BROADACRE FARM PRODUCTIVITY AND PROFITABILITY IN SOUTH WESTERN AUSTRALIA [1]

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[1] A contributed paper to the 55th Annual Conference, Australian Agricultural and Resource Economics Society, Melbourne, February 9-11, 2011. The authors gratefully acknowledge Chris O'Donnell for his critical comments and suggestions on the earlier draft of the paper.

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Abstract

This paper examines broadacre farm performance in south-western Australia. This region has experienced pronounced climate variability and volatile commodity prices over the last decade or so. Relationships between productivity and profitability are explored using panel data from 50 farms in the study region. The data are analysed using non-parametric methods. Components of farm productivity and profitability are measured over the period 1998 to 2008. Economies of scale and scope are shown often to be positive contributors to productivity and profitability. However, the main finding is that technical change, much more so than technical efficiency, has supplied over 68 percent of the improvement in total factor productivity for farms in the different climatic zones of the region from 1998 to 2008. In addition, growth in total factor productivity is the main contributor to farm profitability. By implication, technical change, often accompanied by scale and mix efficiencies, is the main driver of farm profitability. These findings indicate a vital role for innovation and R,D&E to deliver technologies and practices that bolster farm profitability, as well as a continuing role for scale and scope economies. The products and knowledge that come from innovation and R,D&E are the springboard for technical change. Through technical change and scale and scope efficiencies farmers in this study have achieved higher profits.

Keywords: *Productivity, Profitability, Technical change, Farm businesses*

1. Introduction

It is often argued that in order to remain internationally competitive Australian farming needs ongoing gains in productivity. Given limitations to Australia's agricultural resources of arable land and water, the future growth in agricultural production seems destined to depend largely on increases in productivity (Zhao *et al*. 2008; Nossal and Sheng 2010). Of encouragement are empirical findings that Australia's largest agricultural sector, known as broadacre agriculture, has achieved in recent decades reasonably high rates of productivity gain; with total factor productivity (TFP) growth averaging 1.4 percent per annum from 1977-8 to 2007-8 (Nossal and Sheng 2010). However, of some concern is the suggestion that this productivity growth has slowed recently. Nossal and Sheng (2010) report that between 1977-78 and 2000-01, broadacre productivity grew at 2 per cent per annum, but since 2000-01 up until 2007-8 growth averaged -1 per cent per annum. This slowdown is largely attributed to drought effects (Sheng *et al*. 2010).

Whether these drought conditions are part of underlying climate variability or a portent of unfolding climate change is not clear (CSIRO 2007). With some regional and seasonal variations, the annual average temperature across Australia has increased and average rainfall has decreased. There are however different opinions over whether these changes are weather variability rather than climate change (Nicholls *et al*. 2003; Van Ittersum *et al*. 2003). Either way, their impact on productivity and farm production has been large, further complicating the management of already complex broadacre farm businesses (Kingwell 2010) and exacerbating the risks associated with farming (Quiggin *et al*. 2010). If projected climate change does unfold, then in some regions farm profitability and viability are likely to be threatened (John *et al.* 2005; Kingwell 2006; Garnaut 2010; Quiggin *et al*. 2010).

To combat the adverse impacts of climate risk and other sources of business risk, productivity growth is vital. In fact, as more broadly shown by Mullen (2007), much of the current value of agricultural production can be attributed to the gains over several decades in productivity improvement by Australian farmers. The gain in productivity over those decades principally has offset adverse movements in farmers' terms of trade and enabled profits from farming to be much higher than otherwise would have occurred. However, over much of the last decade only a weak decline in farmers' terms of trade has been observed (ABARE 2009), so the benefits of productivity gain in recent years have served other risk aspects of farming.

