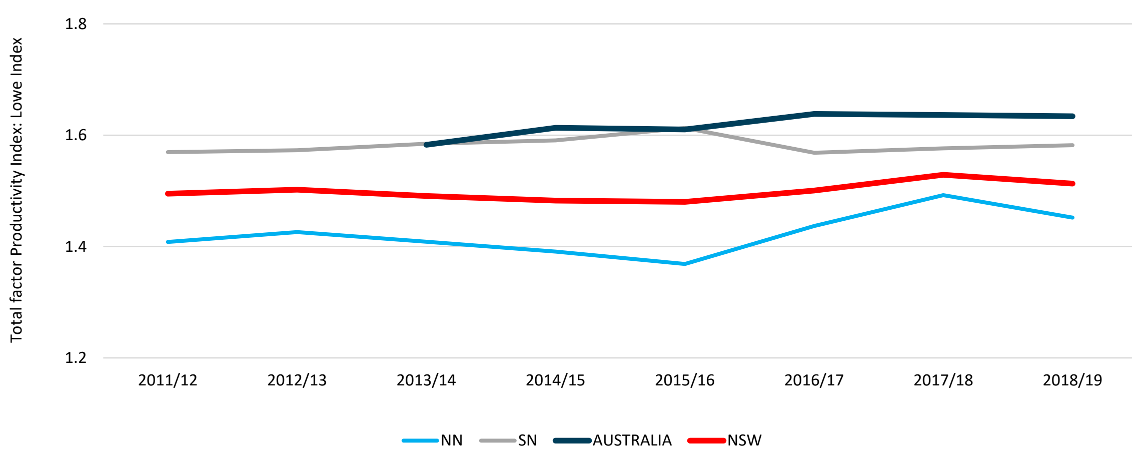
Figure 20: Tasmania: Output orientated technical efficiency index (OTEI)



3.1.4 NSW

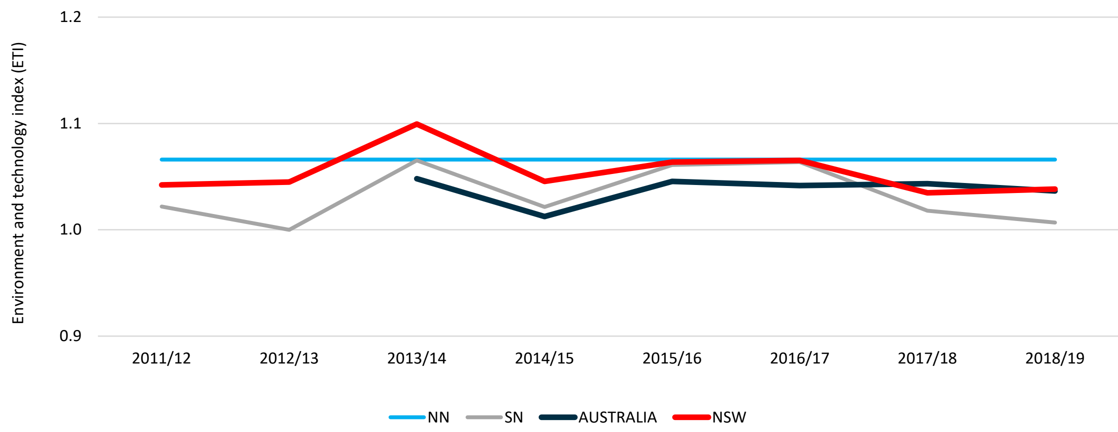
The TFP for NSW appears to be relatively flat over the period from 2011/12 onwards with little variation between the southern and northern regions.

Figure 21: NSW: Total Factor Productivity Index: Lowe Index



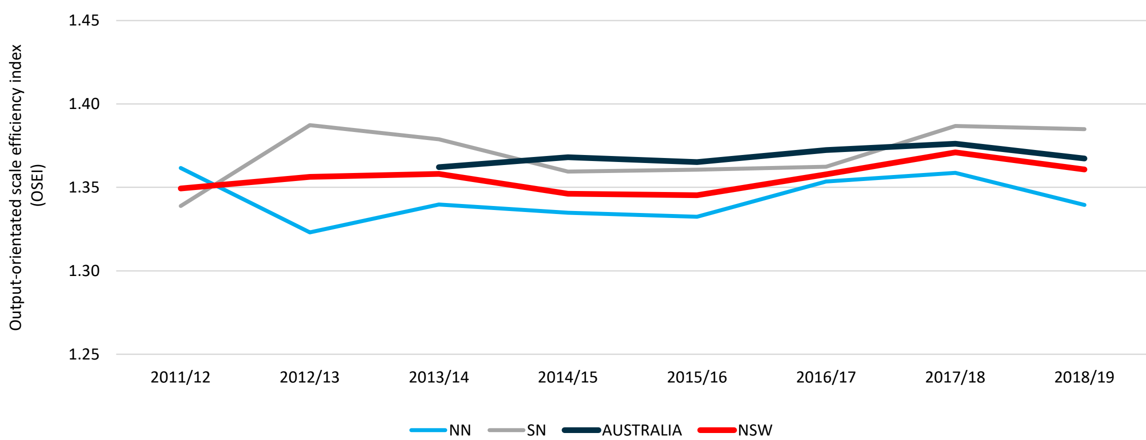
Source: NNI refers to Northern NSW and SN refers to Southern NSW.

Figure 22: NSW: Environment and technology index (ETI)



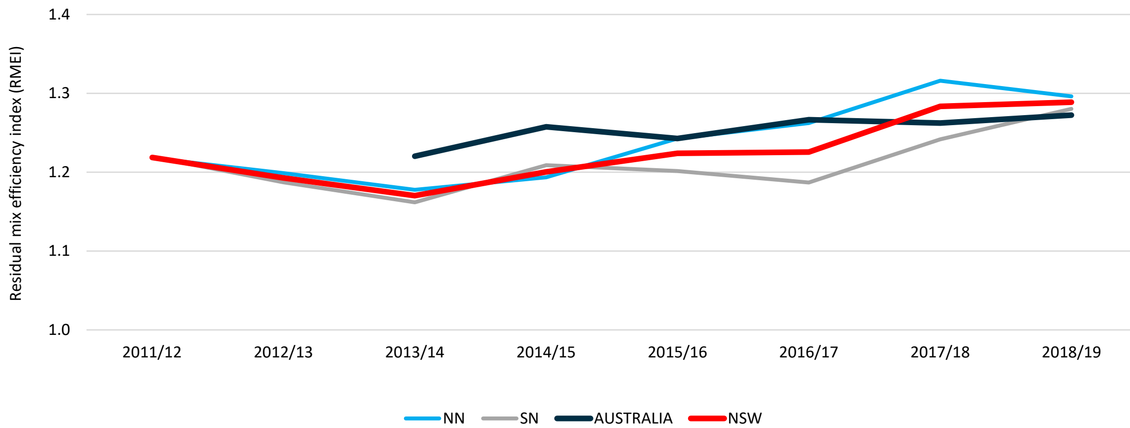
Source: *NNI refers to Northern NSW and SN refers to Southern NSW.*

Figure 23: NSW: Output-oriented scale efficiency index (OSEI)



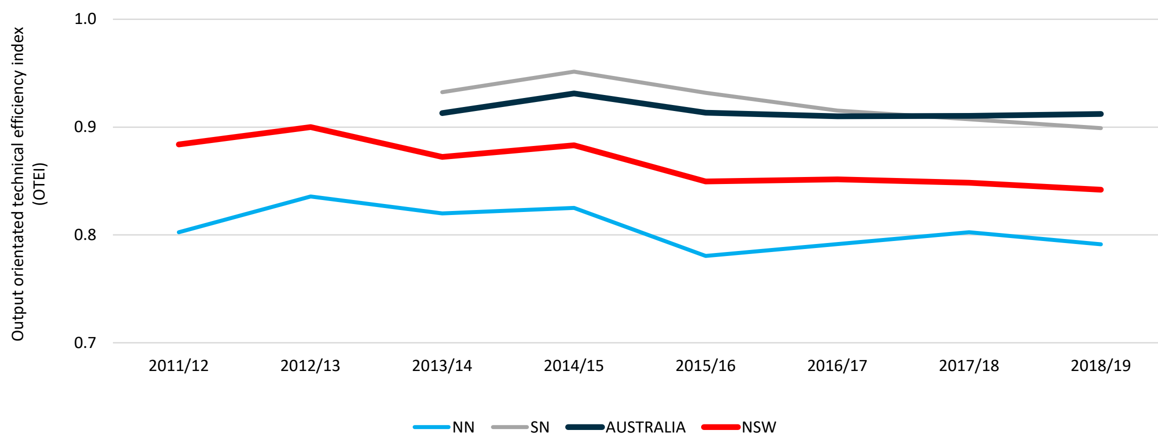
Source: *NNI refers to Northern NSW and SN refers to Southern NSW.*

Figure 24: NSW: Residual mix efficiency index (RMEI)



Source: *NNI refers to Northern NSW and SN refers to Southern NSW.*

Figure 25: NSW: Output orientated technical efficiency index (OTEI)



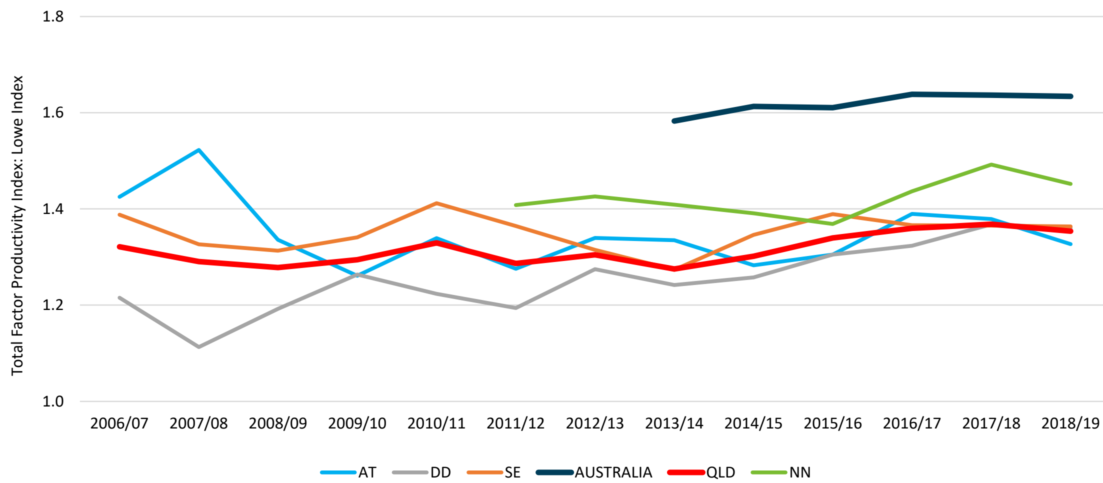
Source: *NNI refers to Northern NSW and SN refers to Southern NSW.*

3.1.5 Queensland

The sub regions for the Queensland industry displayed more variation between years than was represented in the overall flat TFP for Queensland over the study period (Figure 9). However, there do not appear to be clear trends for any of the sub-regions.

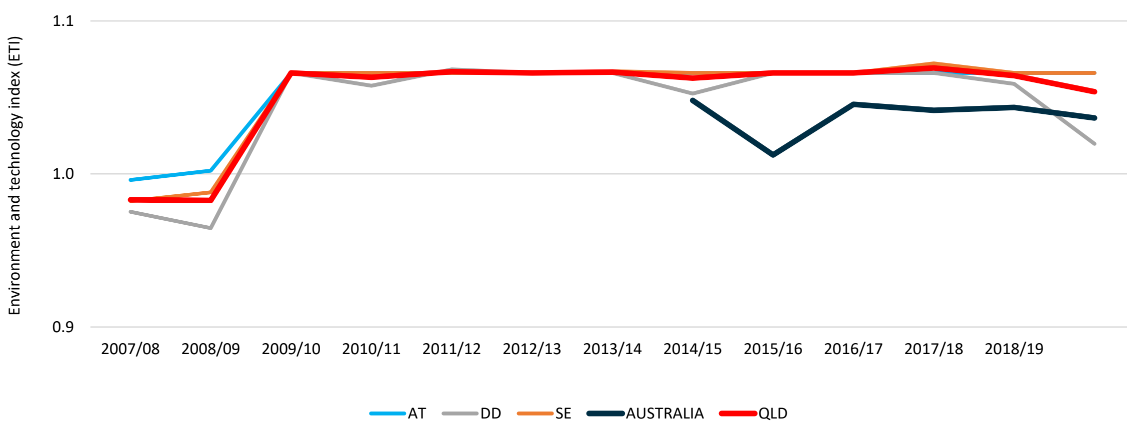
There appeared to some variation across Queensland sub-regions in scale efficiency, which may be a reflection of the substantial structural adjustment that has occurred in this State.

Figure 26: Queensland: Total Factor Productivity Index (Lowe Index)



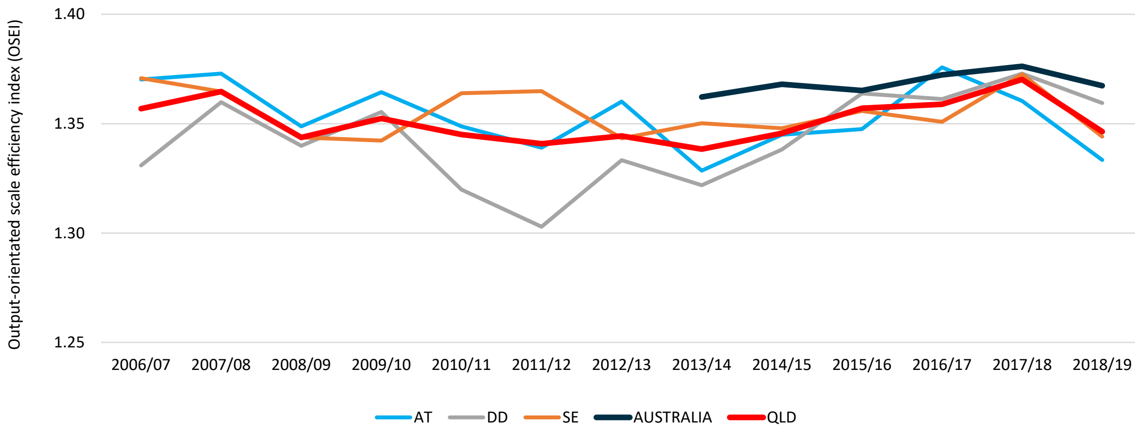
Source: *AT refers to Atherton Tablelands, DD refers to Darling Downs and SE refers to South East Queensland.*

Figure 27: Queensland: Environment and technology index (ETI)



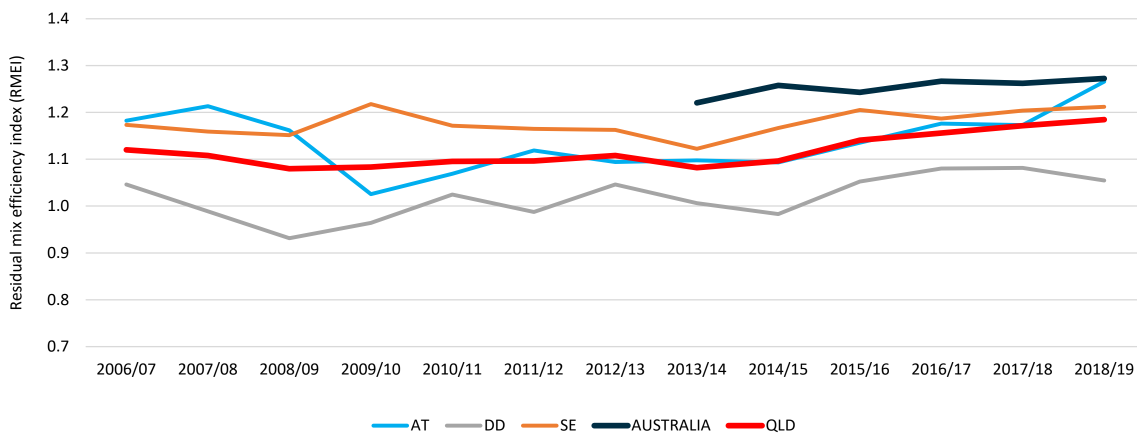
Source: *AT refers to Atherton Tablelands, DD refers to Darling Downs and SE refers to South East Queensland.*

Figure 28: Queensland: Output-oriented scale efficiency index (OSEI)



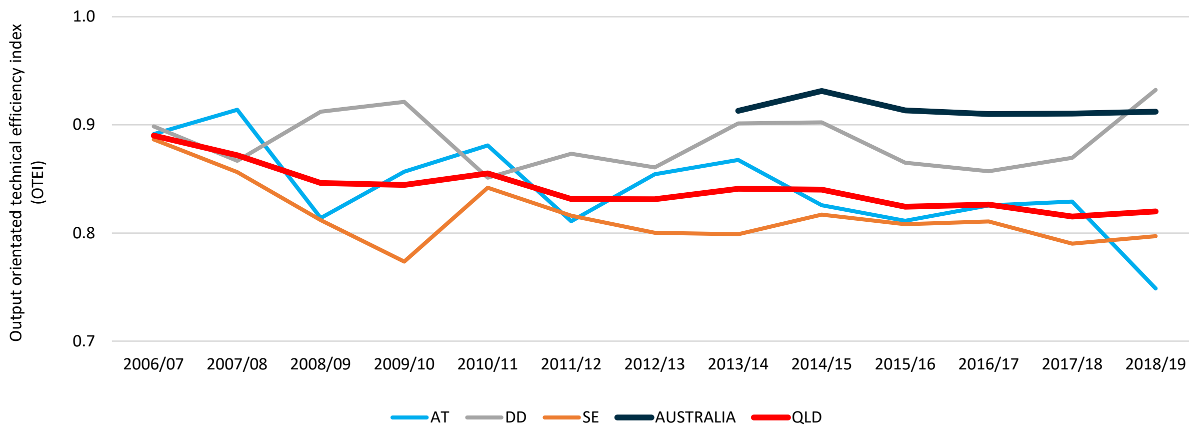
Source: *AT refers to Atherton Tablelands, DD refers to Darling Downs and SE refers to South East Queensland.*

Figure 29: Queensland: Residual mix efficiency index (RMEI)



Source: *AT refers to Atherton Tablelands, DD refers to Darling Downs and SE refers to South East Queensland.*

Figure 30: Queensland: Output orientated technical efficiency index (OTEI)



Source: AT refers to Atherton Tablelands, DD refers to Darling Downs and SE refers to South East Queensland.

3.1.6 South Australia

The TFP for South Australia increases over the study period. However, there is no clear explanation of the main components that led to the increase and some level of caution may be needed given the sample size is relatively small and the operating conditions of the various sub regions are diverse.

Figure 31: South Australia: Total Factor Productivity Index: Lowe Index

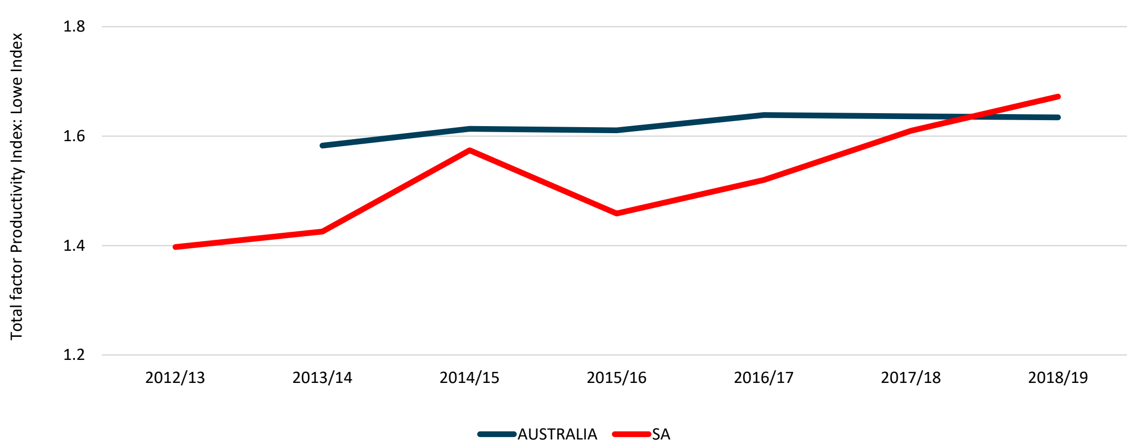


Figure 32: South Australia: Environment and technology index (ETI)

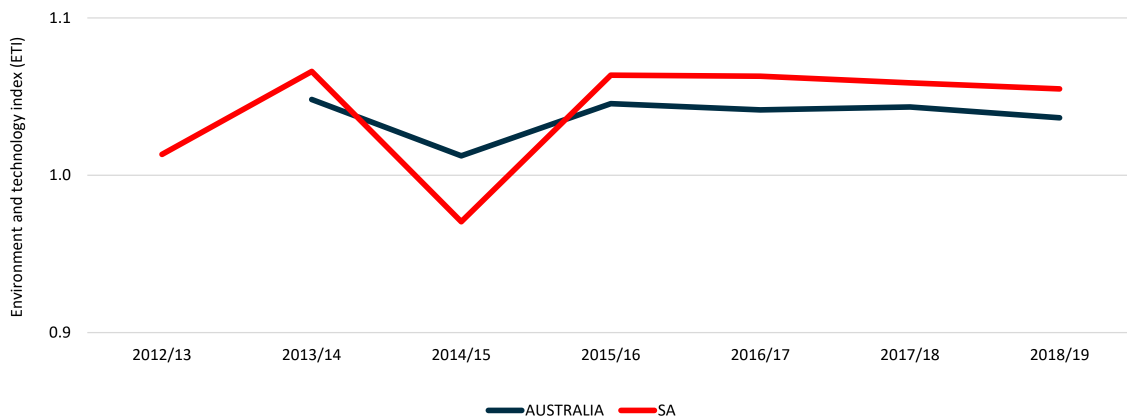


Figure 33: South Australia: Output-oriented scale efficiency index (OSEI)

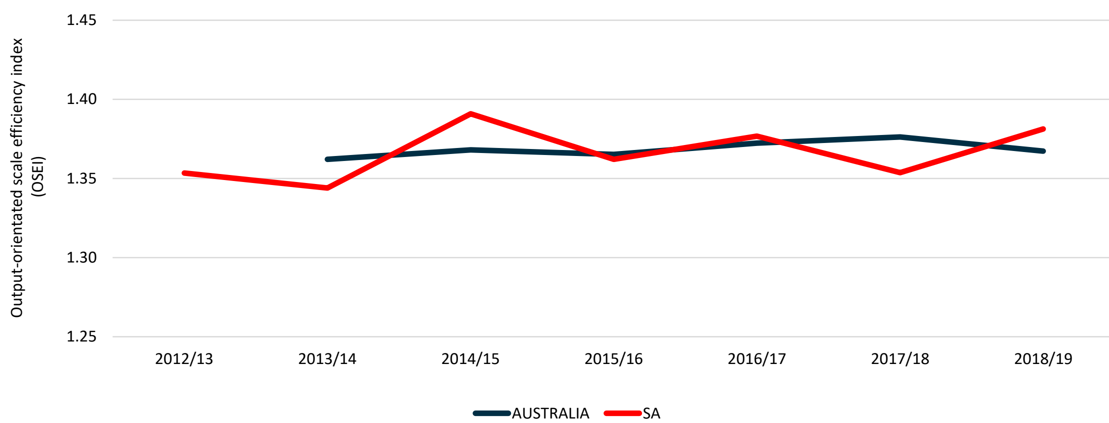


Figure 34: South Australia: Residual mix efficiency index (RMEI)

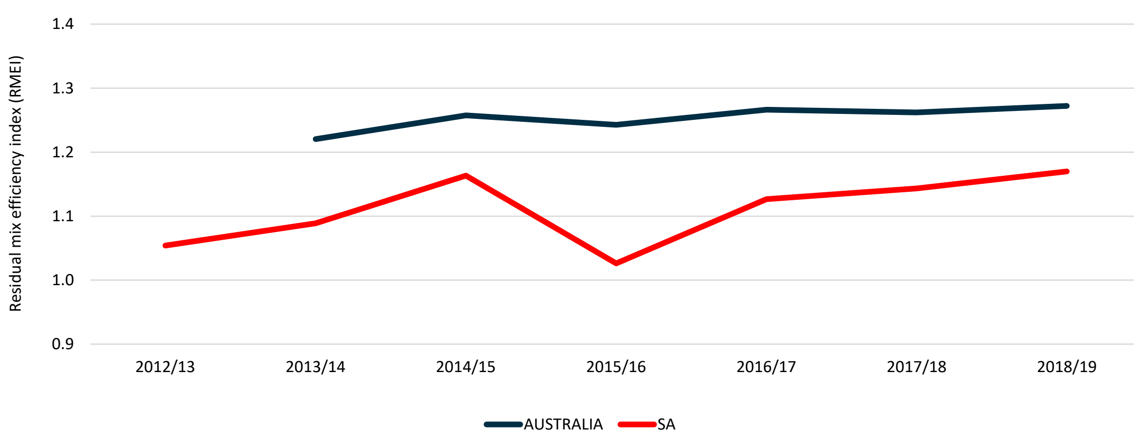
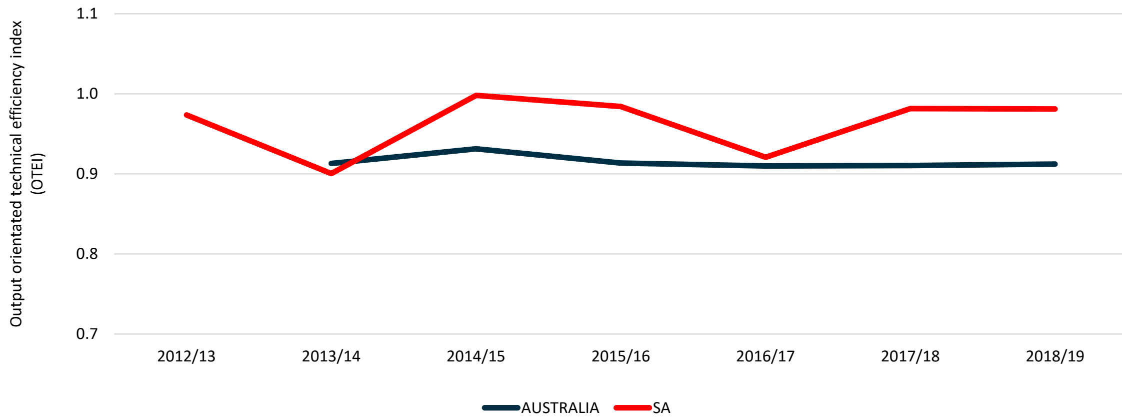


Figure 35: South Australia: Output orientated technical efficiency index (OTEI)



3.1.7 Western Australia

The TFP for the WA dairy industry appears to be relatively flat since the study period commenced in 2013/14.

Figure 36: Western Australia: Total Factor Productivity Index: Lowe Index

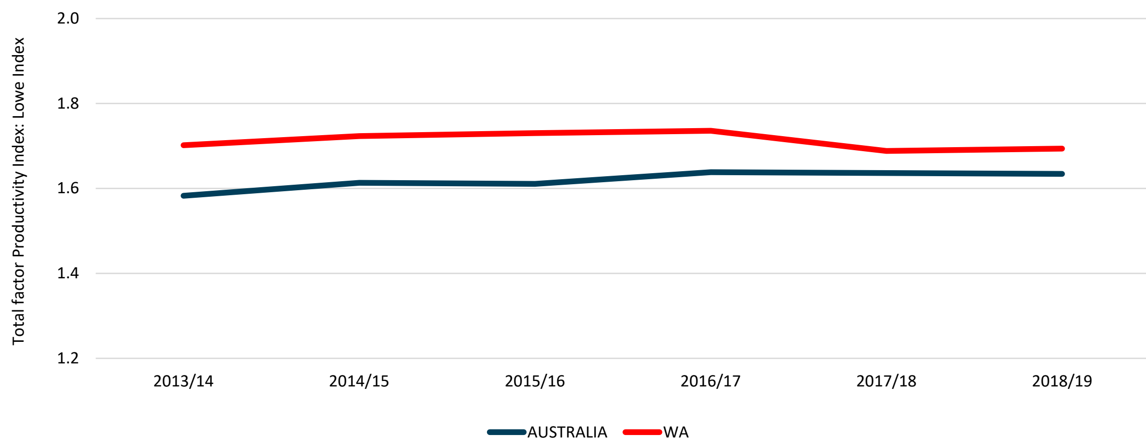


Figure 37: Western Australia: Environment and technology index (ETI)

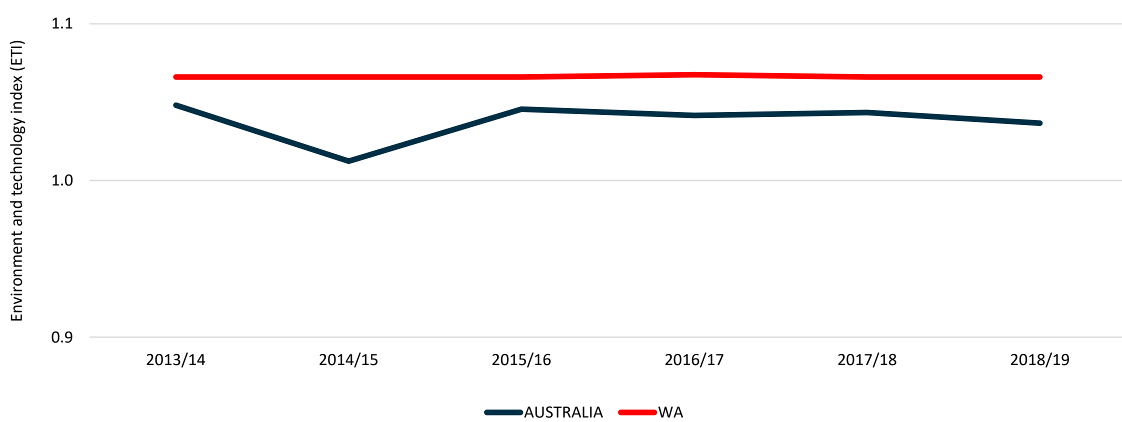


Figure 38: Western Australia: Output-oriented scale efficiency index (OSEI)

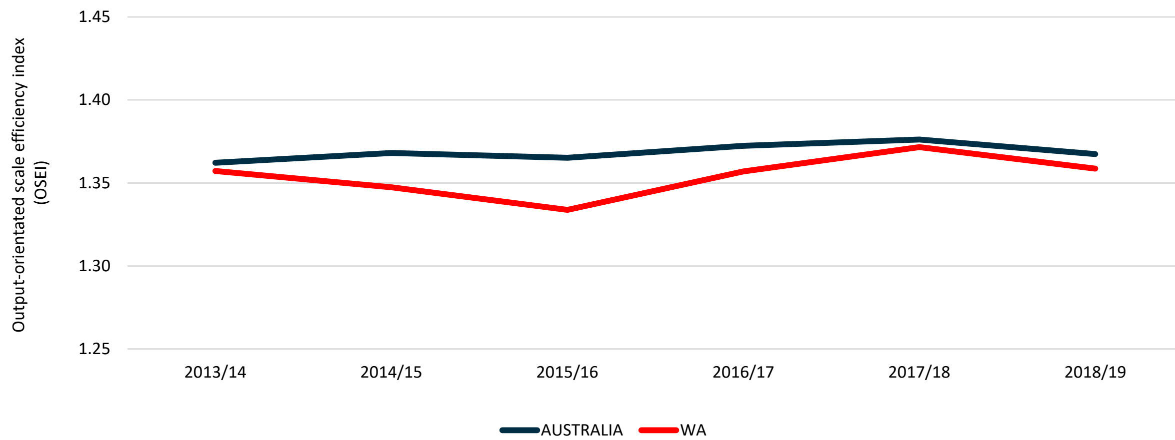


Figure 39: Western Australia: Residual mix efficiency index (RMEI)

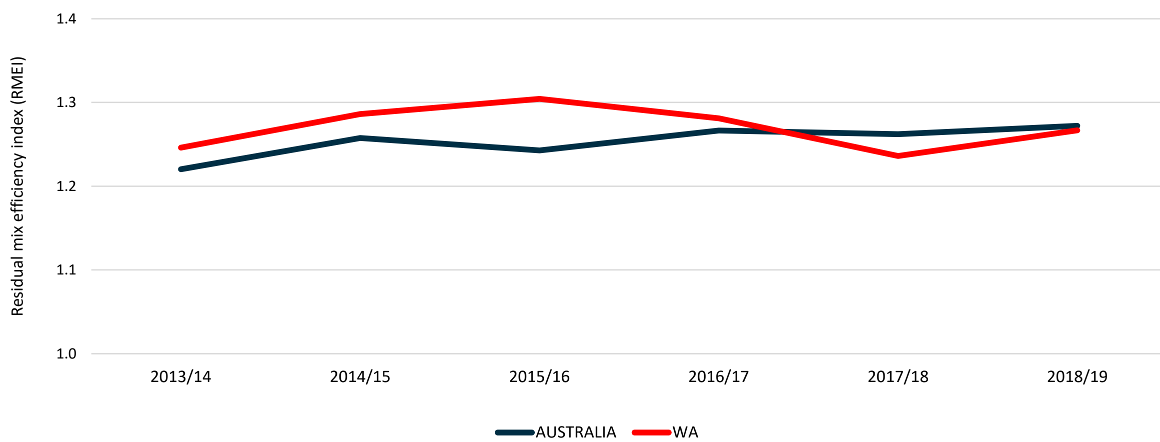
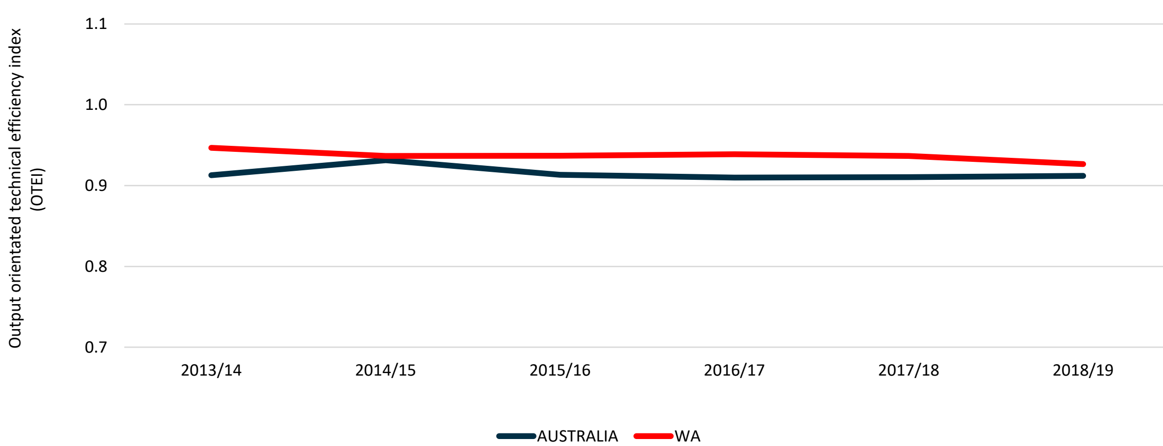


Figure 40: Western Australia: Output orientated technical efficiency index (OTEI)



3.2 National, State and Regional Performance - Stochastic frontier analysis

Under the stochastic frontier analysis (SFA) approach, TFP can be disaggregated using the following formula:

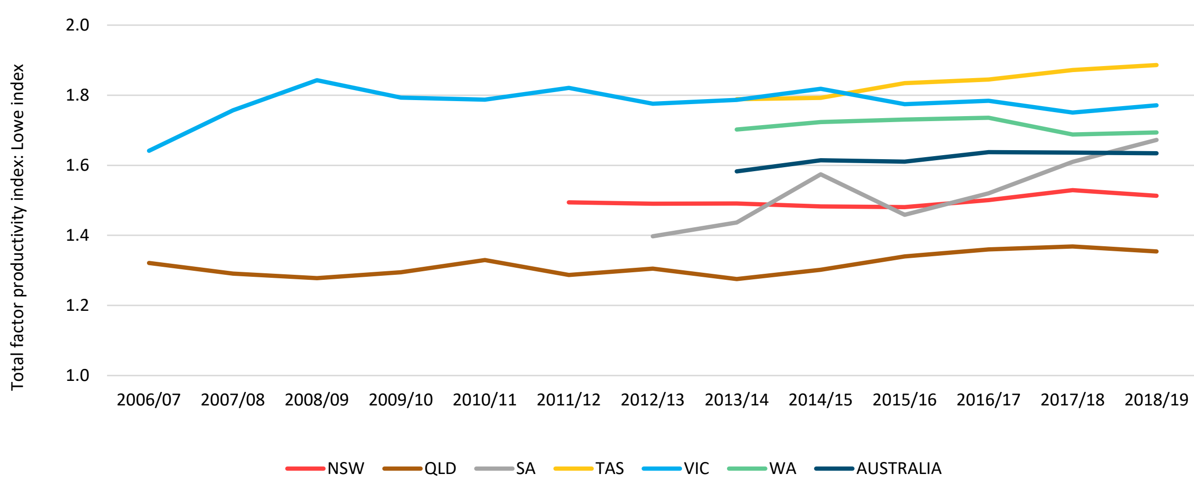
> *Total Factor Productivity Index (Lowe Index) = Output-orientated technology index (OTI) × Output-orientated environmental index (OEI) × Output-orientated technical efficiency index (OTEI) × Output-orientated scale and mix efficiency index (OSMEI) × (Statistical noise index SNI).*

3.2.1 National

Th SFA estimates of productivity are similar in trend to those from the DEA analysis. Productivity performance has been generally flat over the period. More notable changes include:

- after an initial recovery from drought, Victorian productivity steadily declined over the period 2006/07 to 2018/19
- Tasmanian productivity has risen in recent years
- South Australian productivity rose in recent years, but this result needs to be interpreted cautiously given the relatively small number of farms in the dataset.

Figure 41: National: Total Factor Productivity Index: Lowe Index

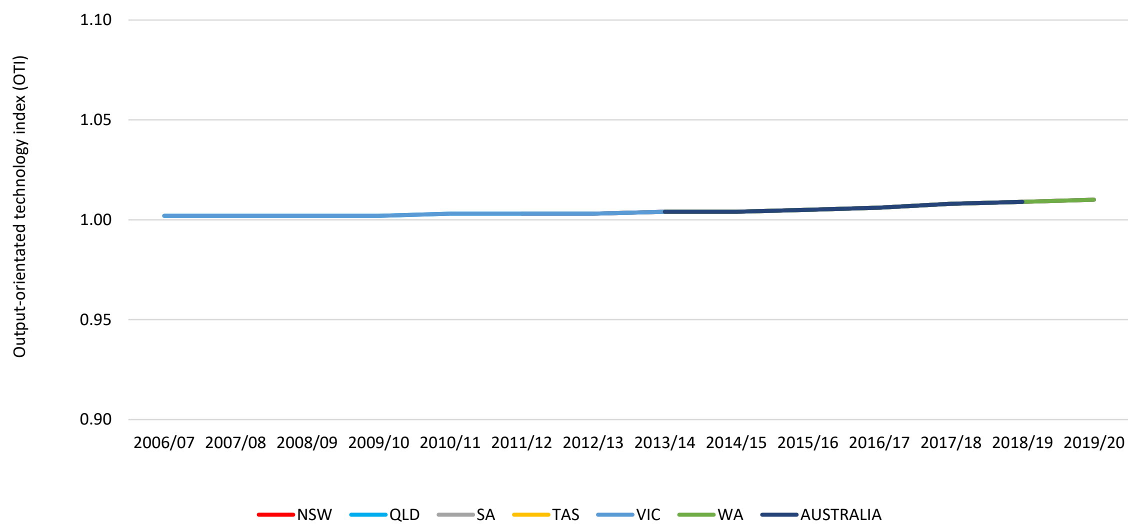


Technological change

SFA analysis enabled the further decomposition of technical change and environmental factors and their influence on TFP.

Technological changes contribution to productivity was very flat over the entire period of analysis. There is some evidence of a very slight increase in the last five years of the data. Further investigation suggests this very slight effect is most likely due to significant changes in livestock outputs from dairy farm systems during that period.

Figure 42: National: Output-orientated technology index (OTI)



Environmental impacts

SFA analysis was used to understand in greater detail the influences of rainfall and THI on productivity performance.

The environmental impact on TFP was remarkably steady over the period despite significant variability and increasing variation in some aspects of some environmental factors in regions particularly in some southern systems. This suggests that dairy farmers are incrementally adapting to changes in environmental conditions overtime with limited impact of productivity.

Indeed, productivity performed better in some very poor seasons - reflecting the skill of farmer to alter the composition of input mixes to maintain relative levels production and the drawing on feedstocks produced in better seasons. This does not mean it was profitable, as terms of trade were negatively affected through higher input prices. Similarly weakening of productivity was associated with very favourable seasonal conditions.

Some reasons for this could include the ‘slackening off’ of intensive feed systems when pasture became abundant, and the extra inputs associated with the additional fodder conservation efforts. A limitation of the DFMP and QDAS datasets is there is insufficient data to enable the productivity analysis to allocate the inputs used to create conserved feed to the period when the feed was used. This productivity analysis allocates inputs to the period in which the feed was produced, regardless of the period when the produced feed is consumed.

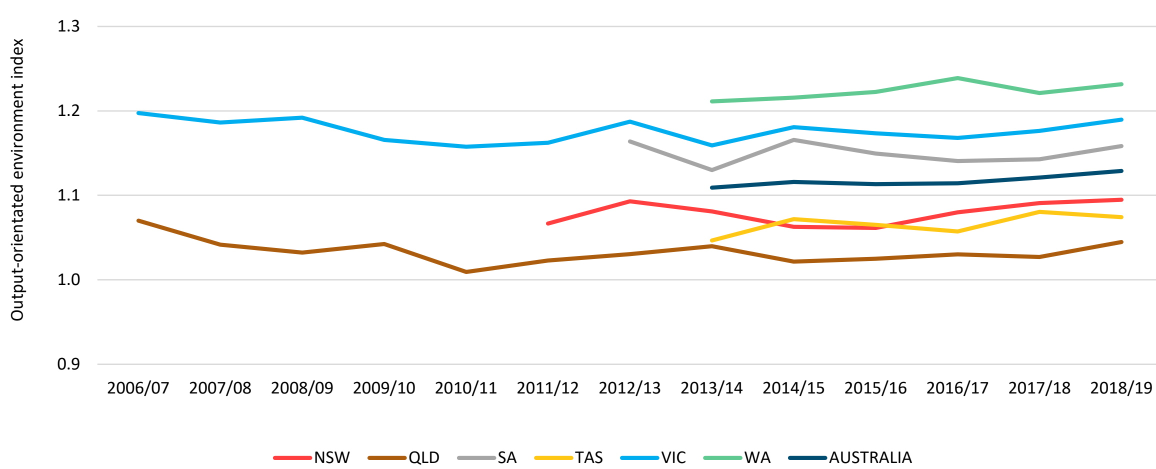
Several environmental variables were constructed:

- annual rainfall
- annual THI
- coefficients of variation for annual rainfall and THI, and
- coefficients of variation for rainfall and temperature for winter and rest of year periods.
- State of Australia
- Dairy Australia region.

Annual rainfall and annual THI were found to be negatively corelated with production levels.

This study found a very weak negative relationship between production and rainfall. Care is required interpreting this given the performance data are annual. When rainfall diminished this is offset by the use of other inputs including stored feed, imported feed and concentrates and irrigation water. When rainfall increases there can be a softening of production as these inputs are reduced and grown pasture is consumed in greater quantities. Moreover, under very wet conditions pasture growth can be negatively impacted along with herd health.

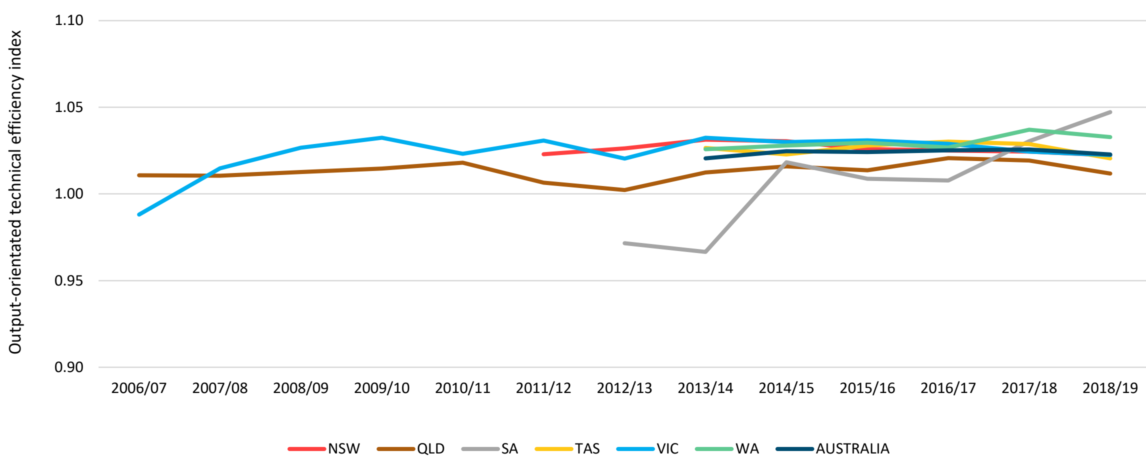
Figure 43: National: Output-orientated environmental index (OEI)



Technical efficiency

Technical efficiency was relatively flat over the period. In Victoria, technical efficiency recovered after the drought of the early 2000s but then gradually weakened. A slight weakening of technical efficiency is observable in number of other States in the later part of the 2010s. Again, the large rise in South Australia needs to be interpreted with caution.

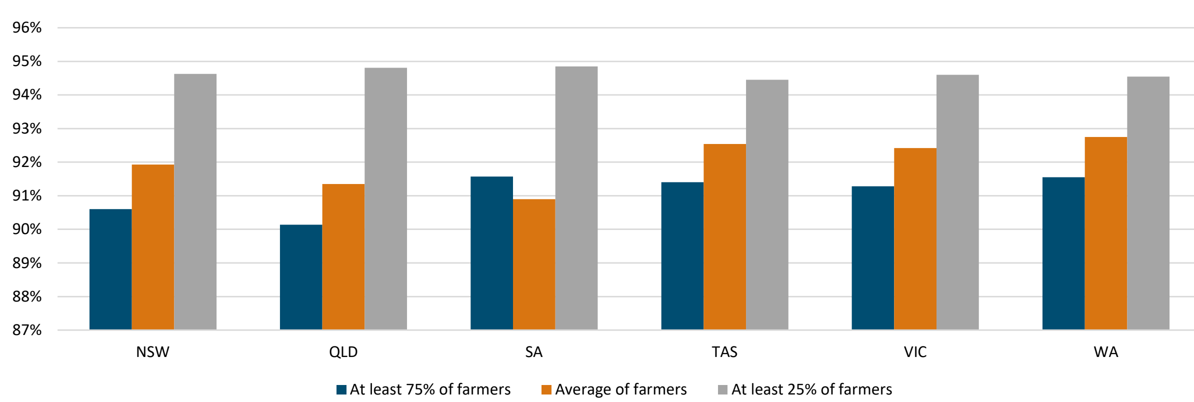
Figure 44: National: Output-oriented technical efficiency (OTEI)



Statistical analysis of the technical efficiency index indicated a relatively high level of technical efficiency — famers ability to optimise output with given inputs and given technology:

- at least 75% of farmers are between 90 and 92% technically efficient across Australia
- on average, farmers are between 91% and 93% technically efficient across Australia
- at least 25% of farmers are more than 94.5% technically efficient across Australia (Figure 45).

Figure 45: Output-orientated technical efficiency

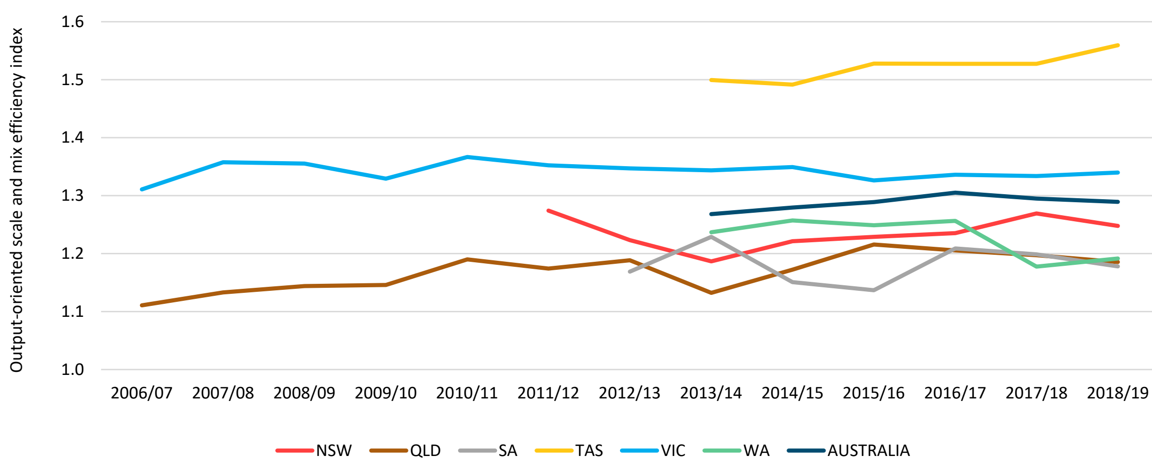


Scale and mix efficiency

The application of statistical methods to the data set using Stochastic Frontier Analysis found scale and mix efficiency were relatively flat over the period (Figure 46).

Further, several tests of scale efficiency were conducted and the results indicate that farms analysed, exhibited constant returns to scale. That is, for a one percent increase in inputs, outputs also rise by one percent. When considered in this light, the results for scale and mix efficiency growth suggest that most change in the contribution to TFP from scale and mix efficiency can be attributed to mix efficiency – that is, farmers altering mixes of inputs in response to circumstances.

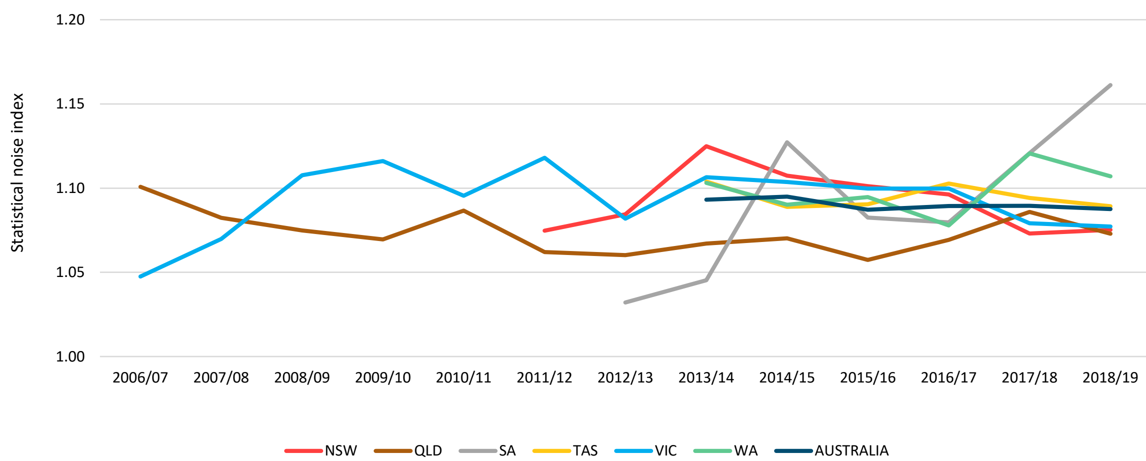
Figure 46: Output-oriented scale and mix efficiency index (OSMEI)



Statistical noise - accuracy of estimates

The SFA estimation procedure uses statistical techniques to estimate productivity indices and these procedures can result in data that cannot be empirically drawn on in the estimates. That is, the estimated model cannot allocate this data to an index or explain its influence on productivity. This unexplained data (sometimes called white noise) is shown below for each State. The data indicate that white noise is more prevalent after there are large shifts in environmental conditions. For example, statistical noise in Victoria rises after the recovery from drought but then remains it is also generally higher in Victoria than most other states. On the whole, the levels of statistical noise are relatively modest and suggest the SFA model and results are a reasonable estimator of productivity performance.

Figure 47: National: Statistical noise index (SNI)



3.2.2 Victoria

While the general trend for TFPI over the study period has been relatively flat, the data in Figure 48 shows some differences between the 3 dairy regions in Victoria. After the recovery from the 2006/07 drought when the low availability and poor quality of fodder impacted productivity, TFPI for South-West Victoria and Gippsland has generally been relatively flat. Northern Victoria has had more variation and appeared to have a downward trend in the last 3 years of the study period which is likely to be associated with relatively hot, dry conditions and low irrigation water availability. Northern Victoria has also had downturns associated with excessive rainfall and flooding.

The majority of the variation for the Victorian regions appeared to come from the Environment and Technology component and this is most likely a reflection of the variation in climatic conditions (Figure 49).

Scale efficiency appeared to have a slight downward trend over the study period for Victoria (Figure 50).