Although much effort has been devoted to measuring the productivity performance of different sectors and agricultural regions of Australia (Kopke *et al*. 2000; Mullen 2007; Nossal *et al*. 2009; Salim and Islam 2010; Sheng *et al*. 2010) the methods employed are not able to indicate causes behind measured trends or differences. Nonetheless, most authors posit plausible explanations for the observed rates of productivity change and workshops have been held to discuss possible underlying causes of productivity changes (e.g. Jackson 2010). Authors point to technological advances such as seed varieties, herbicides, tillage practices and improved machinery. Mullen (2007) observes that the longer production cycles in livestock production could make the transition to better technologies and production methods slower in the livestock industries.

Given the importance of productivity gain for Australian farming, and its key influence on farm profitability, it is worthwhile to understand more about the components of farm productivity and profitability. Furthermore, given the uncertain environment of agriculture and the complex task of farm business management, it is important to know how farm business profitability and productivity fare in this environment. A better understanding the components of farm productivity and profitability, for example, may help policy makers, innovation funders and product developers to be more effective in assisting farm businesses.

Hence, this paper explores the profitability and productivity components of Australian farms, using the case study region of Australia's south-west. This region is of particular interest since from the mid-1970s, it has displayed a warming and drying trend and has been characterised by marked climate variation, as well as having experienced significant commodity and input price volatility over the last decade. The paper comprises three sections. Section 2 describes the study's methodology and data, and then Section 3 presents the results, discussion and conclusion.

2. Methodology and data

Method

Farm productivity and efficiency gaps in agricultural productions exist as farms face different production opportunities due to differences in factors such as: (i) physical resource endowments (e.g. quality of soils and climate), (ii) technology, capital and infrastructure, (iii) management skill and social support, and (iv) levels of costs and prices (Hayami 1969; Hayami and Ruttan 1971; Lau and Yotopoulos 1989; Battese *et al*. 2004; O'Donnell *et al.* 2008). To measure farm productivity and efficiency, increasingly sophisticated methodologies have been developed to deal with a raft of issues surrounding data discrepancies, functional forms and behavioural assumption restrictions, *inter alia*. Ozkan *et al*. (2009) have reviewed literature on the approaches for measuring efficiency in agricultural production. The existing approaches can be classified into two groups: parametric and non-parametric. The least-squares econometric production and stochastic frontier production function models are examples of the first category and the traditional Tornqvist-Theil or Christensen and Jorgenson total factor productivity index and data envelopment analysis are examples of the second group. An elaborate review of the productivity estimation methods can be found in Van Beveren (2010) and Van Biesebroeck (2007).

Most of these studies deal with productivity and efficiency issues not with profitability to which farm business viability is closely linked (Lovell 2001). Productivity and profitability, however, are related in the sense that a more productive business typically is also more profitable, and a faster growth in productivity often translates into faster growth in profitability, *ceteris paribus*. In reality however, the relationship between productivity and profitability is not linear which makes it difficult to decompose variations in profitability into variations in productivity and efficiency.

Economists have used numerous methods to demonstrate a relationship between profitability and productivity changes. Althin *et al.* (1996) show that the index of profitability is approximately equal to the efficiency change component of productivity change, which implies improvements in productivity are accompanied by improvements in profitability. Grifell-Tatjé and Lovell (1999) show that sources of profit change are driven by changes in quantities and prices. The changes in quantities can be further decomposed as illustrated in Figure 1 into five categories the affect quantities produced. Hadley and Irz (2008) have applied the hierarchy displayed in Figure 1 using farm-level production data for England and Wales.