Figure 48: TFPI: Lowe Index

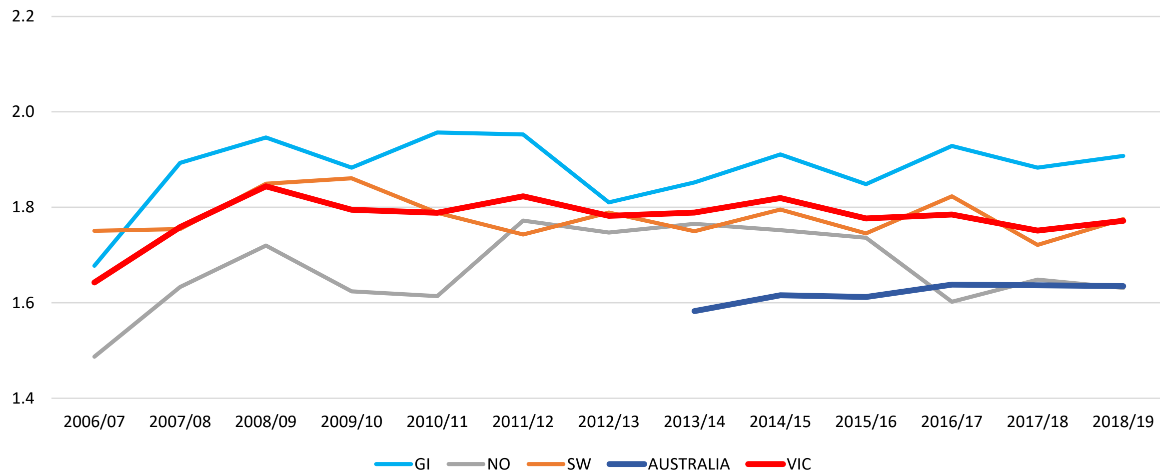


Figure 49: Environmental and technology index (ETI)

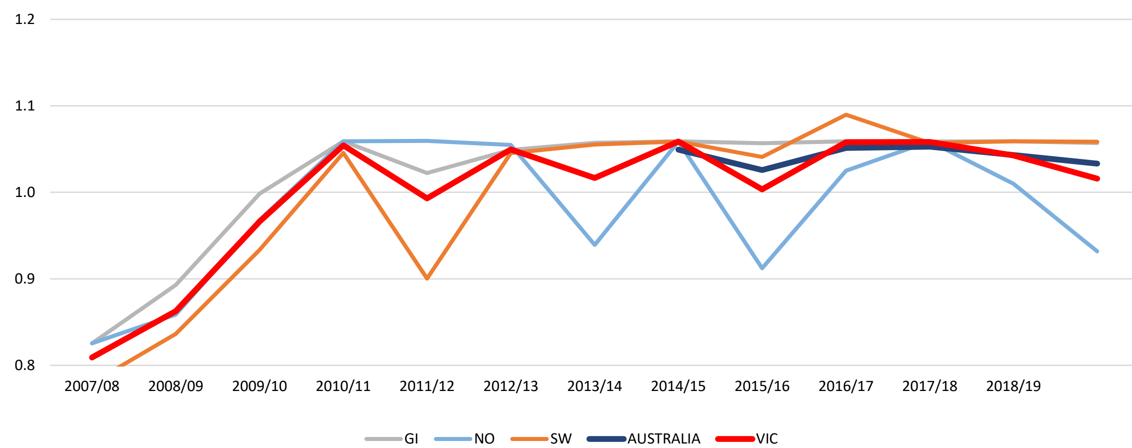


Figure 50: Output-orientated scale efficiency index (OSEI)

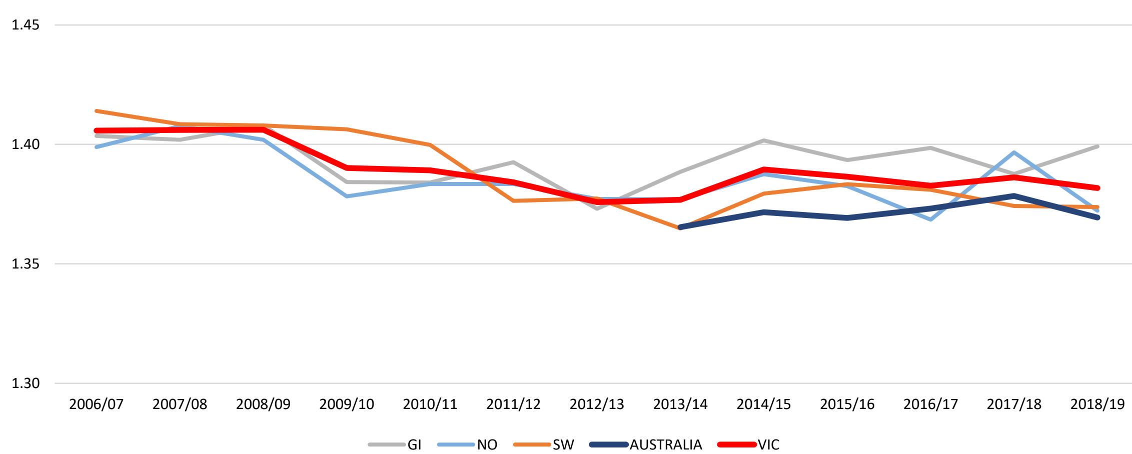


Figure 51: Residual mix efficiency index

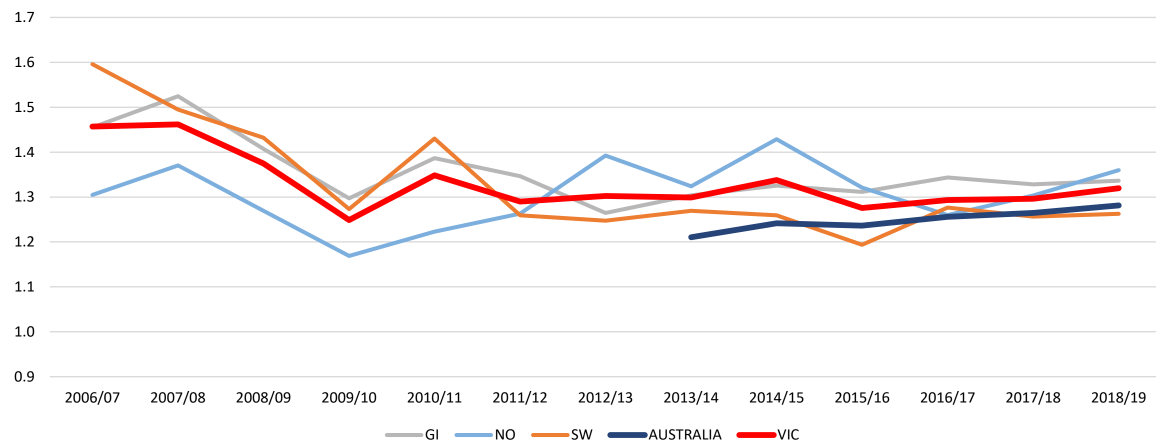
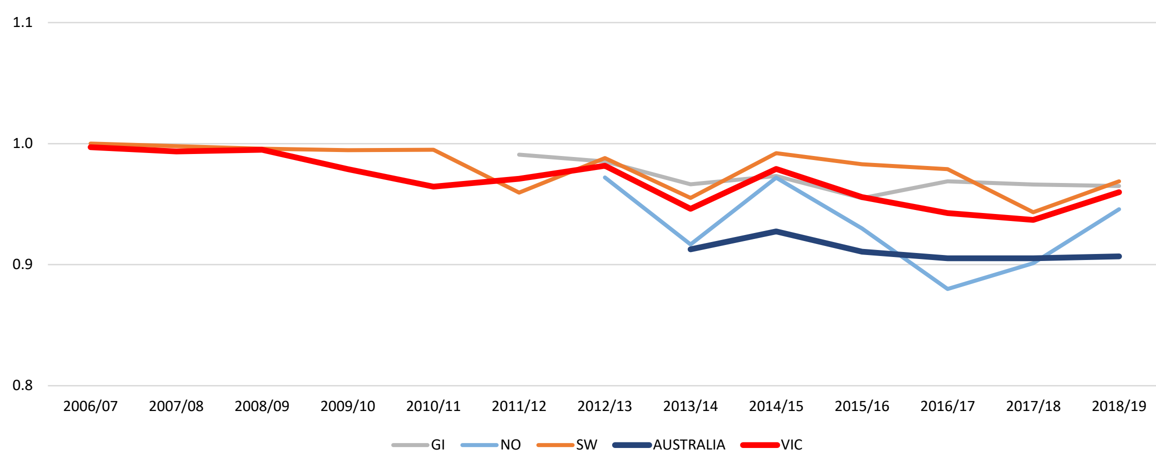


Figure 52: Output orientated technical efficiency index (OTEI)



3.2.3 Tasmania

Tasmania appears to have had a slight increase in TFPI since 2013/14 (Figure 53). This appears to have come about mainly through an improvement in mix efficiency (Figure 56) and improvements in the environmental index (Figure 54). Scale has not contributed positively to TFPI (Figure 55).

Figure 53: TFPI: Lowe Index

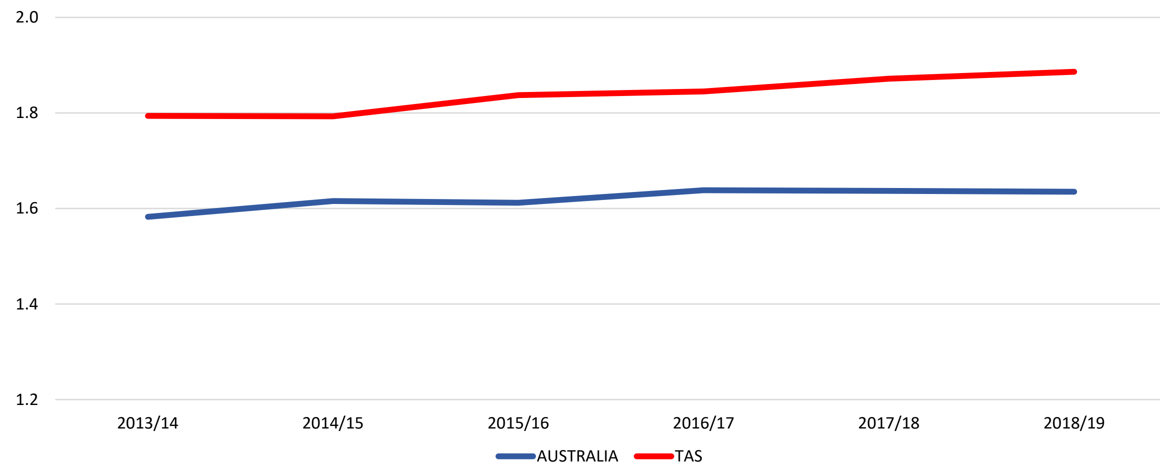


Figure 54: Environmental and technology index (ETI)

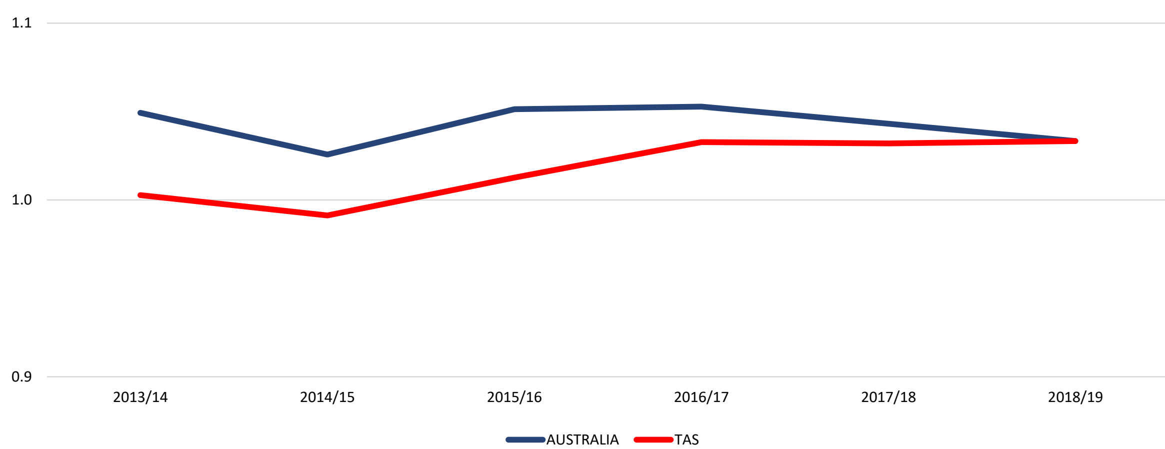


Figure 55: Output-oriented scale efficiency index (OSEI)

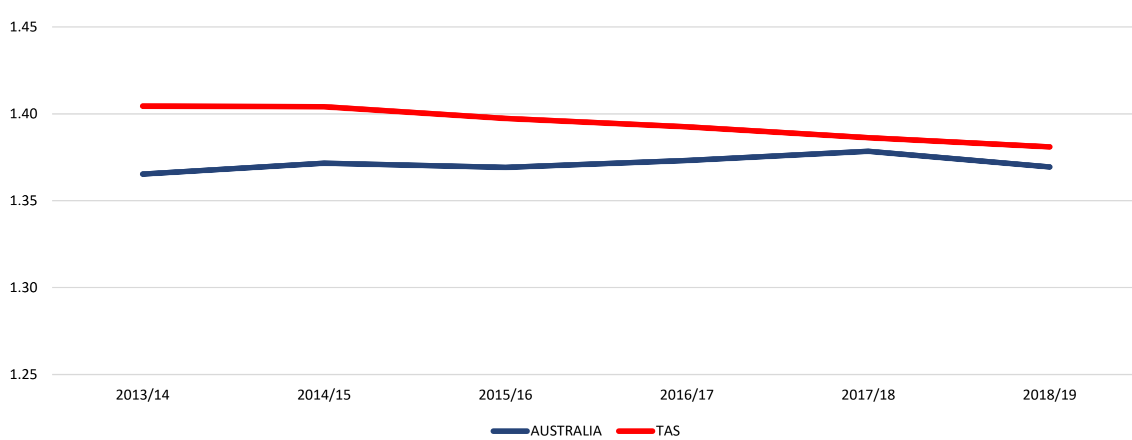


Figure 56: Residual mix efficiency index (RMEI)

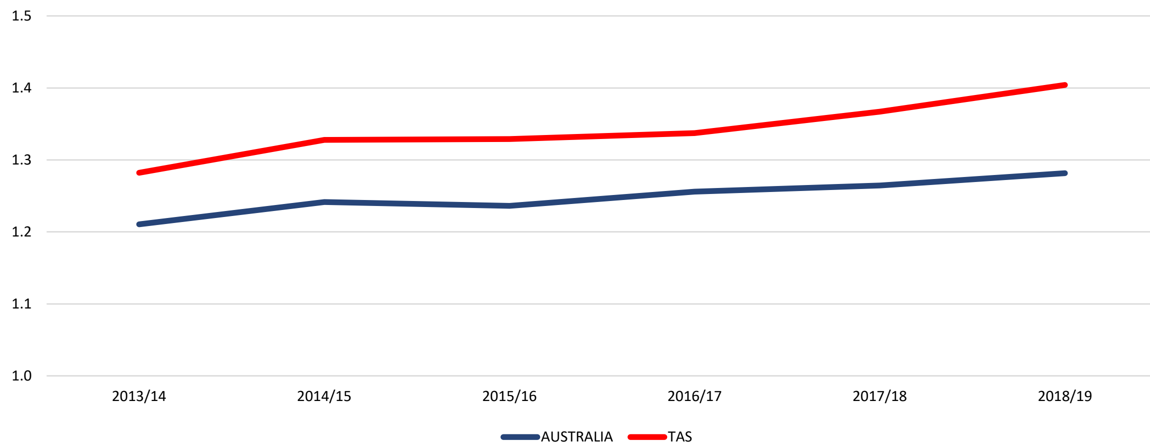
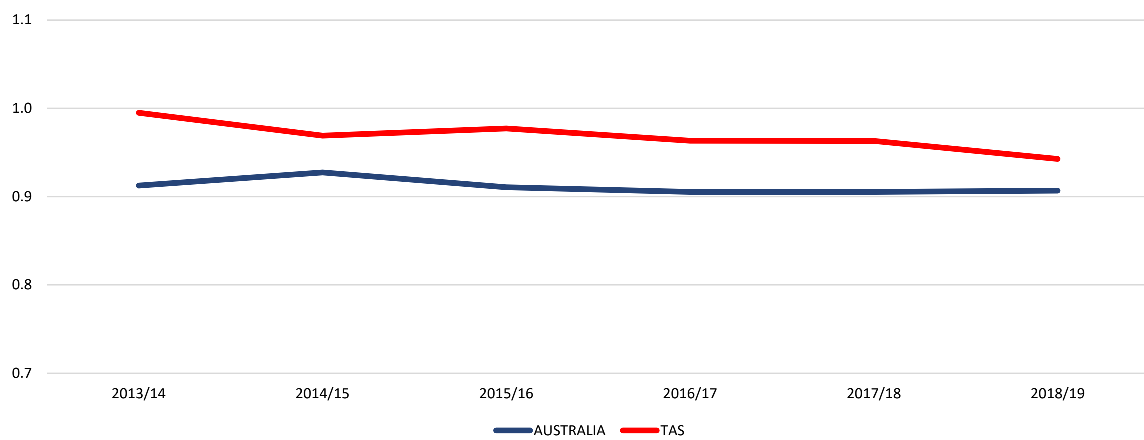


Figure 57: Output orientated technical efficiency index (OTEI)



3.2.4 New South Wales

Overall, for NSW TFPI appears to have been relatively flat since 2011/12. However, northern NSW appears to have had a slight upward trend in recent years (Figure 59), mainly due to a positive contribution from mix efficiency (Figure 61). The TFPI for southern NSW has been nearly flat, some downturns in the Environmental Index in recent years and in 2012/13 (associated with poor climatic conditions and low irrigation water availability) have been balanced somewhat by the Scale Efficiency Index (Figure 60).

Figure 58: Lowe Index (TFPI)

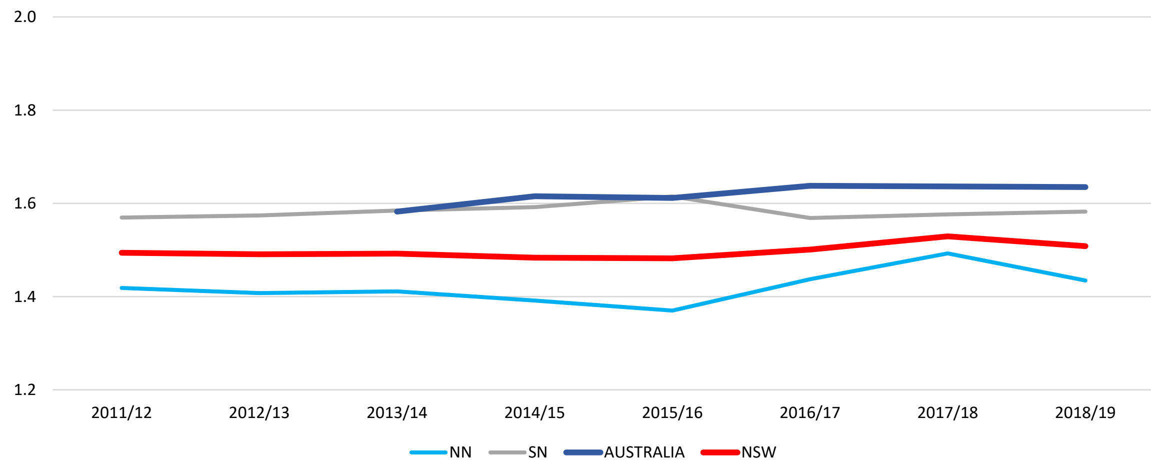


Figure 59: Environmental and technology index (ETI)

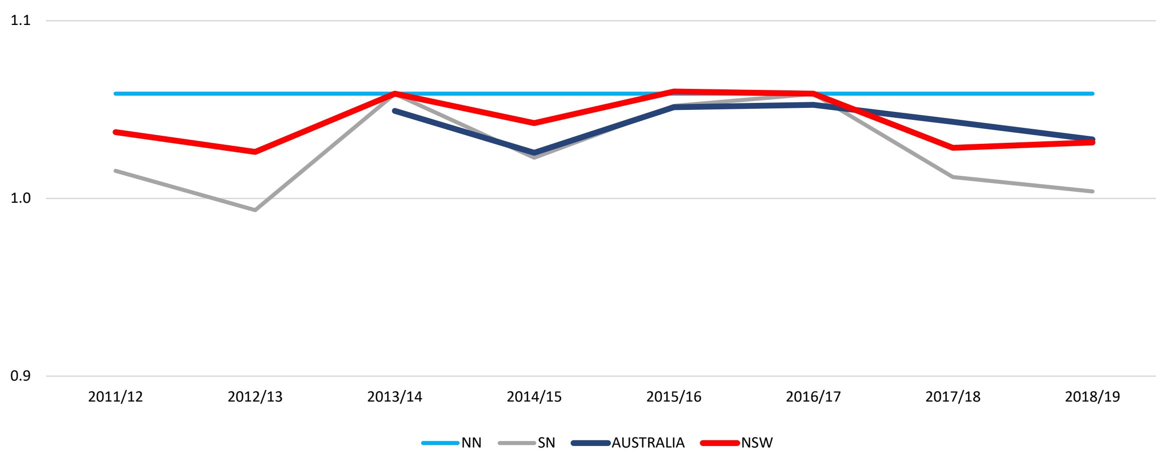


Figure 60: Output-orientated scale efficiency index (OSEI)

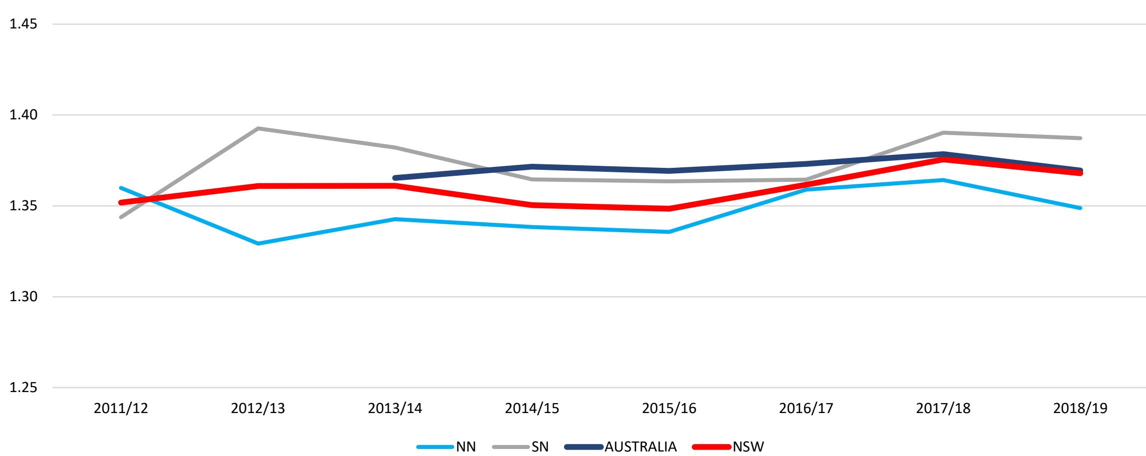


Figure 61: Residual mix efficiency index (RMEI)

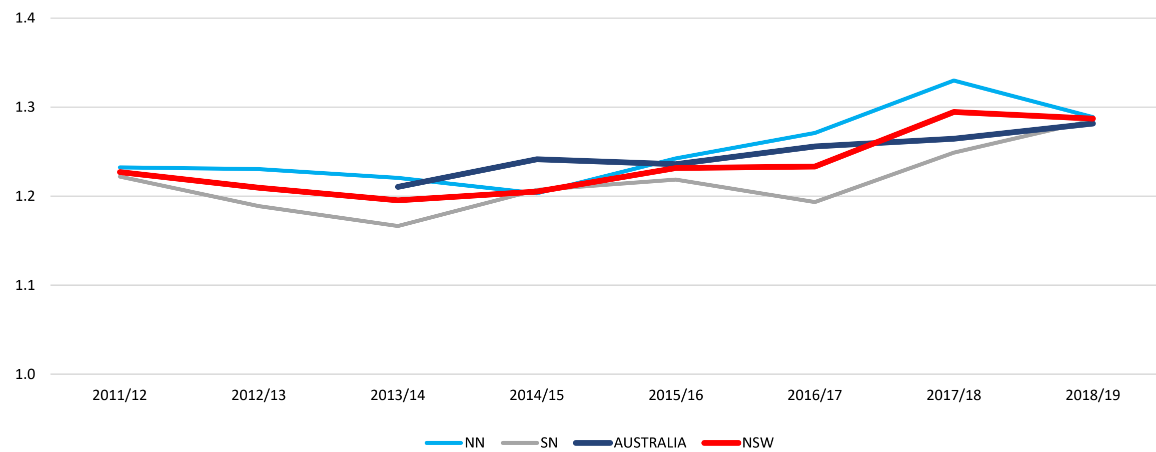
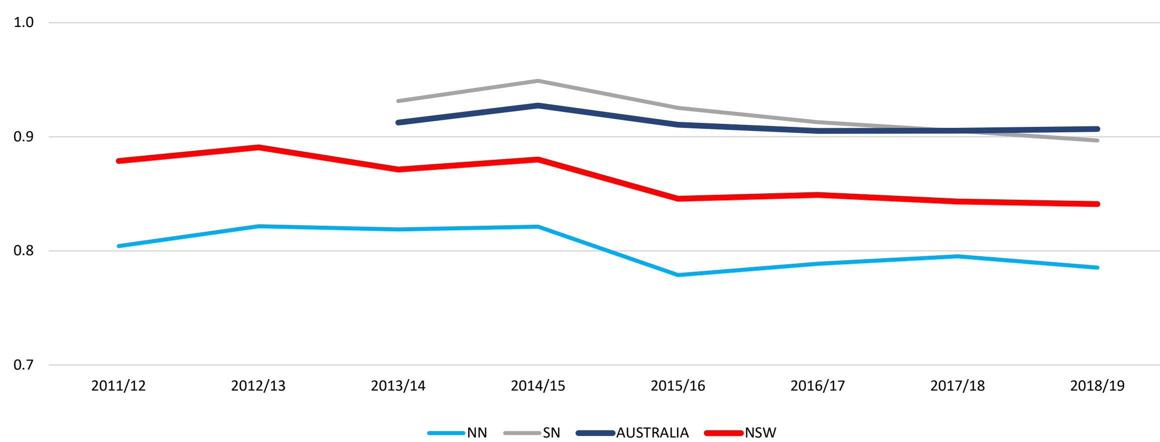


Figure 62: Output orientated technical efficiency index (OTEI)



3.2.5 Queensland

Overall, the TFPI for Queensland has not increased much since 2006/07. There has been some more marked variation between years in some of the sub-regions within the State but clear trends over the long study period are not clear. The Environmental Index rose in 2009/10 following some drought years but has stayed surprisingly flat since (Figure 64). The Scale Index has been fairly flat overall despite some variation between years (Figure 65). There appears to be a slight downward trend in the Technical Efficiency Index (Figure 67) except in the Darling Downs region.

Figure 63: Lowe Index (TFPI)

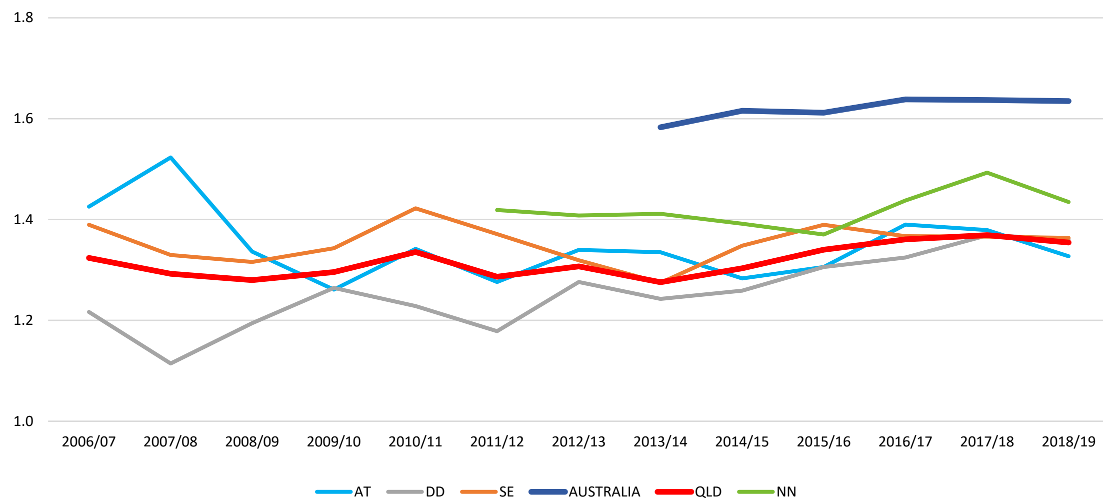


Figure 64: Environmental and technology index (ETI)

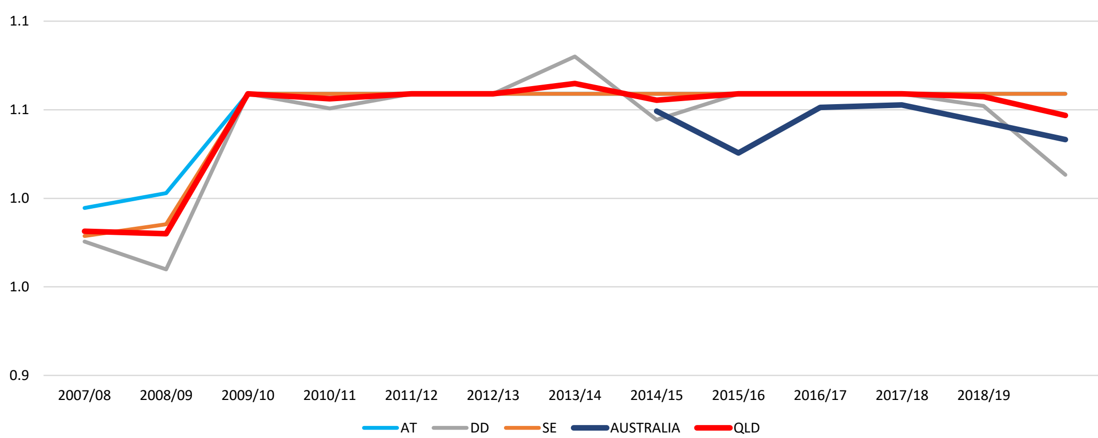


Figure 65: Output-orientated scale efficiency index (OSEI)

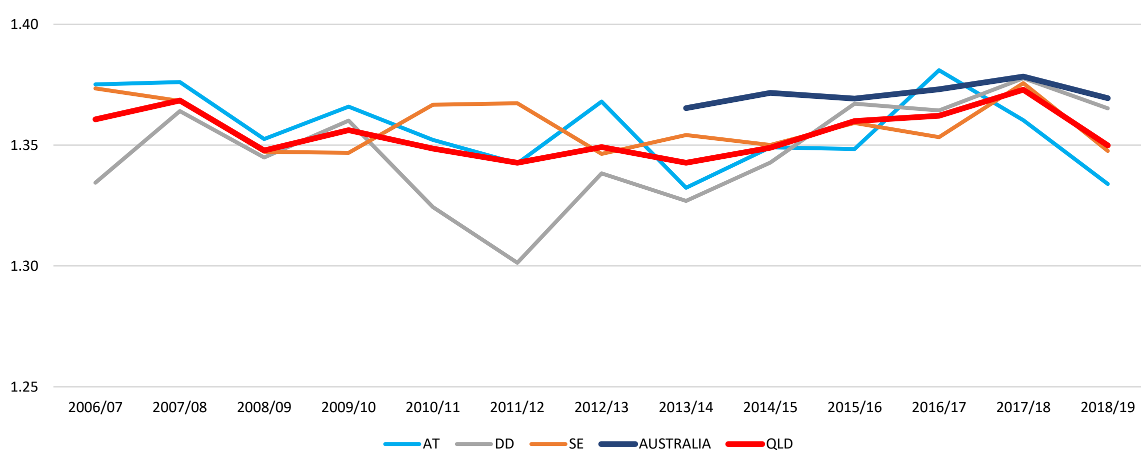


Figure 66: Residual mix efficiency index (RMEI)

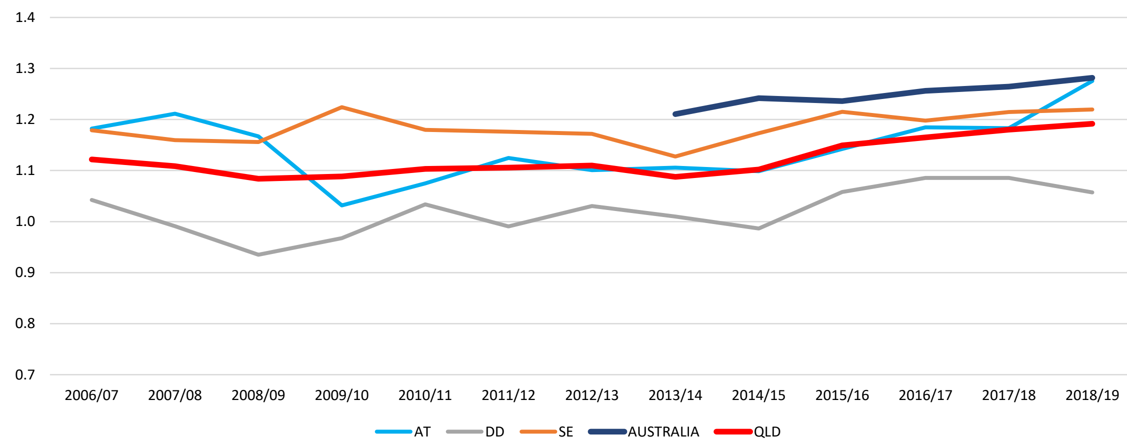
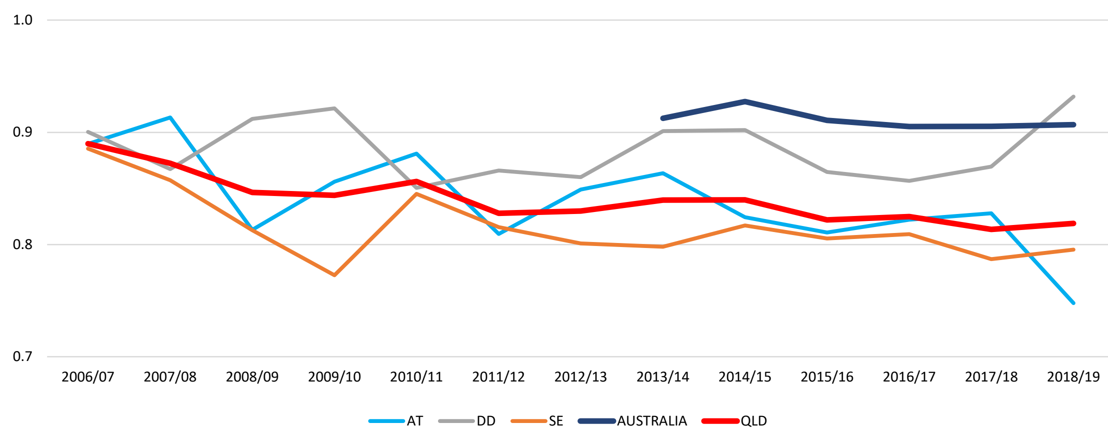


Figure 67: Output orientated technical efficiency index (OTEI)



3.2.6 South Australia

There is an upward trend in TFPI in SA (Figure 68) which is mainly due to improved mix efficiency (Figure 71). However, these results need to be treated with caution as previously mentioned.

Figure 68: Lowe Index (TFPI)

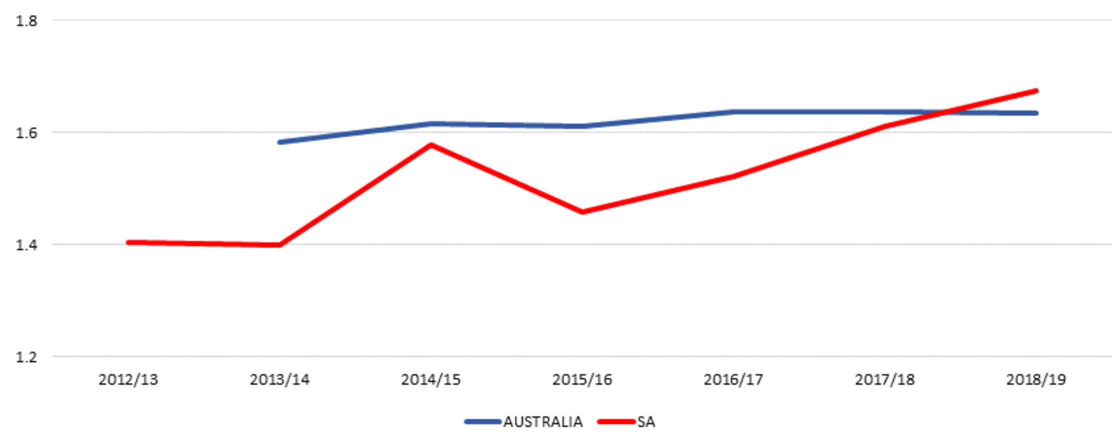


Figure 69: Environmental and technology index (ETI)

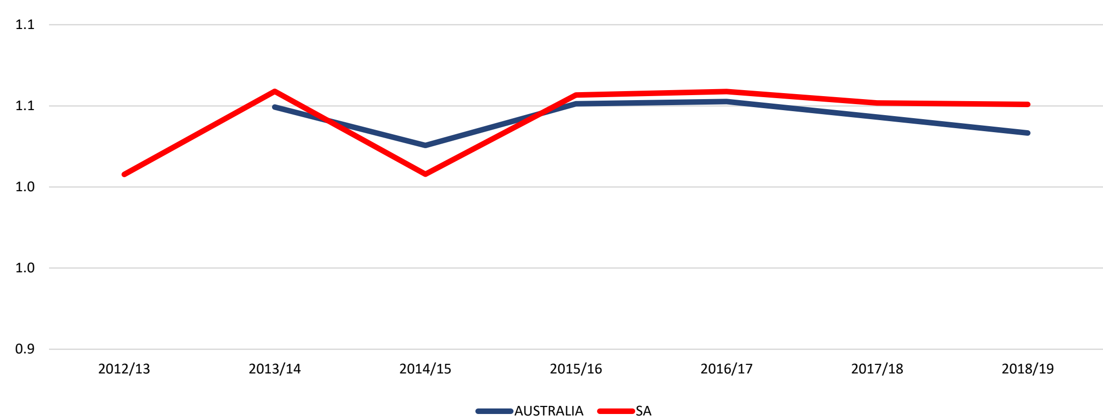


Figure 70: Output-orientated scale efficiency index (OSEI)

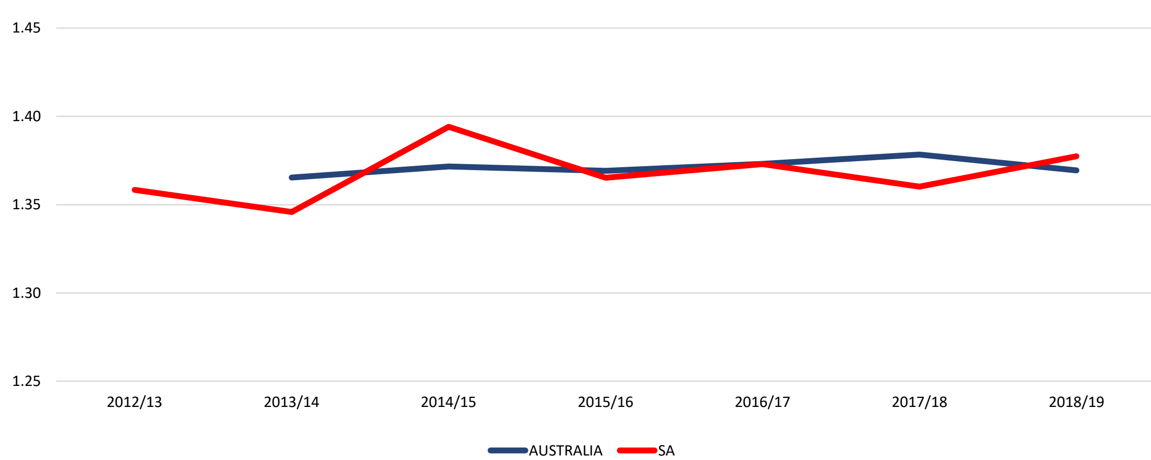


Figure 71: Residual mix efficiency index (RMEI)

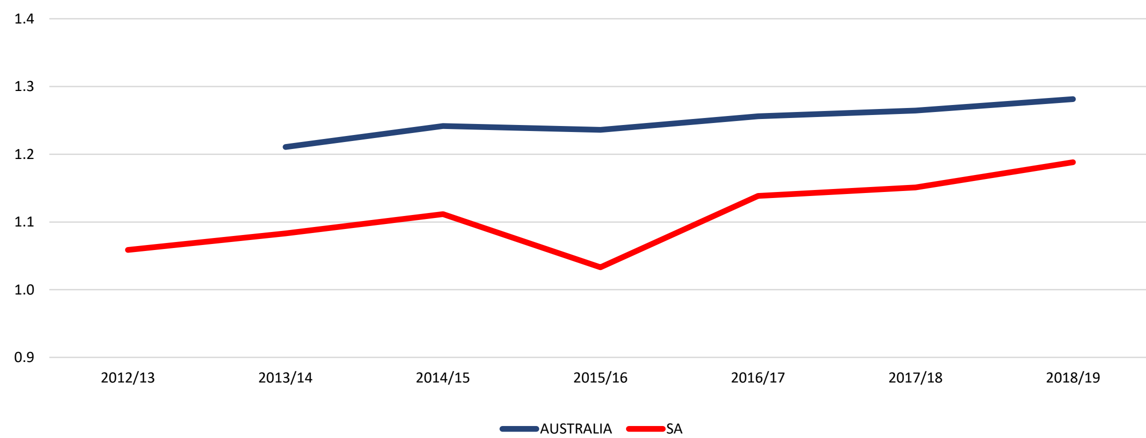
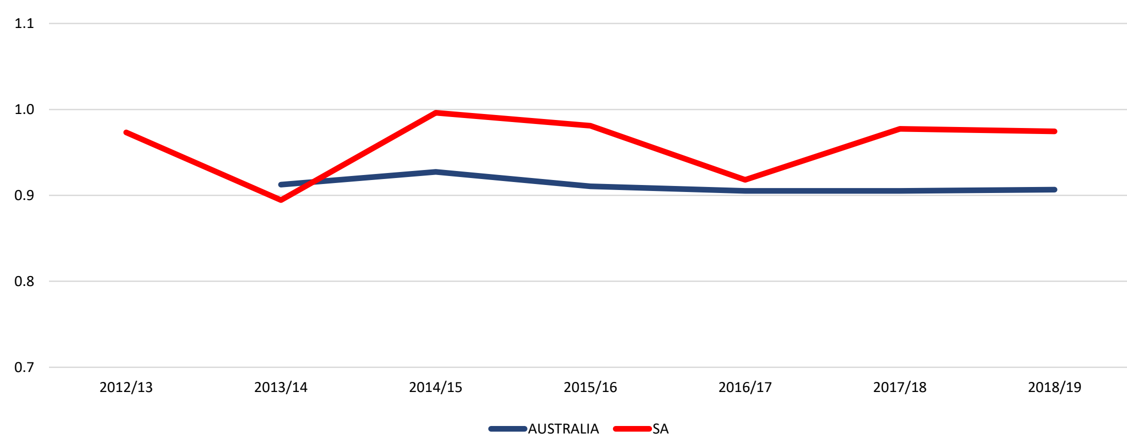


Figure 72: Output orientated technical efficiency index (OTEI)



3.2.7 Western Australia

For WA TFPI has been almost flat over the relatively short study period from 2013/14 (Figure 73). The breakdown of TFPI into the various components did not reveal any trends of note.

Figure 73: Lowe Index (TFPI)

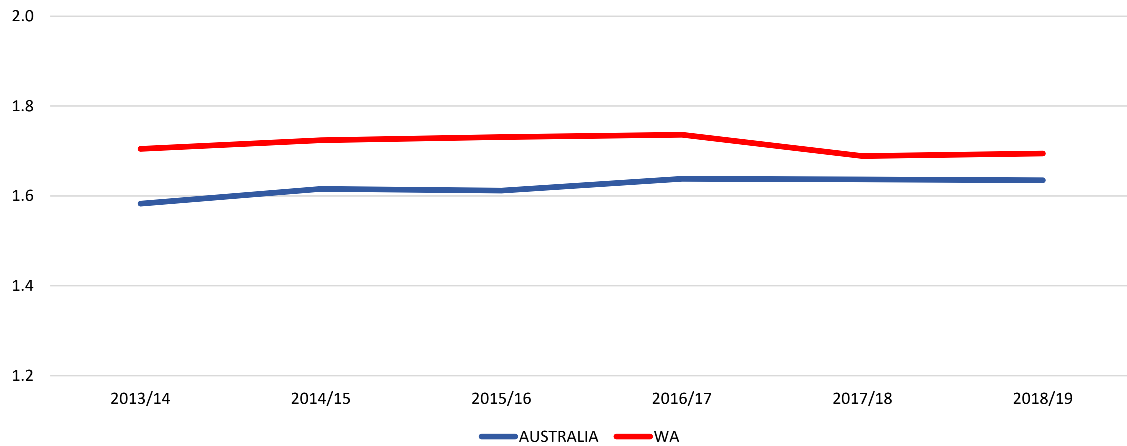


Figure 74: Environmental and technology index (ETI)

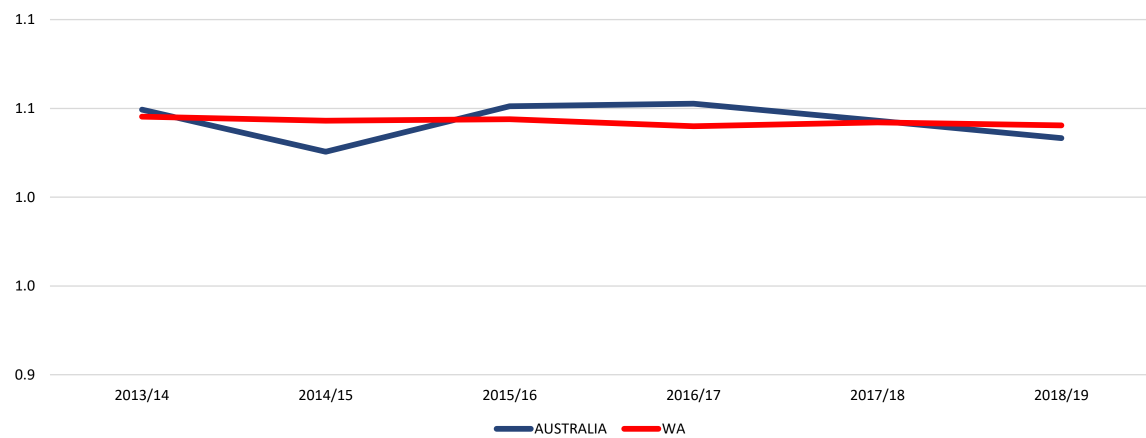


Figure 75: Output-orientated scale efficiency index (OSEI)

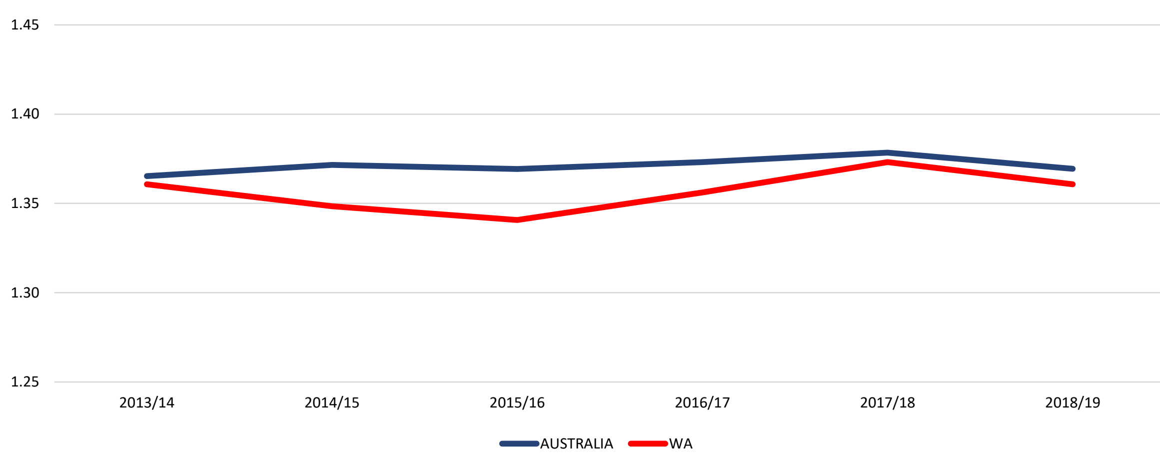


Figure 76: Residual mix efficiency index (RMEI)

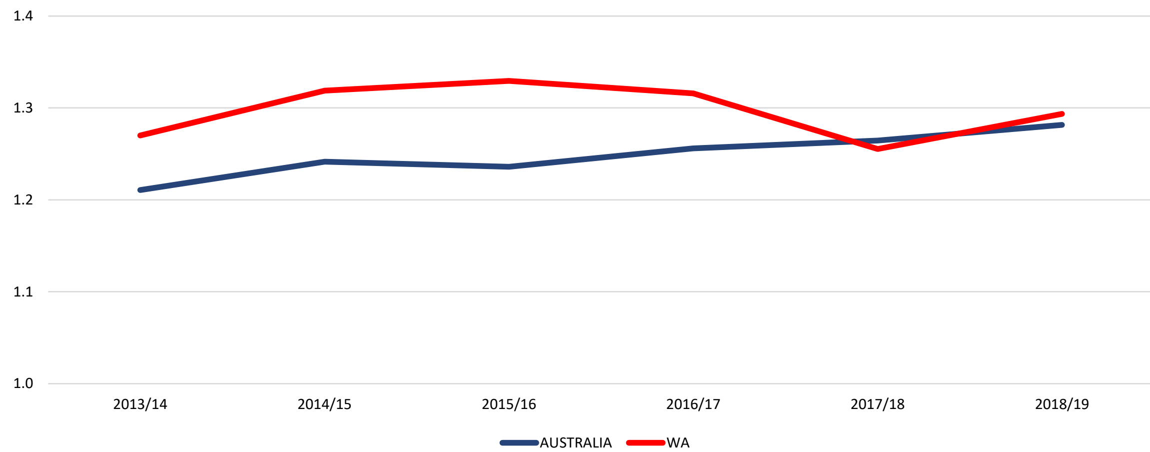
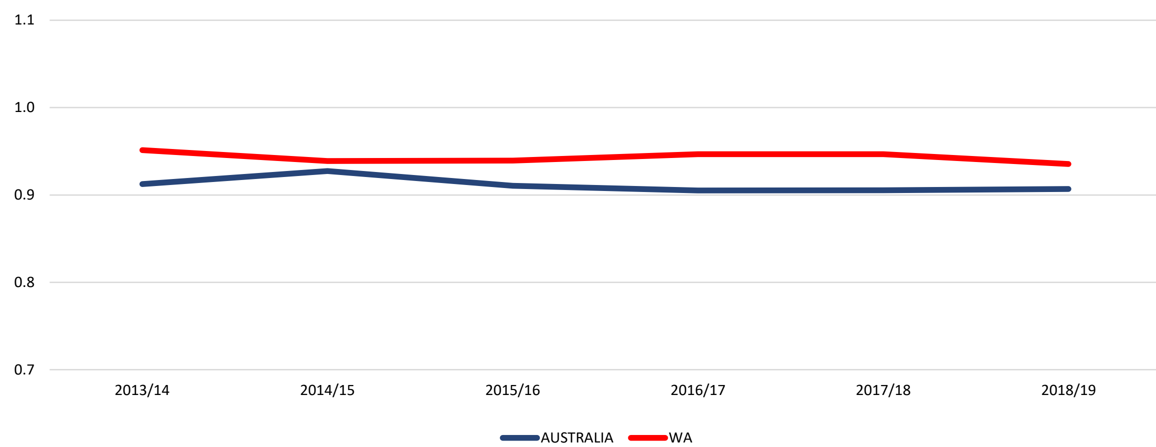


Figure 77: Output orientated technical efficiency index (OTEI)



3.3 Terms of trade estimates

There is little published information on the terms of trade of the dairy industry. The construction of productivity indexes in this study has enabled the construction of a terms of trade index for the DFMP and QDAS farms.

The terms of trade represent the relationship between output prices received and input prices paid. Over the long run, other things equal, a positive terms of trade contributes to profitability and can help offset the effects of weakening productivity.

The terms of trade position of the Australian dairy industry in 2018/19 was much the same as it was at 2013/14 (the start of the Australian data series) –Figure 78. The data series for Australia is truncated in time length as this is the only time period for which all states have recorded data. Terms of trade for Queensland and Victoria (which have longer time series than other states) also have a similar level of terms of trade at the start and end of the time series, albeit with some volatility in between. The increase in 2006/07 for Victoria was at the time of the end of the drought and also corresponded with a significant rise in commodity prices.