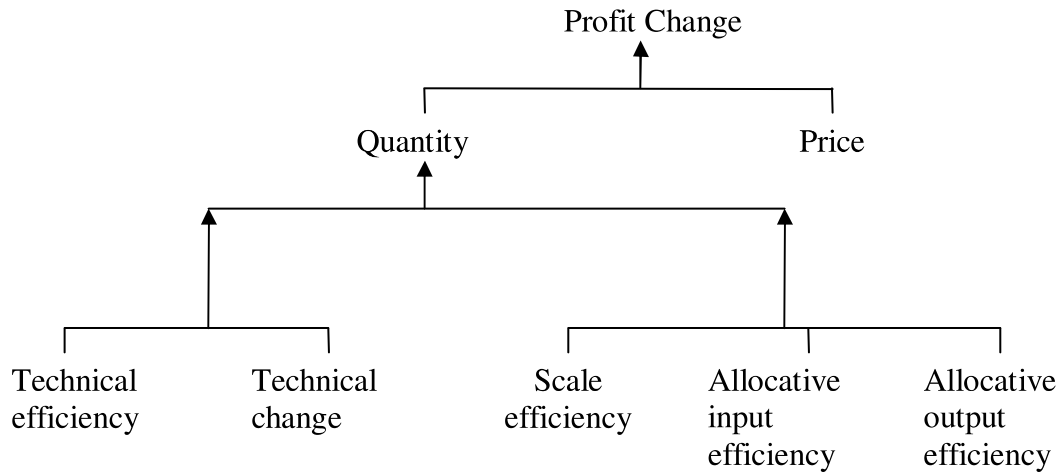


Figure 1. Profit Decomposition

Advancing this decomposition approach O'Donnell (2010a) distinguished a difference between 'profitability change' and 'profit change' and showed that the sources of profitability change are driven by the changes in term of trade (i.e. change in the output-input price ratio in place of an output-input price difference), productivity and various measures of efficiency indexes. The distinction he drew between profit and profitability considered profit as revenue less cost while profitability was defined as the ratio of revenue to cost. According to O'Donnell (2010a), the sources of profitability change can be decomposed into three stages provided that: (a) the output and input quantity aggregates are associated with input and output price aggregates; (b) the quantity and price aggregates are non-negative and linear homogeneous in prices; and (c) any quantity-price aggregator function pair satisfy the product rules. The formulae for decomposing these profitability and productivity drivers are presented in simplified forms in equations 1 – 6 below.

Firstly, the profitability index change (*d*PROF) between firms or periods, *o* and *t,* can be decomposed into the indexes of changes in the terms of trade (*d*TT) and total factor productivity (*d*TFP):

$$d\text{PROF} = d\text{TT} * d\text{TFP} \tag{1}$$

Since O'Donnell (2010a) has used a multiplicatively complete index number, the change of index numbers used in equations (1) to (6), between firms or periods *o* to *t*, can be computed using firm or period *o* as a base. For example, the change in profitability (*d*PROF) can be computed as the ratio of profitability in time *t* over profitability in time *o*. This can be expressed as: $d\,\text{PROF} = \text{PROF}_t / \text{PROF}_o$.

Secondly, the total factor productivity change (*d*TFP) index can be further decomposed into the indexes of technical change (*d*Tech) and technical efficiency change (*d*Eff):

$$d\text{TFP} = d\text{Tech}*d\text{Eff} \qquad (2)$$

Finally, the index of efficiency change (*d*Eff) can be decomposed into various indexes of efficiency change:

$$d\text{Eff} = d\text{OTE}*d\text{OME}*d\text{ROSE} \qquad (3)$$

$$d\text{Eff} = dO\text{TE}*d\text{OSE}*d\text{RME} \qquad (4)$$

$$d\text{Eff} = d\text{ITE}*d\text{IME}*d\text{RISE} \qquad (5)$$

$$d\text{Eff} = d\text{ITE}*d\text{ISE}*d\text{RME} \qquad (6)$$

The detail about the definitions and graphic illustrations of the index numbers specified in equations (1) to (6) can be found in O'Donnell (2010a). To save space we provide a brief explanation of these index numbers below.