Profitability change can be decomposed into the product of the total factor productivity (TFP) index and a terms of trade index (which is an index measuring changes in relative output and input prices). The link between profitability (as expressed as revenue/costs as per O'Donnell 2010), terms of trade and TFP for Victoria and Queensland is shown in Figure 79 and Figure 80. In Victoria and Queensland, productivity growth has been weak over the 13-year period and profitability changes have been largely driven by changes in terms of trade.

Figure 78: Terms of trade across Australia (2018/19 = 1 for all states)

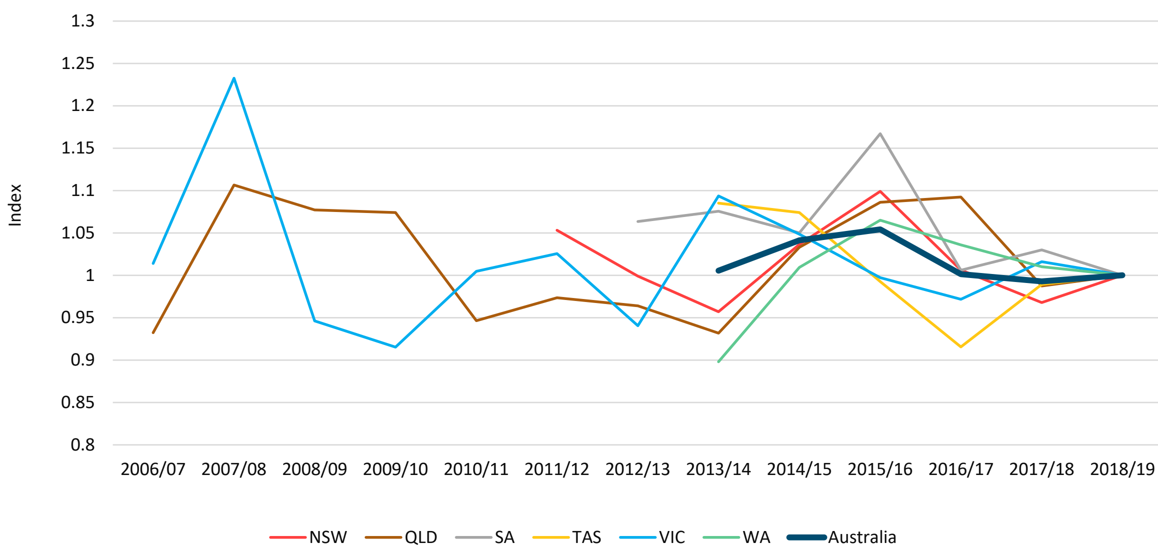
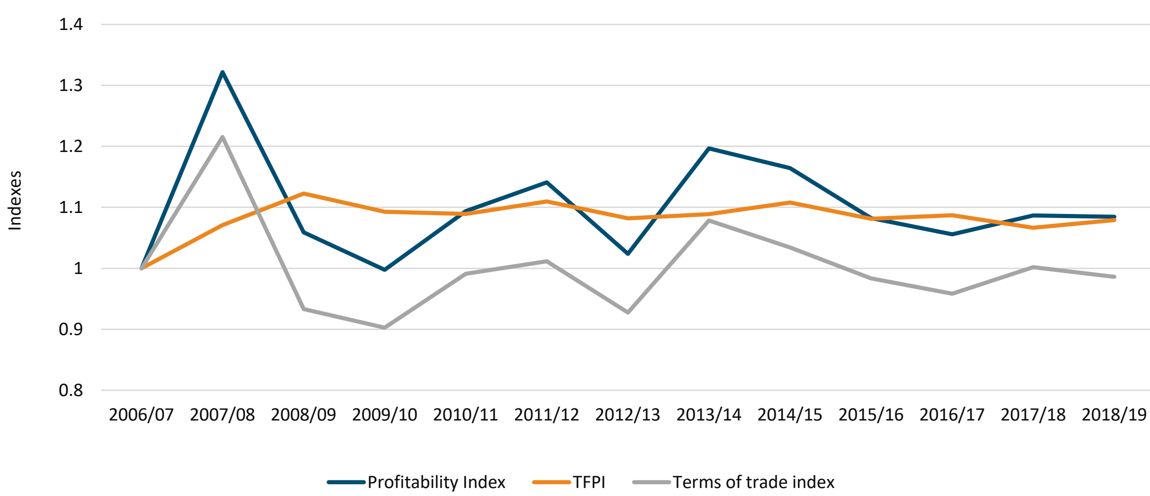
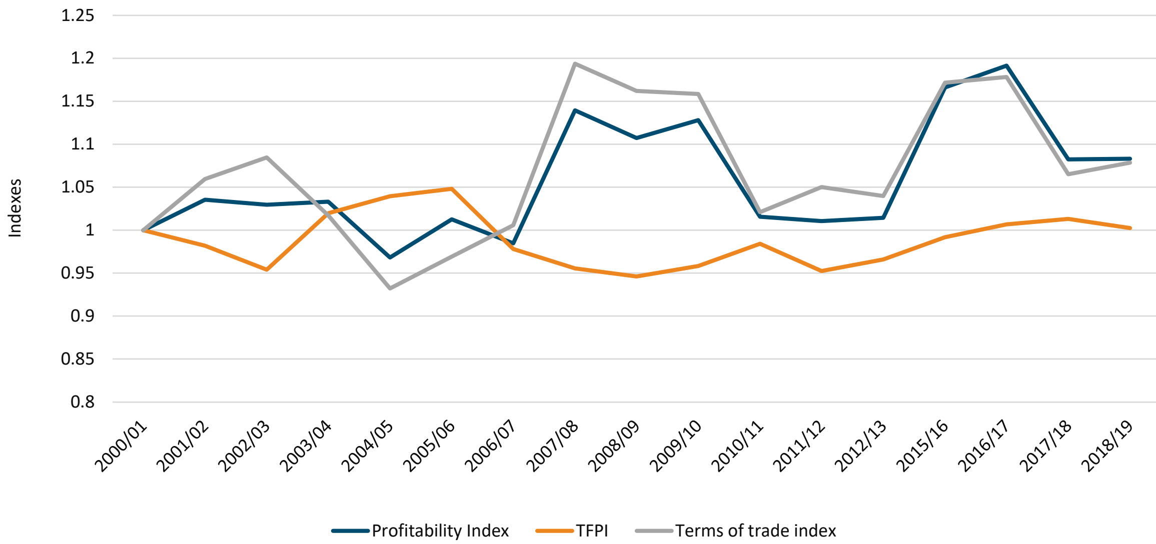


Figure 79: Victoria: Profitability, terms of trade and TFP indexes (Indexes = 1 for 2006/07)



Note: Profitability index = TPFI x Terms of Trade Index

Figure 80: Queensland: Profitability, terms of trade and TFP indexes (Indexes = 1 for 2006/07)



Note: Profitability index = TPFI x Terms of Trade Index

3.4 Conclusion

Annual dairy farm monitor data was converted to an annual timeseries database of individual farm physical inputs and physical outputs. A set of proper productivity indexes were calculated from this data to estimate the annual level and change in productivity at different industry spatial groupings. Two key productivity techniques were applied – data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Each approach has advantages and disadvantages but taken together can provide robust overview of productivity performance.

Overall dairy industry productivity has been relatively weak. Overall relative levels of productivity across regions reflected general levels of comparative advantage in farms between regions. While farmers are highly technical efficient there has been very limited growth the in the over level of technical efficiency. Scale of the farms had little impact on farm productivity performance.

The impacts of weak productivity can be offset by terms of trade. However the analysis found that this was not always the experience of the dairy industry. Sometimes weak productivity also corresponded with periods of weak terms of trade. Generally it was found that most of the dairy industry trends in profitability could be explained by shifts in the terms of trade rather changes productivity.

4. Economy wide analysis

While improving productivity is important to the growth of the dairy industry, the performance relative to other competitors for resources, such as land and water, is also important. The TERM Model was used to assess the industry and economy-wide impacts of R&D investments that lead to productivity improvements in dairy cattle production. A small increase in R&D investments may not be sufficient to counter adverse terms-of-trade movements faced by the sector. A larger increase may counter such movements with consequent national welfare gains, despite demand adversity. Productivity gains in dairy cattle production benefit domestic and overseas consumers. Productivity gains that more than offset terms-of-trade losses may raise national welfare, but not stop output declines in the total amount of milk produced by the Australian dairy industry.

4.1 Model specification and shocks

TERM is a dynamic computable general equilibrium model of the regional and national Australian economies. The model represents 216 sectors in 334 SA3 regions in a bottom-up format. A detailed description of the models and shocks are provided in Appendix 1.

The dairy bodies align with TERM regions where:

- "WADairy" = Western Dairy
- "FleurPLimMur" = DairySA
- "WarrnamSWVic" = WestVic Dairy
- "LattbGippslnd" = Gipps Dairy
- "MurrayVic" and "MurrayNSW" = Murray Dairy

The remaining state aggregations are used to represent the remaining geographical distribution of the dairy industries. In DairyTas, the producers it represents are spread evenly across a number of Tasmanian regions. DairyNSW includes some concentration in the South Coast region, but is spread widely elsewhere. Subtropical Dairy's producers in Queensland and northern NSW are also widely dispersed.

The composition of the value of output by the industries that comprise the dairy industry is also set out in Appendix 1 according to total value ($million) and the percentage share of the total regional value added. Some regions have a higher total dollar value and higher share of industries associated with the dairy sector. Warrnambool South East, for example, has the highest total values and highest total shares of any region.

Our conversations with key dairy research investors including Dairy Australia, Agriculture Victoria and the Gardner Foundation indicates that total annual national public investment in dairy RD&E is generally in the order of $55-60 million annually. The total range of investment could be within the bound of $50-70 million annually depending on how investments are defined as RD&E and those which are attributed to dairy research. Public funding for R&D is sourced from an industry levy, with top-up funds from the Commonwealth. In 2020, for example, the levy raised $31.6 million. The Commonwealth government contributed $21.8 million with addition state government funding. R&D expenditure for the year totalled about $60 million. We note a concern among some international agricultural economists such as Professors Julian Alston and Phil Pardey is that insufficient R&D is being devoted to agriculture globally. They suggest that as a result farm productivity growth has slowed over time, after accounting for seasonal variation and climate change. And given that there are historically, high returns to R&D there may be substantial underinvestment in R&D.

We use TERM to simulate shifts in productivity, terms of trade and the levels of RD&E expenditure and assess their combined impacts on regional economies. Six scenarios (see **Error! Reference source not found.**) were run as model shocks that alter the mix of RDE/productivity assumptions and the terms of trade assumptions — where there are three RDE assumptions (a high medium and low RDE spend with corresponding impact on productivity) and mix of rising, steady and falling terms of trade assumptions. They represent a mix of optimistic and pessimistic scenarios where:

- productivity and terms of trade both deteriorate at the same time
- productivity and terms of trade movements offset each other and
- productivity and terms of trade move positively together.

Table 2: RD&E and productivity modelling assumptions

Scenario	RDE and productivity assumptions	Terms of trade assumptions
1.R&D and productivity gains do not offset industry terms-of-trade losses	• $5m incremental R&D increase per annum 2020 to 2025, $10m productivity gain 2022 to 2027	• International demand falls 0.5% per annum between 2020 and 2027, and domestic demand by 0.25% per annum in this time
2. R&D and productivity gains, no terms-of-trade losses	• $5m incremental R&D increase per annum 2020 to 2025, $10m productivity gain 2022 to 2027	• No change in demand conditions

Scenario	RDE and productivity assumptions	Terms of trade assumptions
3. R&D and productivity gains, increased demand for cheese and yoghurt	• $5m incremental R&D increase per annum 2020 to 2025, $10m productivity gain 2022 to 2027	• Demand is unchanged except for cheese and yoghurt products, in which there is a gradual increase in domestic and international demand between 2020 and 2027
4. Larger R&D investments and productivity gains large enough to offset industry terms-of-trade losses	• $8m incremental R&D increase per annum 2020 to 2025, $16m productivity gain 2022 to 2027	• International demand falls 0.5% per annum between 2020 and 2027, and domestic demand by 0.25% per annum in this time
5. Larger R&D investments and productivity gains without industry terms-of-trade losses	• $5m incremental R&D *decrease* per annum 2020 to 2025, $10m productivity *loss* 2022 to 2027	• No change in demand conditions
6. R&D reductions, productivity losses and industry terms-of-trade losses	• $5m incremental R&D *decrease* per annum 2020 to 2025, $10m productivity *loss* 2022 to 2027	• International demand falls 0.5% per annum between 2020 and 2027, and domestic demand by 0.25% per annum in this time

4.2 Regional impacts

The regional impacts of each scenario are summarised in Appendix 2. Regional results are presented for the region Warrnambool and South West to illustrate the order of scale of the impacts as this region has the highest dependence of any regional economy on the dairy industry with a dairy industry share of the regional GDP of 7.8 per cent.

4.2.1 Scenario 1: R&D and productivity gains do not offset industry terms-of-trade losses

National impacts are small reflecting the dairy industry is a small proportion of the national economy. The net present value is a welfare loss of $170 million. At a 2.5% discount rate, this equates to an annuity loss of $4 million.

The declining terms-of-trade has the largest impact on Warrnambool and South West:

- weakening the local labour market — employment falls to around 0.1% or 50 jobs below base and real wages fall to around 0.25% below base by the end of the simulation period

- capital stocks decline relative to base — spending power for a given level of output declines as terms-of-trade decline resulting in the region's aggregate household consumption declining by a larger percentage than real GDP

4.2.2 Scenario 2: R&D and productivity gains, no terms-of-trade losses

National welfare increases reflecting the productivity gains with no offsetting terms-of-trade declines. The net present value of the welfare gain is $620 million, or $15 million as an annuity.

At the national level, employment rises above base for several years, peaking at 0.0019% or 200 jobs above base in 2027-28, before moving back to base as labour market adjustment occurs.

Without terms-of-trade declines, there is a small increase in output of dairy cattle and dairy products relative to base. However, given that dairy cattle productivity is about 2.4% above base by 2026-27, inputs into the sector decrease, since the percentage output expansion is smaller than the primary factor input percentage saving.

In Warrnambool and South West, there is a decrease in overall demands. This still translates to a weakening of the labour market relative to base though the impact is smaller than in scenario 1.

4.2.3 Scenario 3: R&D and productivity gains, increased demand for cheese and yoghurt

The national welfare gains rise to $1,490 million in net present value terms of an annuity of $37 million.

There are virtually no economic losses in Warrnambool and South West, but productivity gains do outweigh output gains, and as a result investment demands fall relative to base.

4.2.4 Scenario 4: Larger R&D investments and productivity gains large enough to offset industry terms-of-trade losses

The national welfare gain is $164 million in net present terms or $4 million as an annuity.

This is an important scenario from R&D policy perspective — increased R&D investments and consequent productivity gains are sufficient to ensure that terms-of-trade losses for dairy products do not result in welfare losses. Despite this there are still small losses at the regional level because the percentage increase in dairy output is substantially smaller than the percentage decrease in primary input requirements.

In Warrnambool and South West, the fall in employment relative to base is larger than in scenario 1. Employment falls to 0.11% or 60 jobs below base in 2027-28. Real consumption and real investment are also slightly worse at the regional level than in scenario 1.

4.2.5 Scenario 5: Larger R&D investments and productivity gains without industry terms-of-trade losses

The net present value of welfare is an increase of $950 million or an annuity of $24 million.

Repeating the demand assumptions of scenario 2 in scenario 5 with higher R&D and productivity gains, the outcome in Warrnambool and South West is slightly less favourable than in scenario 2.

4.2.6 Scenario 6: R&D reductions, productivity losses and industry terms-of-trade losses

This scenario combines the terms-of-trade setting of scenario 1 with R&D expenditures and productivity movements in the opposite direction

The national welfare loss is $1390 million, or an annuity of minus $35 million.

The regional impacts in Warrnambool and South West are slightly less negative than in scenario 1. This is because percentage declines in output are smaller than the increased primary factor demands in the dairy sector, the latter arising from deterioration in productivity. For example, labour inputs into dairy cattle production in the region are 1% above base in 2026-27.

This welfare outcome underlines the finding that industry specific productivity losses or gains are shared with society over time, implying that R&D funding to enhance productivity should also rely on some funding from outside the industry.

4.3 Conclusions

The importance of RDE and productivity to industry competitiveness can be demonstrated through the analysis of whole of the economy and industry economic modelling. The TERM model enables complex dynamics between the dairy industry and regional economies and the national economy to be understood.

At a national level the productivity performance of the dairy industry has relatively minor impacts – this is because the industry is small share of the national economy. At regional scales these outcomes are more important where the industry is a more important share of those economies. This is the case in the major dairy regions in parts of Victoria and Tasmania.

In those economies the long term impact of productivity can have three important consequences. First better productivity performance boosts farm household income and manufacturing output. This improves regional economic outcomes. Second these gains can be reduced where rising productivity simultaneously weakens the farm services sector as less labour and few inputs are required. A third important consideration is the net effect of benefits to the region from improved productivity against the loss of income from the region in the form of RDE expenditure. This is particularly important when the performance of productivity does not offset losses from a weak terms of trade. In those circumstances regional economies can be worse off but there is insufficient incentive to farmers to invest more in RDE address this problem. This may create a case for additional government investment in dairy RDE.

Appendix 1. Construction of inputs, outputs and environment variables for modelling

This section describes the data sources and calculation of the quantities and prices the output, input and environment variables used in the DEA and stochastic frontier modelling in this report.

Table 3: Outputs - quantities and prices

Output quantity/Price	Output type	Used in the following analysis	Source and calculation
Output quantity	Milk Sales - kilograms of milk solids	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Sourced from DFMP and QDAS data.
Output quantity	Livestock sales (head)	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Sourced from DFMP data for Victoria. • Remaining regions calculated using livestock cash flows from DFMP data divided by livestock prices for Victoria (also sourced from DFMP). ABARES livestock price index (from ABARES agricultural commodities publication) used for early years of the data set.
Output price	Milk price - $/kg	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Calculated as milk income divided by production (kg). Both data sourced from DFMP and QDAS.
Output price	Livestock - $/head	• Data Envelopment Analysis • Stochastic Frontier Analysis	• A livestock price series was developed using DFMP data for Victoria with ABARES livestock price index (from ABARES agricultural commodities publication) used for early years of the data set.

Table 4: Inputs - quantities and prices

Output quantity/Price	Output type	Used in the following analysis	Source and calculation
Input quantity	Herd health and replacement	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Herd health and replacement quantity data was estimated using DFMP and QDAS cost data which was then divided by a nominal index using Australian Bureau Statistics data.
Input quantity	Capital	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Capital quantity data was estimated using DFMP and QDAS data cost data which was then divided by a nominal index using Australian Bureau Statistics data.
Input quantity	Land	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Land quantity data (hectares per usable farm area) was sourced from DFMP and QDAS data.
Input quantity	Labour	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Labour quantity data (labour per farm) was sourced from DFMP and QDAS data. Labour includes owner and employed labour.
Input quantity	Metabolisable energy (ME) (Grain/concentrates/fodder/agistment)	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Metabolisable energy (ME) quantity data was sourced from DFMP and QDAS data. In some cases, ME was estimated based on grain/concentrates and other costs (sourced from DFMP and QDAS) based on an estimated cost per ME.
Input quantity	Fuel and oil (litres)	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Fuel and oil quantity data was sourced from DFMP and QDAS data (with the addition of a fuel equivalent amount of shed power and hay and silage making)
Input quantity	Irrigation	• Data Envelopment Analysis • Stochastic	• Irrigation quantity data was sourced from DFMP and QDAS data. Estimates were made for missing data based on relationship between irrigation and rainfall.

Output quantity/Price	Output type	Used in the following analysis	Source and calculation
		Frontier Analysis	
Input quantity	Fertiliser	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Fertiliser quantity data was sourced from DFMP and QDAS data cost data which was then divided by an index of fertiliser prices (ABARES).
Input quantity	Overhead	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Overhead quantity data was sourced from DFMP and QDAS cost data which was then divided by a nominal price index using Australian Bureau Statistics data.
Input quantity	Repairs and Maintenance	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Repairs and maintenance quantity data was sourced from DFMP and QDAS cost data which was then divided by a nominal price index using Australian Bureau Statistics data.
Input quantity	Pasture improvement	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Pasture improvement quantity data was sourced from DFMP and QDAS cost data which was then divided by a nominal price index using Australian Bureau Statistics data.
Input quantity	Number of cows	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Number of cows was sourced from DFMP and QDAS data.
Input prices	Herd health and replacement	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Nominal price index using Australian Bureau Statistics data
Input prices	Capital	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Nominal price index using Australian Bureau Statistics data. Capital price was calculated as a rental of capital assets.

Output quantity/Price	Output type	Used in the following analysis	Source and calculation
Input prices	Land	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Land prices were estimated using land valued sourced from DFMP and QDAS data which was then divided by land hectares. • Land was then calculated as a rental of land assets.
Input prices	Labour	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Labour price was estimated using DFMP and QDAS cost data divided by labour full time equivalents.
Input prices	ME (Grain/concentrates/fodder/agistment)	• Data Envelopment Analysis • Stochastic Frontier Analysis	• ME price was estimated using DFMP and QDAS cost data divided by estimated quantity of ME.
Input prices	Fuel and oil (litres)	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Fuel and oil prices were estimated using DFMP and QDAS cost data divided by estimated fuel and oil quantities.
Input prices	Irrigation	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Irrigation price data was estimated using DFMP and QDAS cost data divided by irrigation quantities.
Input prices	Fertiliser	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Fuel and oil prices were estimated using DFMP and QDAS cost data divided by estimated fertiliser quantities.
Input prices	Overhead	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Nominal price index using Australian Bureau Statistics data

Output quantity/Price	Output type	Used in the following analysis	Source and calculation
Input prices	Repairs and Maintenance	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Nominal price index using Australian Bureau Statistics data
Input prices	Pasture improvement	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Nominal price index using Australian Bureau Statistics data
Input prices	Number of cows	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Cow prices were based on a heifer price index provided by Dairy Australia which was then converted to a rental of cow assets.

Table 5: Outputs - quantities and prices

Environment variable	Used in the following analysis	Source and calculation
Annual rainfall	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Annual rainfall data for each farm was estimated in the following way: – Respecting the confidentiality of the DFMP and QDAs data, DA and DFMP and QDAS staff provided GIS data for each farm that identified the farm was located within a generalised locale of approximately 5-10 kilometres or nearest local town. In this way farms were then linked to the nearest local weather station. – Using this data on farms and their nearest weather station, daily rainfall data estimated by Dr Craig Beverly of Agriculture Victoria.
Annual average Temperature Humidity Index (THI)	• Data Envelopment Analysis • Stochastic Frontier Analysis	• Annual average THI data for each farm was estimated in the same was as for rainfall. • The THI is based on diurnal data.

Environment variable	Used in the following analysis	Source and calculation
Coefficient of variation of rainfall (summer grouping)	• Stochastic Frontier Analysis	• The coefficient variation was estimated as the standard deviation of daily readings of rainfall for each farm divided by the mean value. The 'summer grouping' is defined differently for each region and includes the summer months plus some other months either side depending on the region. • The coefficient of variation data was estimated with the assistance of Dairy Australia.
Coefficient of variation of rainfall (winter grouping)	• Stochastic Frontier Analysis	• The coefficient variation was estimated as the standard deviation of daily readings of rainfall for each farm divided by the mean value. The 'winter grouping' is defined differently for each region and includes the winter months plus some other months either side depending on the region. • The coefficient of variation data was estimated with the assistance of Dairy Australia.
Coefficient of variation of THI (summer grouping)	• Stochastic Frontier Analysis	• The coefficient variation was estimated as the standard deviation of daily readings of THI for each farm divided by the mean value. The 'summer grouping' is defined differently for each region and includes the summer months plus some other months either side depending on the region. • The coefficient of variation data was estimated with the assistance of Dairy Australia.
Coefficient of variation of THI (winter)	• Stochastic Frontier Analysis	• The coefficient variation was estimated as the standard deviation of daily readings of THI for each farm divided by the mean value. The 'winter grouping' is defined differently for each region and includes the winter months plus some other months either side depending on the region. • The coefficient of variation data was estimated with the assistance of Dairy Australia.
State of Australia	• Stochastic Frontier Analysis	• This is defined as the state of Australia within which the farm resides. This data was sourced from the DFMP and QDAS data.
Dairy Australia region	• Stochastic Frontier Analysis	• This is defined as the region of Australia within which the farm resides. This data was sourced from the DFMP

Environment variable	Used in the following analysis	Source and calculation
		and QDAS data.

Appendix 2. TERM modelling

R&D investments to counter adverse terms-of-trade movements in the dairy sectors

Glyn Wittwer,

Centre of Policy Studies,

May 2021

Abstract

This study examines the industry and economy-wide impacts of R&D investments that lead to productivity improvements in dairy cattle production. The benefits at the industry and national levels depend on underlying domestic and international demand for dairy products. A small increase in R&D investments may not be sufficient to counter adverse terms-of-trade movements faced by the sector. A larger increase may counter such movements with consequent national welfare gains, despite demand adversity. Gains to the industry and society will magnify if there are favorable demand changes for dairy products over time.

A key issue is the distribution of gains between the dairy sector and rest of the economy. Productivity gains in dairy cattle production benefit domestic and overseas consumers. Productivity gains that more than offset terms-of-trade losses may raise national welfare, but not

stop output declines in the dairy sectors. Such an outcome underlines a justification for the rest of the economy to contribute to R&D expenditures concerning dairy cattle.

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Introduction

R&D expenditure in the dairy industry in Australia is around $55 million. Funding for R&D is sourced from an industry levy, with top-up funds from the Commonwealth. In 2020, for example, the levy raised $31.6 million. The Commonwealth government contributed $21.8 million with addition state government funding. R&D expenditure for the year totalled about $60 million.

A concern that insufficient R&D is being devoted to agriculture is global. A symptom of this in econometric analysis is that farm productivity growth has slowed over time, after accounting for seasonal variation and climate change. Given that historically, returns to R&D have been high, there may have been substantial underinvestment in R&D.

This study reports modelling of different scenarios in which R&D expenditure increases, and dairy cattle productivity with it.

Table 1: Summary of scenarios

R&D and productivity assumptions, dairy cattle	**Domestic and international demand, dairy products**
$5m incremental R&D increase 2020 to 2025, $10m productivity gain 2022 to 2027	1. Decline 2020 to 2027 2. No change 3. Cheese/yoghurt demand increases
$8m incremental R&D increase 2020 to 2025, $16m productivity gain 2022 to 2027	4. Decline 2020 to 2027 5. No change
$5m incremental R&D *decrease* 2020 to 2025, $10m productivity *loss* 2022 to 2027	6. Decline 2020 to 2027

Table 1 provides a summary of hypothetical scenarios. There are two sets of R&D/productivity scenarios. In the first, dairy industry R&D increases incrementally by $5m per annum from 2020 to 2025. Given that actual expenditure was $60 million in 2020, this depicts a gradual increase to $90 million by 2025. With a two year lag, that is, from 2022 to 2027, the dairy cattle sectors has incremental productivity increases equivalent to $10 million per annum.

The supply side assumptions are run in three different demand settings. In the first, there are ongoing declines in the terms-of-trade faced by dairy products.[9] (1) International demand falls 0.5% per annum between 2020 and 2027, and domestic demand by 0.25% per annum in this time. (2) In a second scenario, there are no changes in demand conditions. (3) Finally, demand is unchanged except for cheese and yoghurt products, in which there is a gradual increase in domestic and international demand between 2020 and 2027.

Each demand setting has a rationale. In (1), the assumption is that international trade sanctions continue, and potentially may worsen should China turn to dairy products for further import restrictions against Australian products. On the domestic front, the assumption is that per capita consumption of dairy products may decline, given dietary concerns.

The rationale for (2) is that the international trade environment may deteriorate no further for the dairy sector. In domestic consumption, the assumption is that there will be no further dietary adjustments by consumers to reduce dairy intake. Finally, the assumption of (3) is that for selected products, yoghurt and cheese, domestic and international demand will increase. The probiotic properties of yoghurt may increase demand. For cheese, there may be increasing interest by consumers in gourmet products.

Two of the scenarios are repeated with a higher level of additional R&D funding and consequent productivity gains. In scenarios 4 and 5, R&D expenditures increase by $8 million per annum from 2020 to 2025, reaching $108 million in 2025. From 2022 to 2027, the dairy cattle sectors have incremental productivity increases equivalent to $16 million per annum.

Finally, the demand setting assumed in scenario 1 is repeated, but this time with dairy cattle productivity losses and a decline in R&D funding, in scenario 6.

Scenario 1: R&D and productivity gains do not offset industry terms-of-trade losses

Table 2 shows the deviations in national output of dairy sectors from base for scenario 1. The table shows that an ongoing decline in the terms-of-trade faced by the primary and downstream

[9] "Terms-of-trade" has industry-specific and macroeconomic contexts. Industry specific terms-of-trade concern the price of industry outputs divided by the price of industry inputs. At the macroeconomic level, the terms-of-trade refer to the price of exports divided by the price of imports. In the scenarios in this study, examining output prices faced by dairy cattle and products in isolation, the industry-specific terms-of-trade deviations drive macroeconomic terms-of-trade deviations.

dairy sectors more than outweigh productivity gains. Industry decline is slower than it would be without productivity gains due to weakening demand.

Table 2: National outputs, dairy, scenario 1

% deviation from base

National outputs, dairy	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2031-32	2032-33
DairyCattle	-0.2	-0.4	-0.4	-0.5	-0.6	-0.8	-0.8	-0.9	-1.0	-1.1	-1.1	-1.1	-1.2	-1.2
MilkCream	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.9	-0.9	-1.0	-1.0	-1.1	-1.1	-1.2
IceCream	-0.2	-0.3	-0.4	-0.5	-0.6	-0.8	-0.9	-1.0	-1.0	-1.1	-1.1	-1.1	-1.1	-1.2
FlavWMilk	-0.2	-0.3	-0.4	-0.6	-0.7	-0.8	-0.9	-1.1	-1.1	-1.1	-1.2	-1.2	-1.2	-1.2
Yoghurt	-0.2	-0.3	-0.4	-0.6	-0.7	-0.8	-0.9	-1.0	-1.1	-1.1	-1.1	-1.2	-1.2	-1.2
Butter	-0.1	-0.3	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.8	-0.9	-0.9	-0.9	-1.0	-1.0
CheeseCurd	-0.2	-0.4	-0.4	-0.5	-0.6	-0.7	-0.8	-1.0	-1.0	-1.1	-1.2	-1.2	-1.3	-1.3
OthDairy	-0.2	-0.4	-0.4	-0.5	-0.6	-0.7	-0.7	-0.8	-0.9	-1.0	-1.1	-1.1	-1.2	-1.2

The region of the model in which dairy cattle production accounts for the largest share of economic activity is Warrnambool and South West. This share in the region is 7.8% of total GDP. The declining terms-of-trade is therefore most apparent in this region. A terms-of-trade decline weakens the local labour market. Employment falls to around 0.1% or 50 jobs below base. Real wages fall to around 0.25% below base by the end of the simulation period (figure 1).

Declining terms-of-trade for dairy sectors result in declining investment (figure 2), which implies that in Warrnambool and South West, capital stocks will also decline relative to base. The spending power for a given level of output declines as terms-of-trade decline. At the macro level, this results in the region’s aggregate household consumption (figure 2) declining by a larger percentage than real GDP (figure 3).

Figure 3 shows that the percentage change in real GDP is smaller than the percentage changes in either employment or capital for much of the simulation period. We base this on the link between output (GDP) and inputs (land, labour (L), capital (K), underlying technology (1/A)): GDP = f(K,L,land,1/A).

If there were no technological change, the deviation in real GDP would approximate the share-weighted sum of the factors. By 2027, productivity in dairy cattle is 2.4% above base and dairy cattle's share of real GDP has fallen to 6%. The technological improvement pushes real GDP up by around 0.14% (=2.4% x 0.06). Figure 3 shows that real GDP remains near base in the region despite falls in employment and capital.

Figure 1: Warrnambool and South West, labour market

% deviation from base

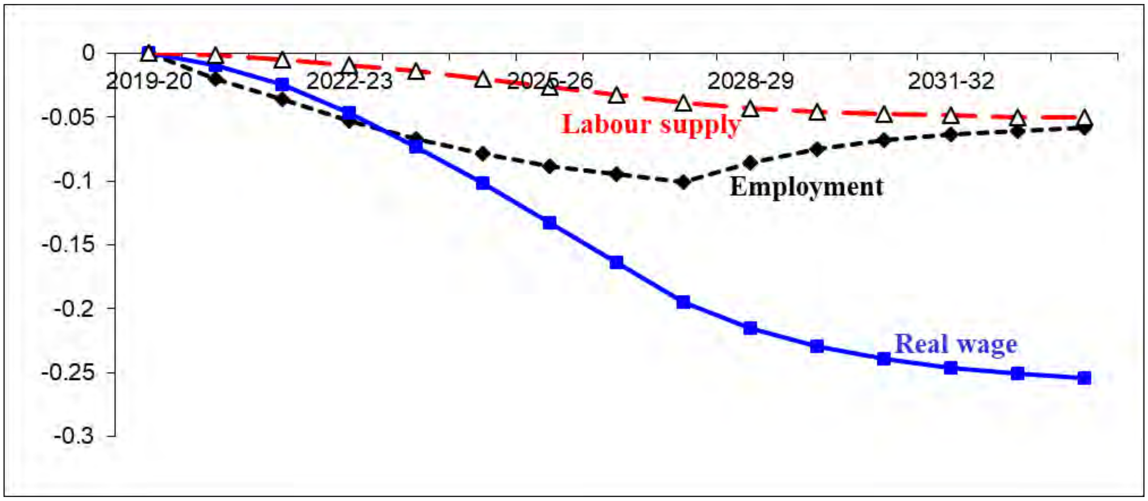


Figure 2: Warrnambool and South West, aggregate consumption and investment

% deviation from base

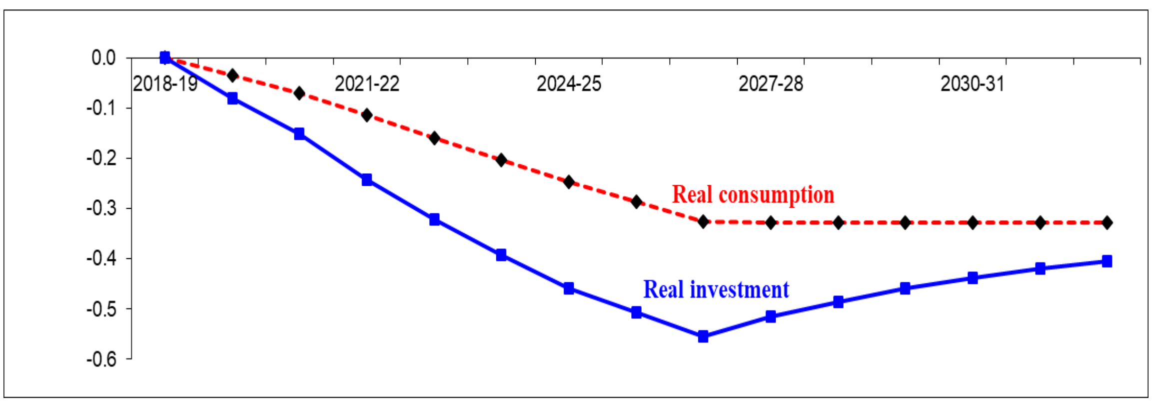


Figure 3: Warrnambool and South West, income side GDP

% deviation from base

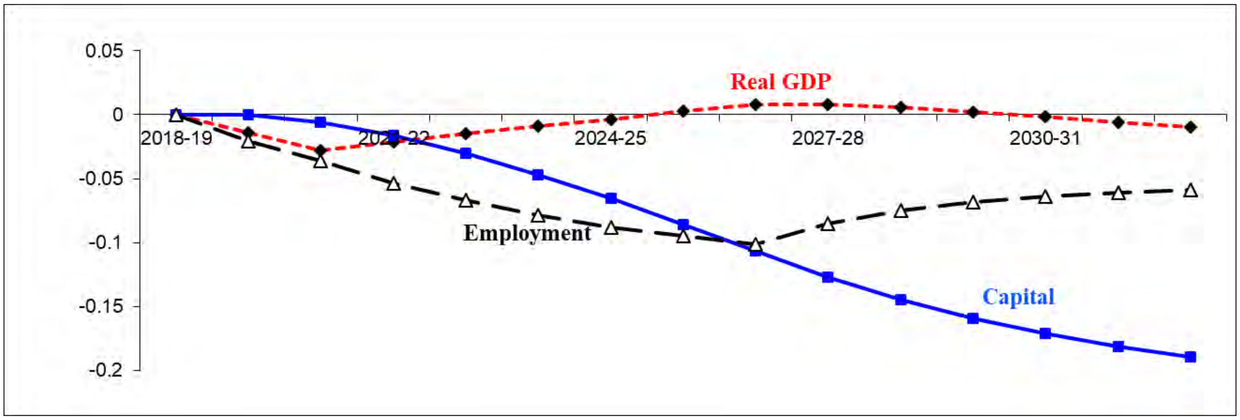
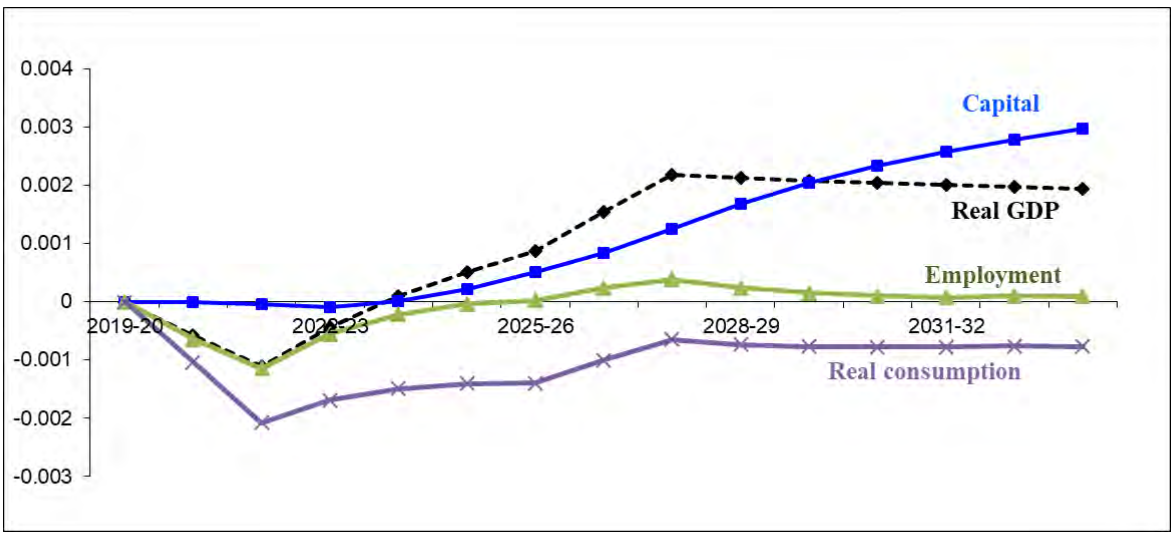


Figure 4: National, income side GDP and aggregate consumption

% deviation from base



The national impacts are shown in figure 4. The percentages shown are small, reflecting the relatively small activity shares of dairy cattle (0.14% of GDP) and dairy products (0.8% of exports). The gap between real consumption and real GDP reflects the movement in the terms of trade. By 2027-28, the gap is 0.003%. Dairy product export prices have fallen to around 0.5% below base by then. Exports account for around one quarter of GDP. The contribution to the gap between real consumption and real GDP from dairy produce is around 0.001% (=0.5% x 0.8% x ¼). The remaining two thirds of the gap (i.e., 0.003%) arises from the movement of factors of production to non-dairy export sectors. Since export demand curves are downward sloping, increased supplies in other sectors push down export prices a little, thereby diminishing macro terms-of-trade a little further.

From the national perspective shown in figure 4, we observe the decrease in real household consumption relative to base. The deviation in welfare (*dWELF*) at the national level is:

$$dWELF = \sum_d \sum_t \frac{dCON(d,t)+dGOV(d,t)}{(1+r)^t} - \frac{dNFL(z)}{(1+r)^z} + \frac{dKstock(z)}{(1+r)^z} \qquad (1)$$

where *dCON* and *dGOV* are the deviations in real household consumption and government spending in region *d* and year *t*; *dNFL* is the deviation in real net foreign liabilities in the final year (*z*) of the simulation; *dKstock* is the deviation in value of capital stock in the final year (*z*) of the simulation; and *r* is the discount rate.

Aggregate consumption is negative but there is a slight decrease in national debt and a slight increase in capital stocks. The net present value is a welfare loss of $170 million. At a 2.5% discount rate, this equates to an annuity loss of $4 million.

Scenario 2: R&D and productivity gains, no terms-of-trade losses

Without terms-of-trade declines, there is a small increase in output of dairy cattle and dairy products relative to base. However, given that dairy cattle productivity is about 2.4% above base by 2026-27, inputs into the sector decrease, since the percentage output expansion is smaller than the primary factor input percentage saving.

Table 3: National outputs, dairy, scenario 2

% deviation from base

National outputs, dairy	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2031-32	2032-33
DairyCattle	0.0	-0.1	0.0	0.1	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3
MilkCream	0.0	-0.1	0.0	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3
IceCream	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2
FlavWMilk	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Yoghurt	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Butter	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.2
CheeseCurd	0.0	-0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.6	0.5	0.5	0.5	0.4	0.4
OthDairy	0.0	-0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.7	0.6	0.6	0.6	0.5	0.5

Consequently, in Warrnambool and South West, there is a decrease in overall demands. This still translates to a weakening of the labour market relative to base (figure 5), though the impact is smaller than in scenario 1. To keep a perspective in Warrnambool and South West, employment bottoms out only 0.02% or 10 full-time workers below base. Real GDP in the region rises above base, but both capital and employment remain slightly below base over time (figure 7).

Figure 5: Warrnambool and South West, labour market, scenario 2

% deviation from base

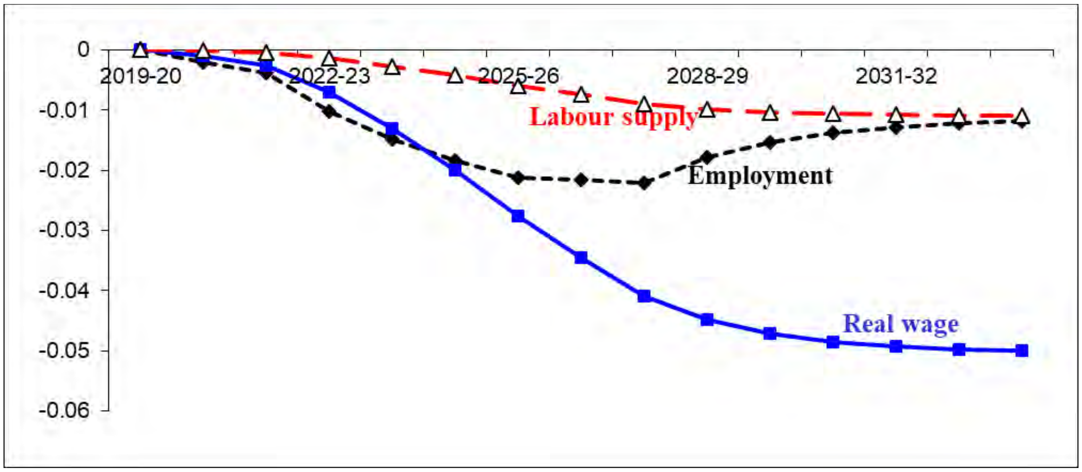


Figure 6: Warrnambool and South West, aggregate consumption and investment, scenario 2

% deviation from base

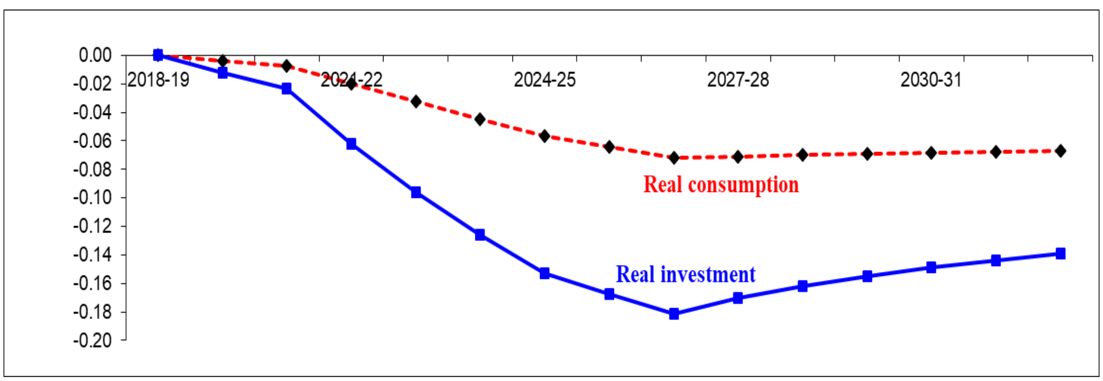


Figure 7: Warrnambool and South West, income side GDP, scenario 2

% deviation from base

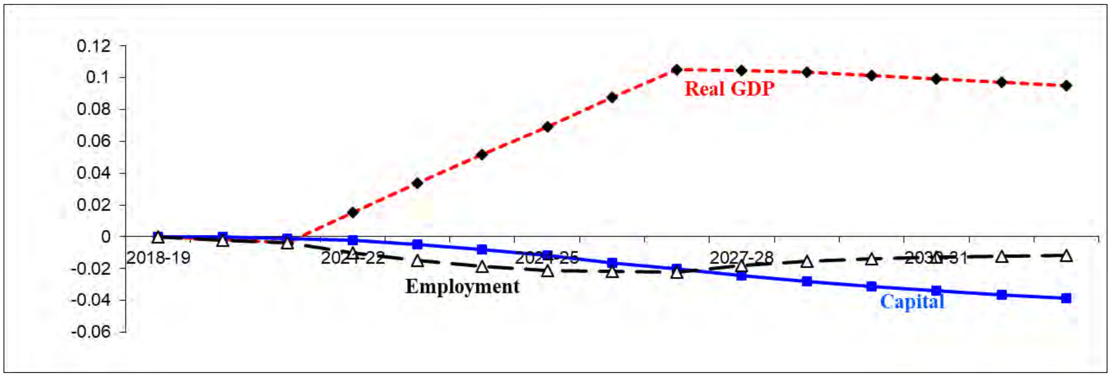
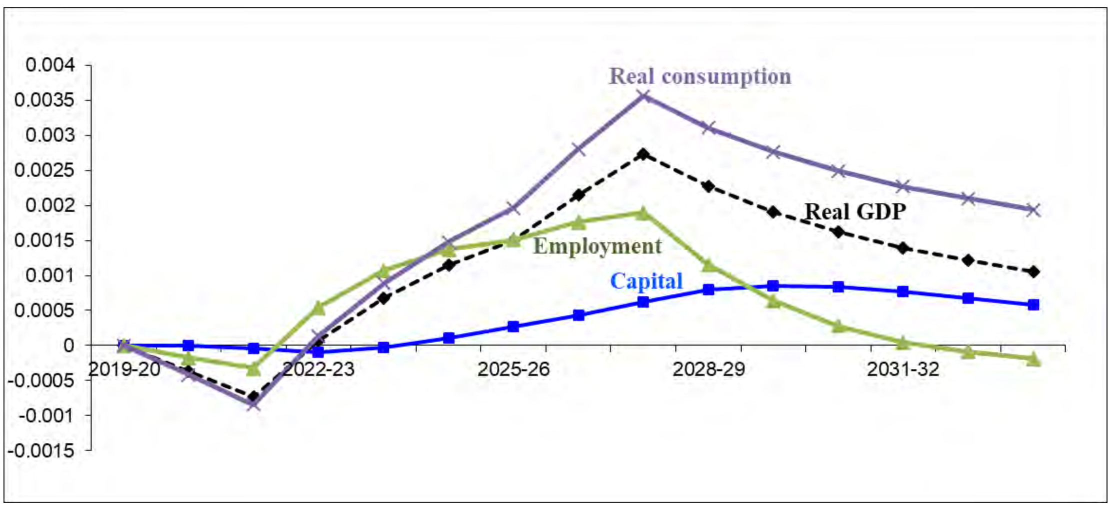


Figure 8: National, income side GDP and aggregate consumption, scenario 2

% deviation from base



At the national level, employment rises above base for several years, peaking at 0.0019% or 200 jobs above base in 2027-28, before moving back to base as labour market adjustment occurs more so through rising real wages relative to base. Since there is no terms-of-trade decline, real household consumption rises in line with real GDP. The dollar increase in real consumption reflects the dollar increase in real GDP, being slightly larger than real GDP in percentage terms.

In this scenario, the national welfare increase reflects the productivity gains, as there are no offsetting terms-of-trade declines. The net present value of the welfare gain is $620 million, or $15 million as an annuity.

Scenario 3: R&D and productivity gains, increased demand for cheese and yoghurt

A more optimistic scenario concerning the demand side is based on consumers showing growing preferences for premium cheese products and, for health reasons, yoghurt. International demand for these two products increases by 0.5% per annum between 2020 and 2027. Domestic demand increase by 0.25% per annum in this period.

Table 4: National outputs, dairy, scenario 3

% deviation from base

National outputs, dairy	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2031-32	2032-33
DairyCattle	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.2	1.2	1.2	1.1	1.1	1.1	1.1
MilkCream	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IceCream	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.6
FlavWMilk	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3
Yoghurt	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Butter	0.2	0.5	0.7	0.9	1.1	1.4	1.6	1.8	1.8	1.8	1.8	1.8	1.8	1.8
CheeseCurd	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4
OthDairy	0.3	0.7	1.0	1.4	1.7	2.1	2.5	2.9	2.9	2.9	2.9	2.9	2.9	2.9

Figure 9: Warrnambool and South West, labour market, scenario 3

% deviation from base

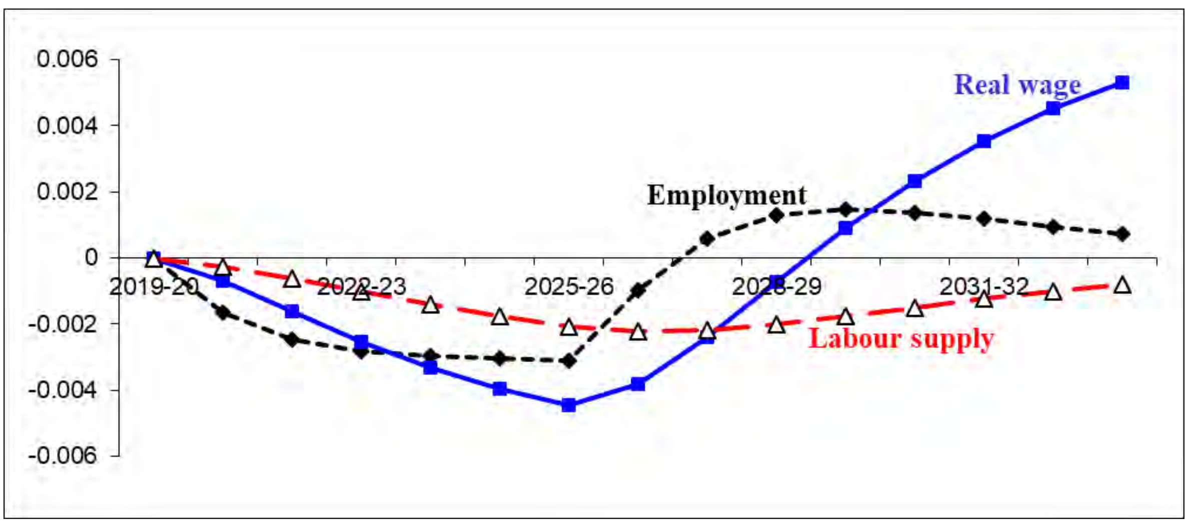


Figure 10: Warrnambool and South West, aggregate consumption and investment, scenario 3