- OTE (ITE) is output-oriented (input-oriented) technical efficiency capturing the potential change in TFP output (input) level by best practice use of existing technology. It is measured by the difference between observed TFP and the maximum TFP that is possible with an existing technology, while holding the output (input) mix fixed and the input (output) level fixed.
- OSE (ISE) is output-oriented (input-oriented) scale efficiency that captures the potential change in TFP if output (input) level is changed to achieve the maximum TFP with an existing technology. It is measured by the difference between TFP at a technically-efficient point and the maximum TFP based on the use of existing technology, while holding the input and output mixes fixed but allowing the levels to vary.
- OME (IME) is output-oriented (input-oriented) mix efficiency that captures the potential change in TFP if output (input) level is changed by altering the mix of enterprises is such a way that output is increased for a given set of inputs (output). It is measured by the difference between TFP at a technically-efficient point on the existing technology or enterprise mix and the TFP that is possible holding the input (output) level fixed but allowing the output (input) level and mix to vary.
- ROSE (RISE) is residual output-oriented (input-oriented) scale efficiency measuring the difference between TFP at a technically and mix efficient point and the maximum TFP that is possible through altering both input and output with the existing technology.
- RME is residual mix efficiency measuring the difference between TFP at a technically and scale efficient point and the maximum TFP that is possible through altering input and output mixes with existing technology.

Study region and farm data

The data for this study was supplied by two farm management consulting firms whose clients are farmers in South Western Australia (see Figure 2). This study region comprises one million hectares and is considered to have experienced a changed climate since the mid-1970s

(IOCI 2005). These changes in climate are summarized as a 0.8ºC increase in average temperature since 1910 and a 10 to 15 percent drop in annual rainfall since the 1970s.

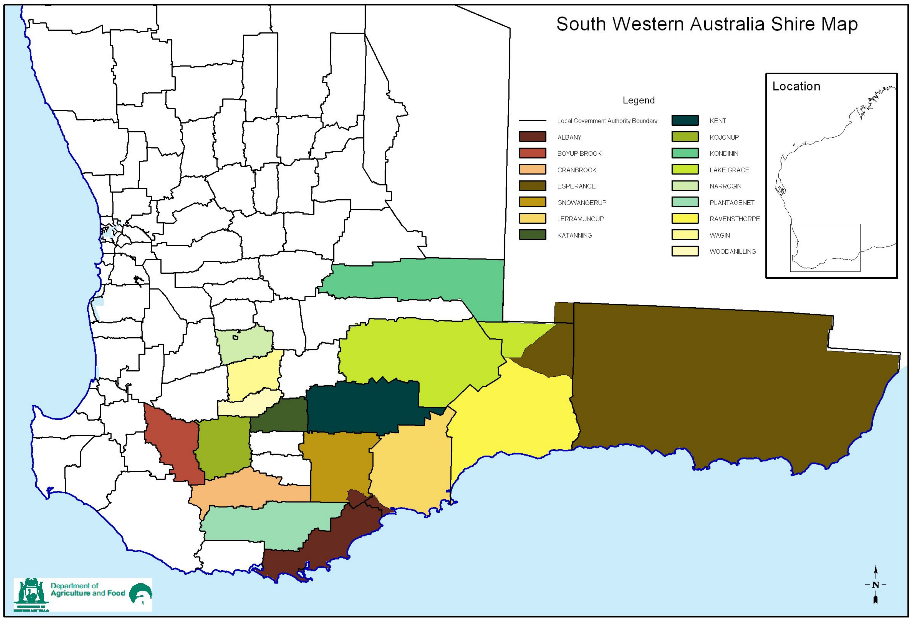
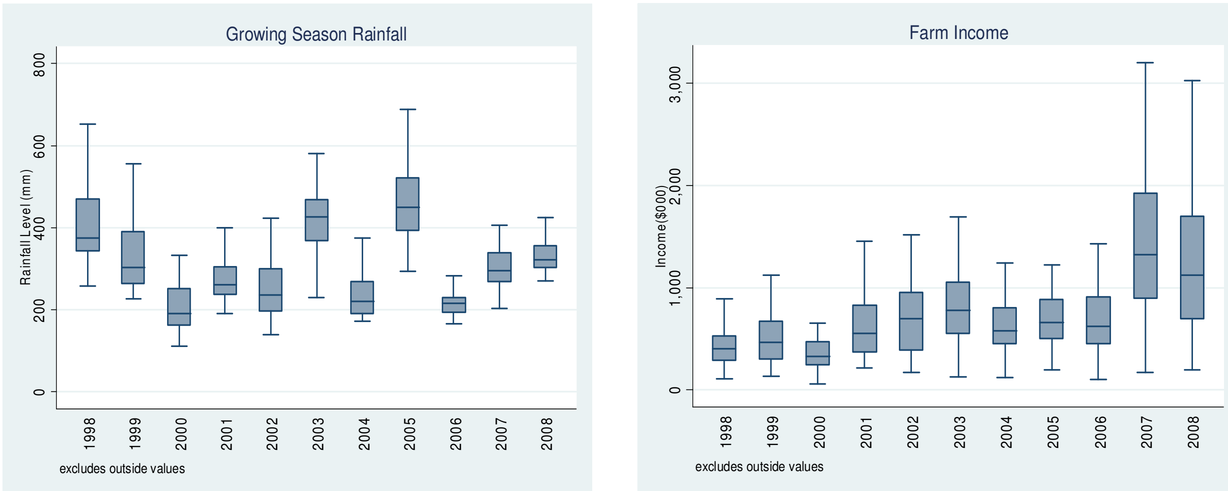