% deviation from base

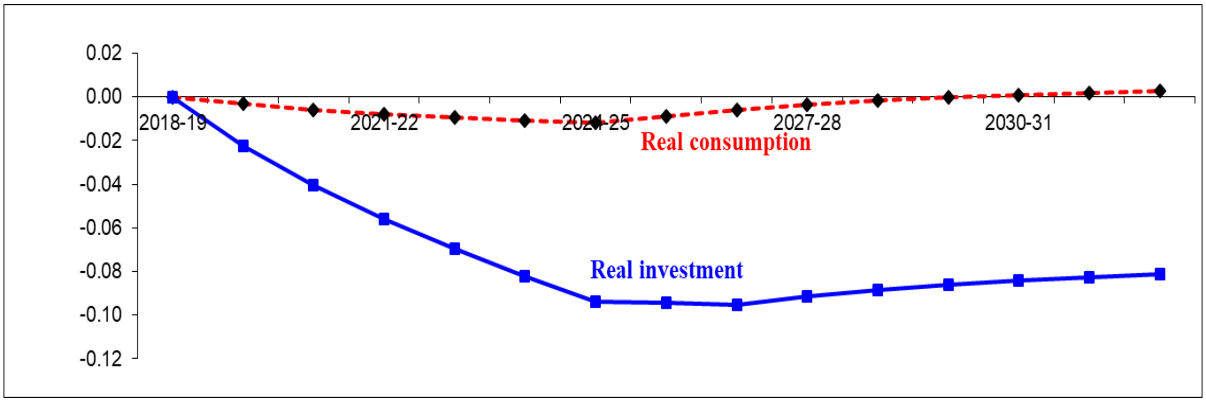


Figure 11: Warrnambool and South West, income side GDP, scenario 3

% deviation from base

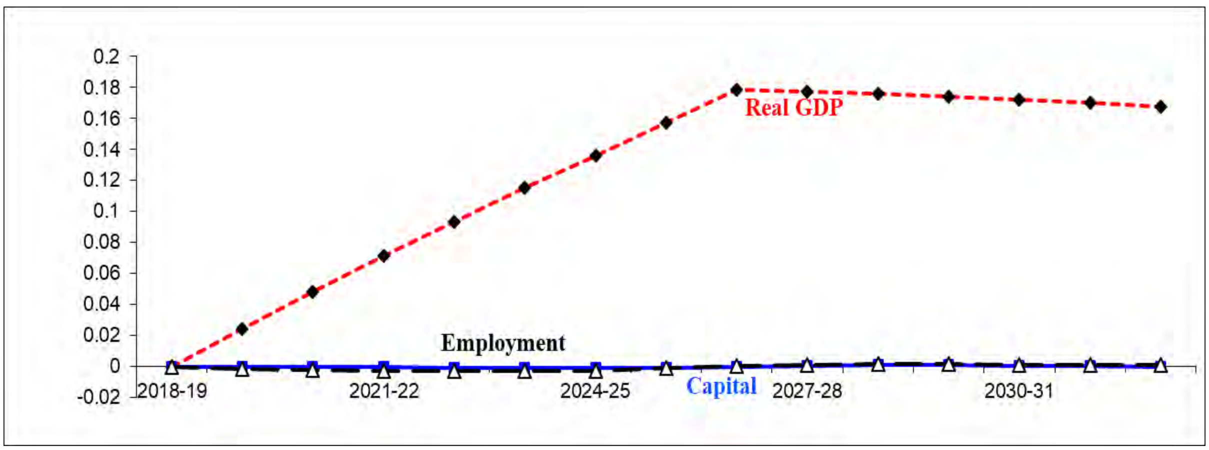
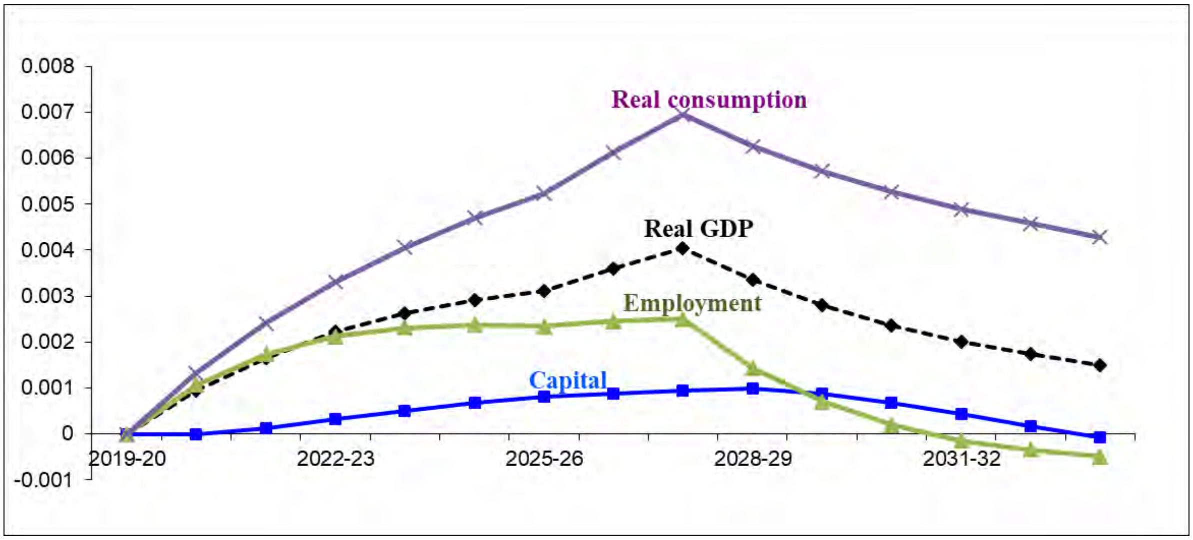


Figure 12: National, income side GDP and aggregate consumption, scenario 3

% deviation from base



In this case, there are virtually no economic losses in Warrnambool and South West relative to base. However, again productivity gains outweigh output gains, so that investment demands fall relative to base (figure 10). The fall in employment in early years relative to base approximates zero (a 0.003% fall is equivalent to little more than 1 worker). National welfare gains in this scenario rise to $1490 million in net present value terms of an annuity of $37 million.

Scenario 4: Larger R&D investments and productivity gains large enough to offset industry terms-of-trade losses

From the perspective of R&D policy, this may be the most important of the scenarios. In this scenario, increased R&D investments and consequent productivity gains are sufficient to ensure that terms-of-trade losses for dairy products do not result in welfare losses. However, there are still small losses at the regional level. This is because the percentage increase in dairy output is substantially smaller than the percentage decrease in primary input requirements.

R&D expenditures increase by $8 million per annum from 2020 to 2025, reaching $108 million in 2025. The dairy cattle sectors have incremental productivity increases equivalent to $16 million per annum from 2022 to 2027.

In Warrnambool and South West, the fall in employment relative to base is larger than in scenario 1. Employment falls to 0.11% or 60 jobs below base in 2027-28 (figure 13). Real consumption and real investment are also slightly worse at the regional level than in scenario 1 (comparing figures 14 and 2).

Table 5: National outputs, dairy, scenario 4

% deviation from base

National outputs, dairy	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2031-32	2032-33
DairyCattle	-0.2	-0.4	-0.4	-0.5	-0.5	-0.6	-0.6	-0.7	-0.7	-0.8	-0.8	-0.9	-1.0	-1.0
MilkCream	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
IceCream	-0.2	-0.4	-0.4	-0.4	-0.5	-0.5	-0.6	-0.6	-0.7	-0.8	-0.8	-0.9	-1.0	-1.0
FlavWMilk	-0.2	-0.3	-0.4	-0.4	-0.5	-0.6	-0.7	-0.7	-0.8	-0.8	-0.9	-0.9	-0.9	-1.0
Yoghurt	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.9	-0.9	-1.0	-1.0	-1.0	-1.1	-1.1
Butter	-0.2	-0.4	-0.4	-0.5	-0.6	-0.7	-0.7	-0.8	-0.9	-0.9	-1.0	-1.0	-1.0	-1.1
CheeseCurd	-0.1	-0.3	-0.3	-0.3	-0.4	-0.5	-0.5	-0.5	-0.6	-0.6	-0.7	-0.7	-0.8	-0.8
OthDairy	-0.2	-0.4	-0.4	-0.4	-0.5	-0.6	-0.6	-0.6	-0.7	-0.8	-0.9	-1.0	-1.1	-1.1

A key point in the assumptions concerning R&D expenditures in all scenarios is that all additional funding is provided by the industry. There is no additional government assistance. The regional impacts in each scenario would be more favorable if the government paid a share of additional R&D expenditure, as a larger share of local income would be available for local consumption. Given that the national welfare outcomes will be similar regardless of who pays for R&D, there is a strong case for shared R&D funding as the benefits are distributed between dairy sectors and the rest of the economy. In this scenario, the welfare gain is $164 million in net present terms or $4 million as an annuity.

Figure 13: Warrnambool and South West, labour market, scenario 4

% deviation from base

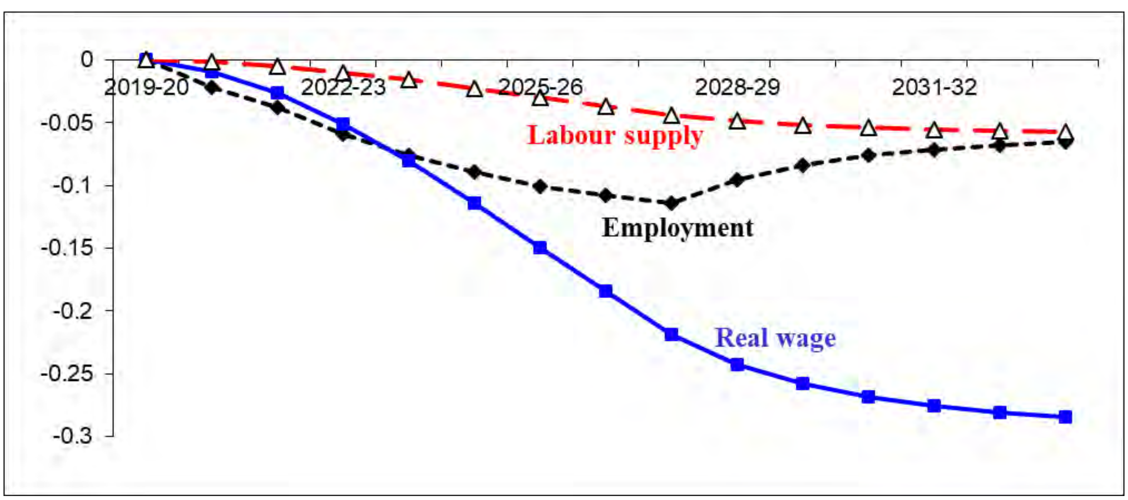


Figure 14: Warrnambool and South West, aggregate consumption and investment, scenario 4

% deviation from base

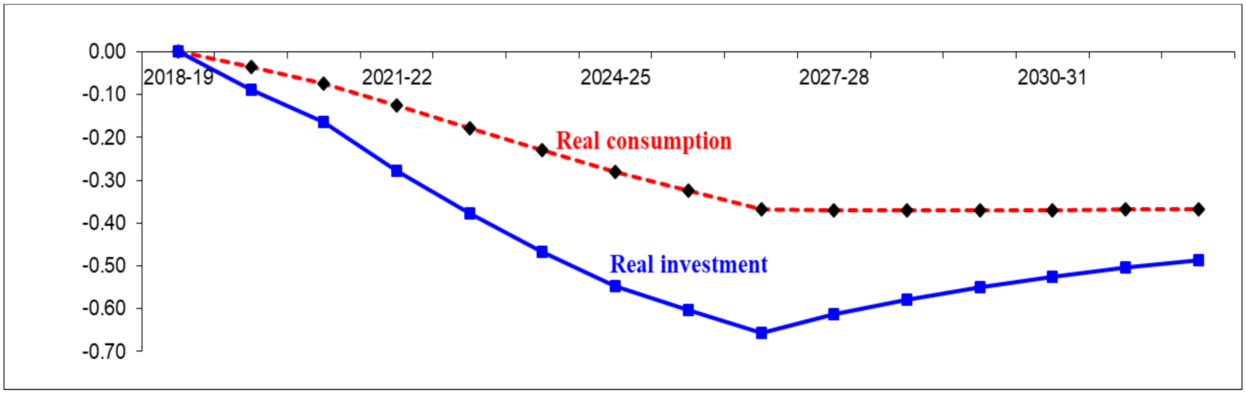


Figure 15: Warrnambool and South West, income side GDP, scenario 4

% deviation from base

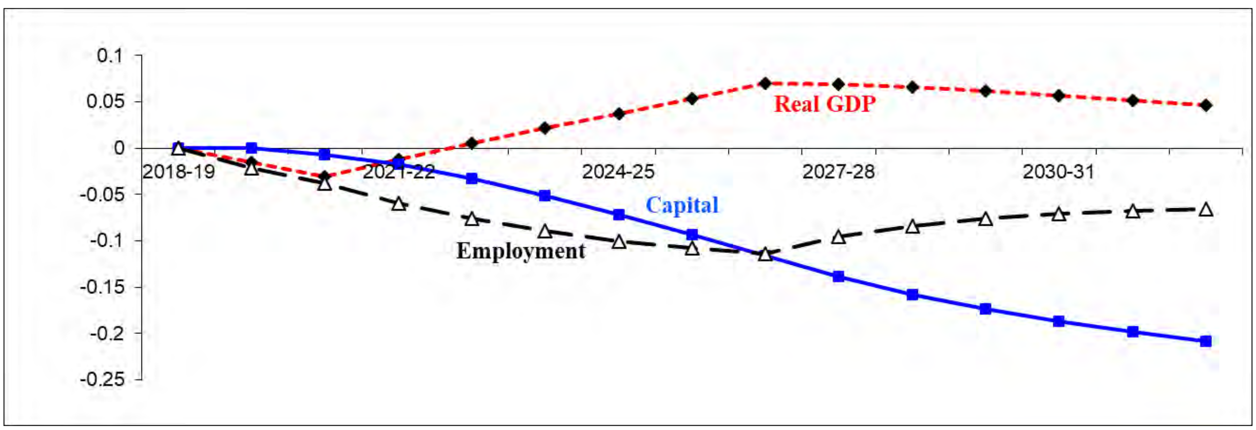
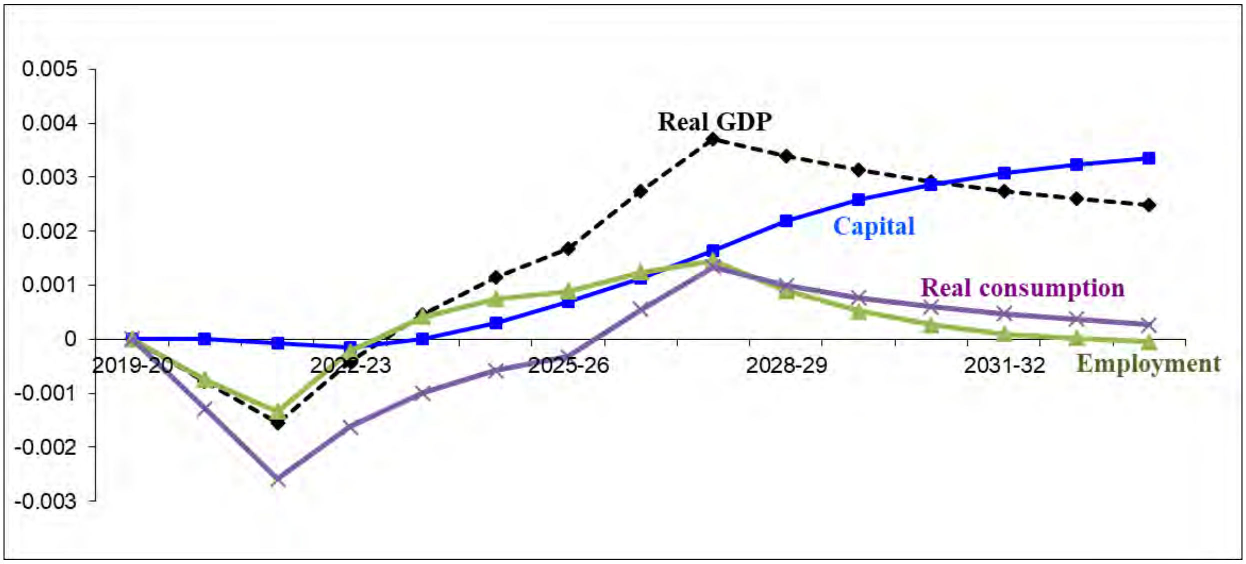


Figure 16: National, income side GDP and aggregate consumption, scenario 4

% deviation from base



Scenario 5: Larger R&D investments and productivity gains without industry terms-of-trade losses

Repeating the demand assumptions of scenario 2 in scenario 5 with higher R&D and productivity gains, the outcome in Warrnambool and South West is slightly less favorable than in scenario 2. In this scenario, the net present value of welfare is an increase of $950 million or an annuity of $24 million.

Table 6: National outputs, dairy, scenario 5

% deviation from base

National outputs, dairy	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2031-32	2032-33
DairyCattle	-0.1	-0.1	0.0	0.1	0.3	0.4	0.5	0.7	0.7	0.6	0.6	0.6	0.5	0.5
MilkCream	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IceCream	0.0	-0.1	0.1	0.2	0.4	0.5	0.7	0.9	0.8	0.8	0.8	0.7	0.7	0.6
FlavWMilk	0.0	-0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.3
Yoghurt	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Butter	0.0	-0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4
CheeseCurd	0.0	-0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.4
OthDairy	-0.1	-0.1	0.1	0.3	0.5	0.6	0.8	1.0	1.0	1.0	0.9	0.9	0.8	0.8

Figure 17: Warrnambool and South West, labour market, scenario 5

% deviation from base

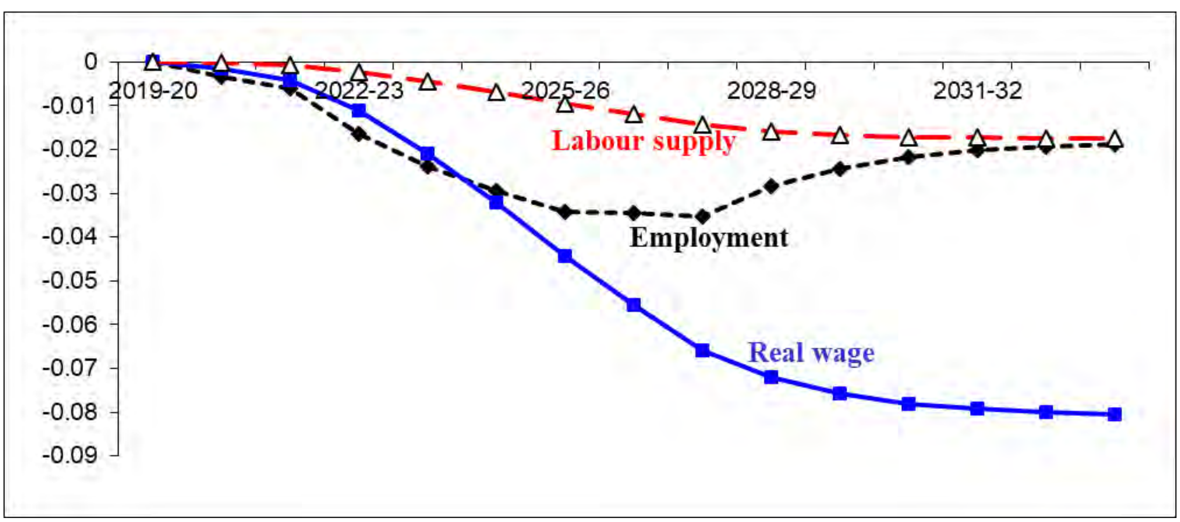


Figure 18: Warrnambool and South West, aggregate consumption and investment, scenario 5

% deviation from base

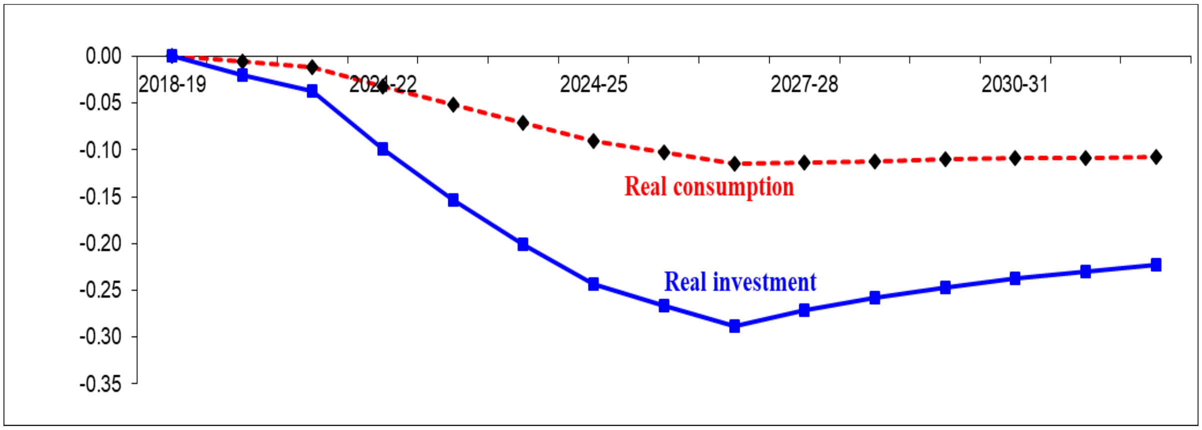


Figure 19: Warrnambool and South West, income side GDP, scenario 5

% deviation from base

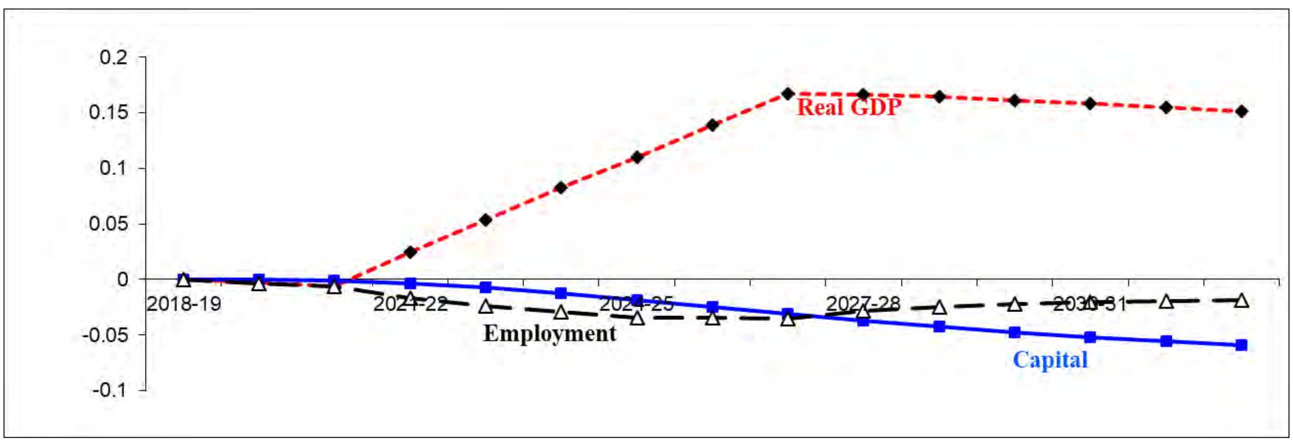
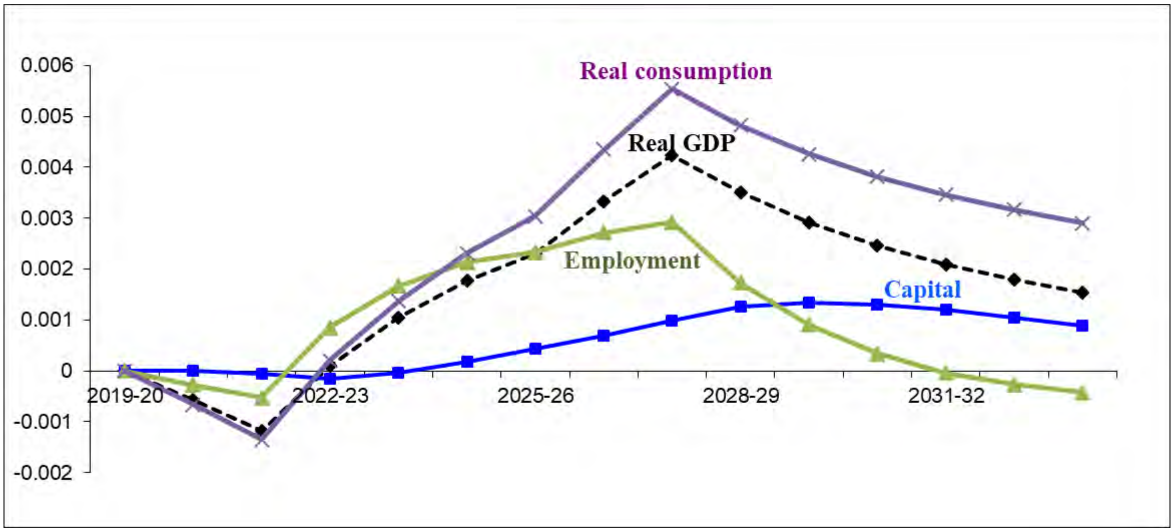


Figure 20: National, income side GDP and aggregate consumption, scenario 5

% deviation from base



Scenario 6: R&D reductions, productivity losses and industry terms-of-trade losses

Scenario 6 combines the terms-of-trade setting of scenario 1 with R&D expenditures and productivity movements in the opposite direction. This time, R&D expenditure declines from $60 million in 2020 to $30 million by 2025. Again, given the time it takes to translate R&D expenditures into productivity impacts, a two year lag applies, so that productivity declines relative to base are realized from 2022 to 2027 in the dairy cattle sectors, equivalent to $10 million incremental productivity losses per annum relative to base.

Table 7: National outputs, dairy, scenario 6

% deviation from base

National outputs, dairy	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2031-32	2032-33
DairyCattle	-0.1	-0.2	-0.5	-0.7	-1.0	-1.2	-1.5	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8
MilkCream	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
IceCream	-0.1	-0.2	-0.5	-0.8	-1.1	-1.4	-1.7	-2.0	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1
FlavWMilk	-0.1	-0.2	-0.5	-0.7	-0.9	-1.1	-1.3	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
Yoghurt	-0.1	-0.3	-0.5	-0.7	-0.9	-1.1	-1.3	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6
Butter	-0.1	-0.3	-0.5	-0.7	-1.0	-1.2	-1.4	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7

CheeseCurd	-0.1	-0.2	-0.4	-0.6	-0.8	-1.1	-1.3	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
OthDairy	-0.1	-0.3	-0.6	-0.9	-1.2	-1.6	-1.9	-2.3	-2.3	-2.4	-2.4	-2.4	-2.4	-2.4

Table 7 shows that national dairy sector outputs are only a little worse than in scenario 1: the identical demand assumptions limit the impact of the difference in dairy cattle productivity between the two scenarios.

Figure 21: Warrnambool and South West, labour market, scenario 6

% deviation from base

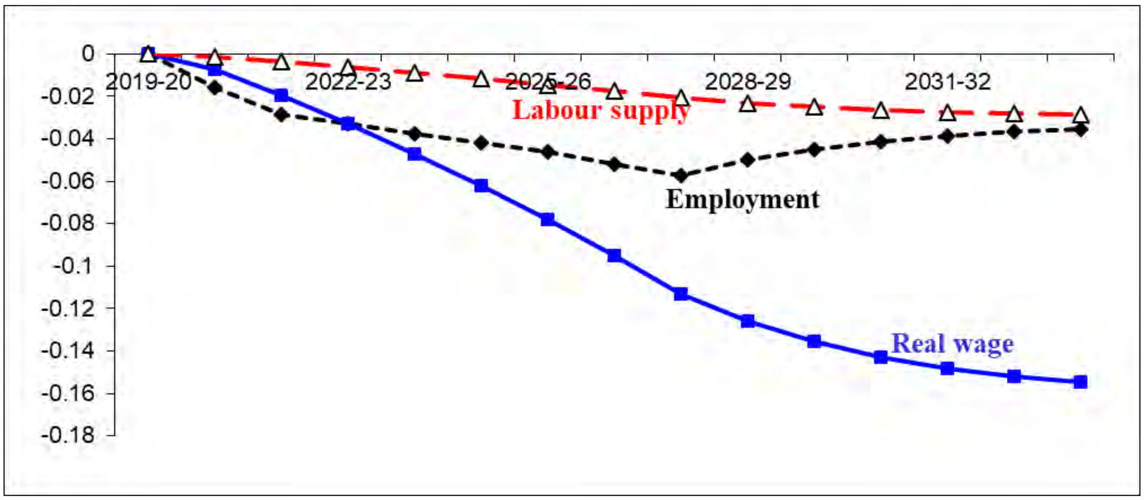


Figure 22: Warrnambool and South West, aggregate consumption and investment, scenario 6

% deviation from base

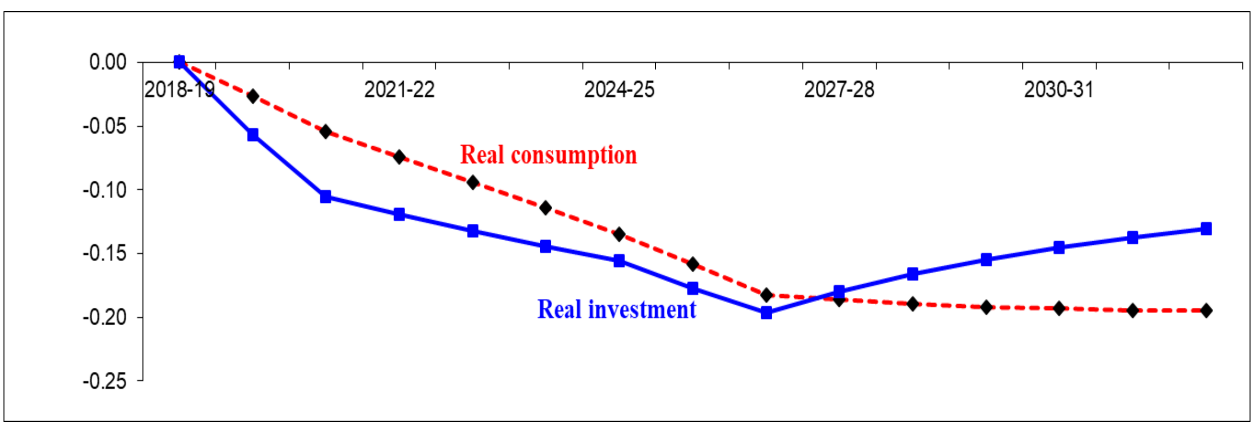


Figure 23: Warrnambool and South West, income side GDP, scenario 6

% deviation from base

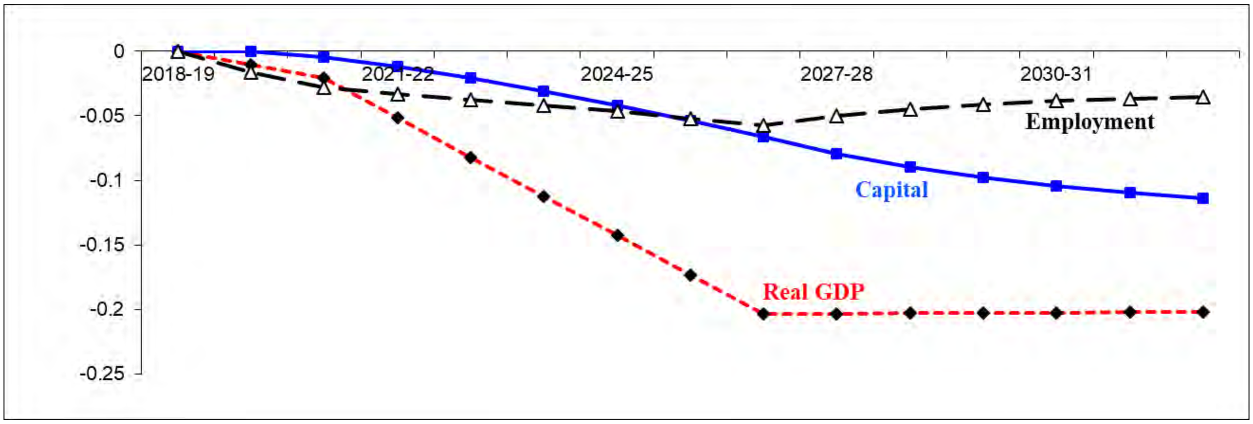
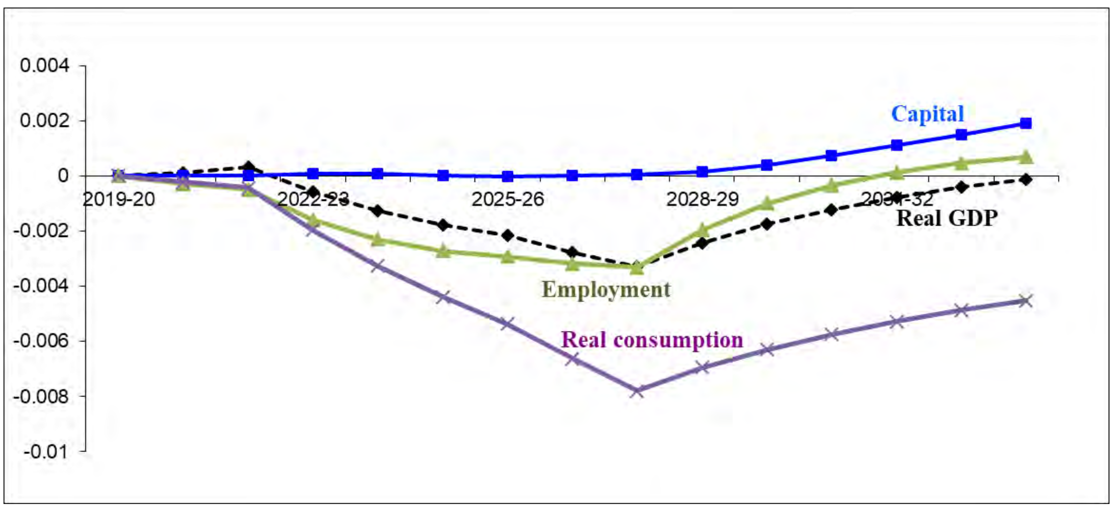


Figure 24: National, income side GDP and aggregate consumption, scenario 6

% deviation from base



The regional impacts in Warrnambool and South West are slightly less negative than in scenario 1. This because percentage declines in output are smaller than the increased primary factor demands in the dairy sector, the latter arising from deterioration in productivity. For example, labour inputs into dairy cattle production in the region are 1% above base in 2026-27.

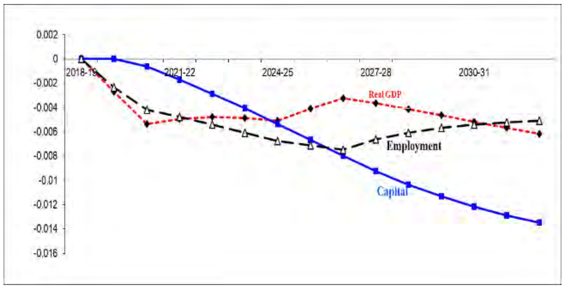
The most telling indicator in this scenario is national welfare. Recall that in scenario 1, the net present value of welfare was minus $170 million. In scenario 6, this has fallen further to minus $1390 million, or an annuity of minus $35 million. That is, the welfare outcome underlines the finding that industry specific productivity losses or gains are shared with society over time, implying that R&D funding to enhance productivity should also rely on some funding from outside the industry.

Figure 25: Comparing regional GDP outcomes

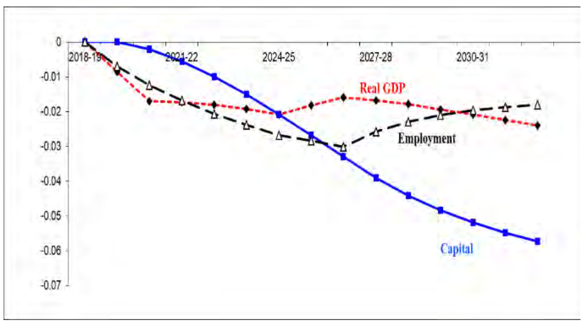
(% deviation from base)

Scenario 1 (productivity growth)

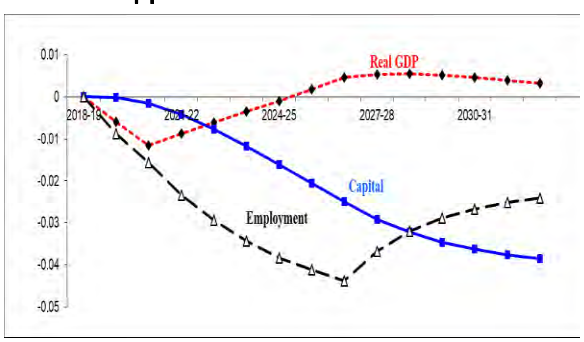
Murray NSW



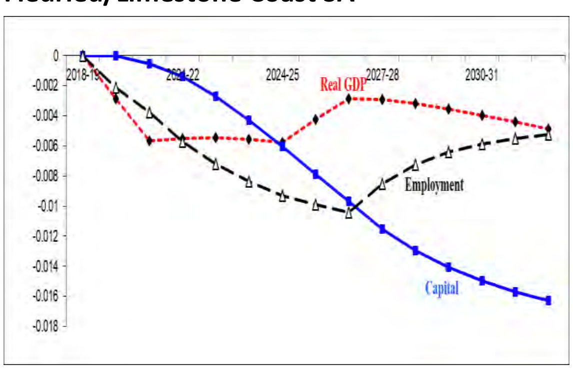
Murray Vic



Latrobe-Gippsland Vic

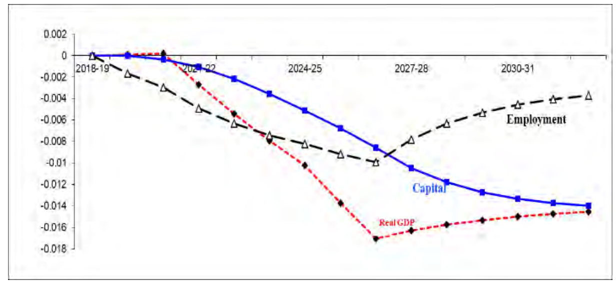


Fleurieu/Limestone Coast SA

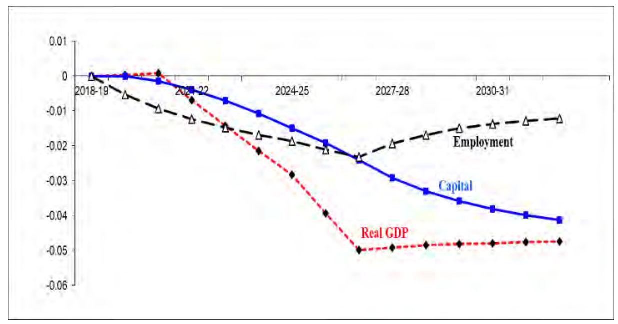


Scenario 6 (productivity decline)

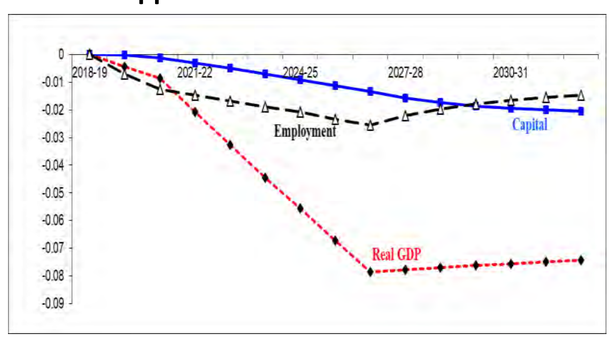
Murray NSW



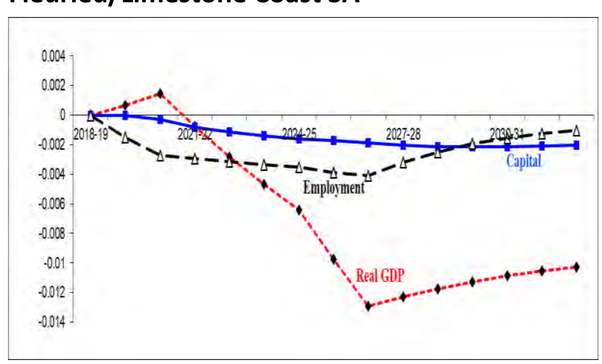
Murray Vic



Latrobe-Gippsland Vic

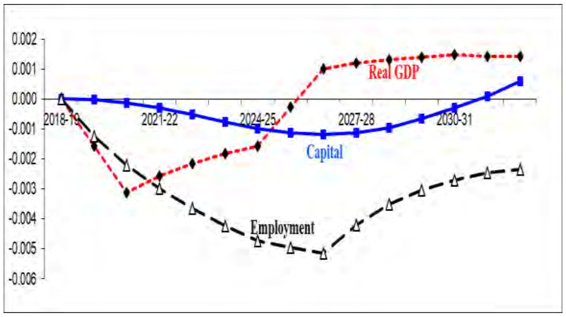


Fleurieu/Limestone Coast SA

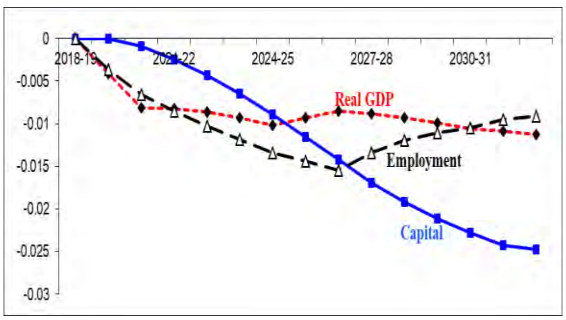


Scenario 1 (productivity growth)

WA Dairy

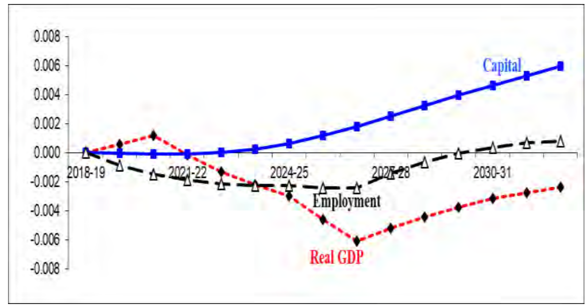


Tasmania

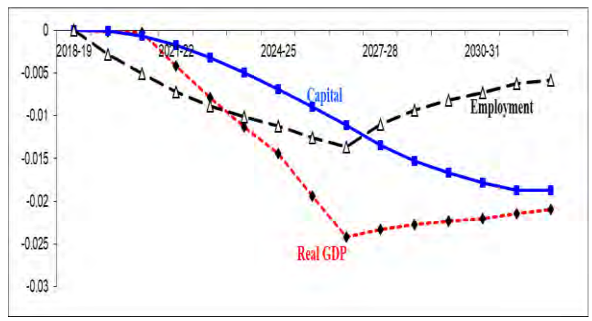


Scenario 6 (productivity decline)

WA Dairy



Tasmania



Appendix 3: details of Dynamic VU-TERM used in this project

What is a computable general equilibrium (CGE) model?

A CGE model can be an economy-wide model. In the context of the current project, it is an economy-wide model that also includes small-region representation. Another sort of model is an input-output model. The difference is that an input-output (IO) solves either for quantities or for prices, but not both at once. A CGE model solves for both prices and quantities together.

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.

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 (Figure A1 is a map of regions in this application). 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.

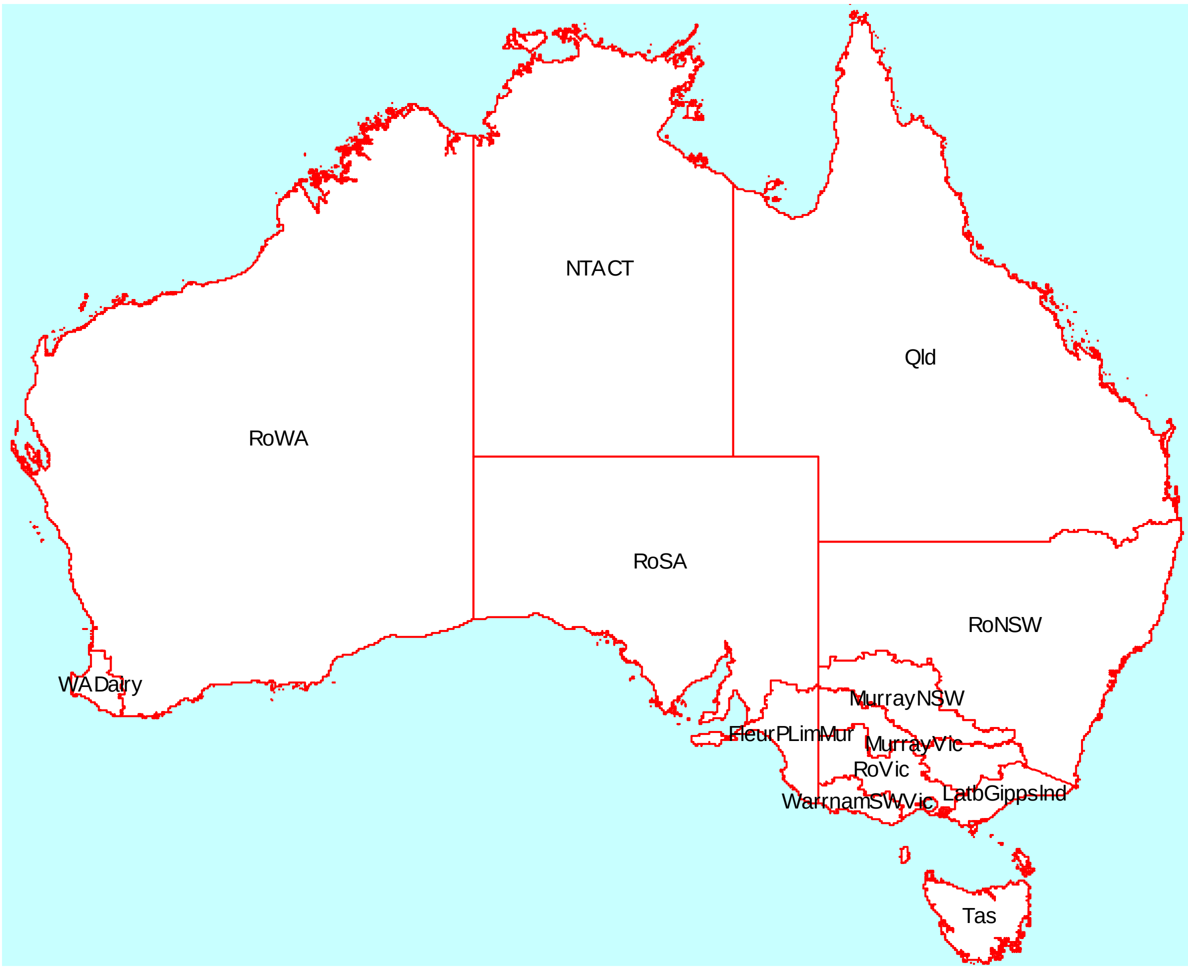
In dynamic VU-TERM, we use an underlying forecast. This may be based on the macro forecasts of other agencies. The underlying forecast or baseline gives us a year-by-year “business as usual” case.

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.

Aligning the master database of VU-TERM with the regions of interest in this study

The master database of VU-TERM represents 216 sectors in 334 SA3 regions in a bottom-up format. We aggregate to retain detail in sectors and regions of interest, while aggregating the database elsewhere. Figure 1 shows the regions used in this study.

Figure 1: VU-TERM aggregation for dairy study



The dairy bodies align with regions as:

“WADairy” = Western Dairy

“FleurPLimMur” = DairySA

“WarrnamSWVic” = WestVic Dairy

“LattbGippslnd” = Gipps Dairy

“MurrayVic” and “MurrayNSW” = Murray Dairy

The remaining dairy bodies represent producers less concentrated in local regions. In the case of DairyTas, the producers it represents are spread evenly across a number of Tasmanian regions. DairyNSW includes some concentration in the South Coast region, but is spread widely elsewhere. Subtropical Dairy's producers in Queensland and northern NSW are also widely dispersed.

Table A1 show value-added by broad sector by each region in $million and as a percentage of total regional value-added. Estimates are based on 2017-18 input-output detail and the 2016 census. They have been projected to 2019-20.

Table A1: Value-added by broad sector by region

$m	MurrayNSW	MurrayVic	LatbGippsInd	WarrnamSWVic	Qld	FleurPLimMur	WADairy	Tas	RoNSW	RoVic	RoSA	RoWA	NTACT
CropsFodder	554	2113	489	291	4740	1146	370	820	4791	2291	1165	2637	143
OthrLivstock	352	1007	680	1027	3736	1024	115	381	2572	2142	949	1352	352
DairyCattle	45	484	508	598	101	101	89	270	187	63	12	12	0
OthPrimary	39	304	2606	294	43256	517	3877	1630	16961	3659	3515	64900	4393
OthManufact	573	1846	1008	494	21269	1233	1446	1748	30775	25259	6087	11435	993
MilkCream	2	29	10	12	77	4	7	14	45	107	16	15	6
IceCream	0	0	1	128	54	0	2	1	29	117	15	3	1
CheeseOth	38	308	189	218	82	28	16	168	329	611	47	11	0
Utilities	162	511	1144	277	10199	320	612	977	13258	8043	2874	4565	1785
Constructn	483	1523	1305	377	33754	686	2202	1896	35765	22968	6679	29182	6668
Services	4433	13360	8660	4177	2E+05	5855	7211	19064	440997	279237	68776	127337	59956
Total	6681	21486	16600	7892	3E+05	10913	15947	26970	545708	344498	90135	241447	74297
% of total													
CropsFodder	8.3	9.8	2.9	3.7	1.4	10.5	2.3	3.0	0.9	0.7	1.3	1.1	0.2
OthrLivstock	5.3	4.7	4.1	13.0	1.1	9.4	0.7	1.4	0.5	0.6	1.1	0.6	0.5
DairyCattle	0.7	2.3	3.1	7.6	0.03	0.9	0.6	1.0	0.03	0.02	0.01	0.01	0.0
OthPrimary	0.6	1.4	15.7	3.7	12.7	4.7	24.3	6.0	3.1	1.1	3.9	26.9	5.9
OthManufact	8.6	8.6	6.1	6.3	6.2	11.3	9.1	6.5	5.6	7.3	6.8	4.7	1.3
MilkCream	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
IceCream	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CheeseOth	0.6	1.4	1.1	2.8	0.0	0.3	0.1	0.6	0.1	0.2	0.1	0.0	0.0
Utilities	2.4	2.4	6.9	3.5	3.0	2.9	3.8	3.6	2.4	2.3	3.2	1.9	2.4
Constructn	7.2	7.1	7.9	4.8	9.9	6.3	13.8	7.0	6.6	6.7	7.4	12.1	9.0
Services	66.4	62.2	52.2	52.9	65.6	53.7	45.2	70.7	80.8	81.1	76.3	52.7	80.7
	100	100	100	100	100	100	100	100	100	100	100	100	100

Sources: https://www.abs.gov.au/statistics/economy/national-accounts/australian-national-accounts-input-output-tables-product-details/latest-release; ABS catalogue 5209.0.55.001; ABS 2016 census data on employment by industry and region.

Farm input movements within VU-TERM

Previous modelling with versions of VU-TERM have accounted for farm factor movements. Wittwer and Griffith (2011) using TERM-H2O concentrated on the southern Murray-Darling Basin in modelling resource movements between irrigated and dry-land farm activities as irrigation water availability changed and dryland productivity collapsed in drought. A relatively simplified resource movement theory was introduced to Wittwer (2020) to depict management of livestock during the recent NSW drought. In this theory, land is substitutable with feed inputs in livestock production. In drought, land productivity collapses, so that livestock production becomes more heavily reliant on purchased feed inputs. Drought modelling requires much larger productivity shocks (plus water input shocks in the case of TERM-H2O) than usually arise from productivity studies.

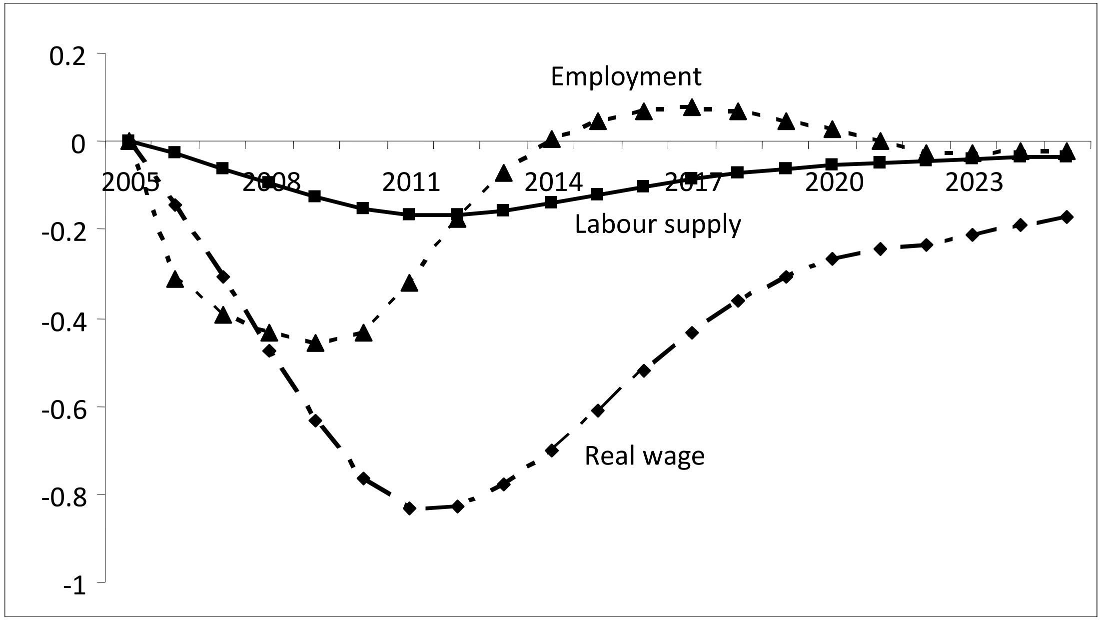
Since VU-TERM is dynamic, it is possible to devise a baseline with seasonal variability. That is, agricultural productivity can rise and fall with better and worse seasons. We can run policy scenarios against either this more elaborate baseline or a relatively bland baseline.

Appendix

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 A1 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.

Figure A1: 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 (Horridge, *et al*. 2018; Harrison and Pearson, 1996).

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