Figure 2. The study shires of South Western Australia region

The set of panel data came from 67 farms, many with complete data for the period 1998 to 2008. The data comprise over 209 descriptors of each farm; including detailed information on physical inputs and outputs of crops grown; livestock types, their number, purchases and sales (including wool sales); financial items and aggregates such as expenditure on casual labour, fertilisers, fuel, chemicals, plant depreciation, repairs, income generated, assets, liabilities and equity. A summary of key aggregates is given in Table 1 and their derivation is described later.

Figure 3 illustrates the variation in the panel dataset in on-farm growing season rainfall (see panel A) and farm income (panel B) for each year in the study period. The box-plot's vertical bar shows the smallest observation, lower quartile (25th), median (50th), upper quartile (75th), and largest observation. In some years such as 2000, 2004 and 2006 average growing season rainfall was around 200 millimeters whereas in 2003 and 2005 average growing season rainfall was over 400 millimeters.



Panel A Panel B

Figure 3. Variations in on-farm growing season rainfall and farm income

The box-plots in Panel A indicate that the rainfall distributions across farms in each year were skewed. Rainfall over the entire period also fluctuated greatly. On the other hand, farm income variations were remarkably less skewed and fluctuated less. This suggests that farm income variations caused by rainfall variation have been offset by other changes such as mollifying adaptive responses.

Table 1. Key aggregates for farms in the dataset: 1998 to 2008

		Low Rainfall Environment (<275mm GSR)					Medium Rainfall Environment (275mm to 325mm GSR)					High Rainfall Environment (>325mm GSR)				
Variable	Unit	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
Quantity of livestock capital (x3)	DSEs	44	2,560	1,092	940	4,752	100	3,042	2,047	477	11,990	56	6,114	3,590	1,687	16,054
Livestock output (q2)	Quantity Index	44	103	40	35	245	100	114	49	34	292	56	120	53	51	297
Crop output (q1)	Tonnes	44	2,691	1,236	522	5,681	100	2,614	1,855	161	9,136	56	2,450	2,179	209	12,359
Labour input (x1)	Person-weeks	44	94	31	44	149	100	99	44	47	263	56	140	80	48	361
Land input (x2)	Hectares	44	2,670	903	1,278	4,750	100	2,311	1,361	740	7,931	56	2,308	1,501	635	6,525
Quantity of variable input (x4)	Quantity Index	44	100	28	20	179	100	100	24	37	168	56	112	52	21	295
Total revenue (TR)	$'000	44	786	440	114	2,000	100	832	645	111	3,300	56	1,101	930	168	5,300
Total cost (TC)	$'000	44	461	222	112	1,100	100	512	367	85	2,000	56	698	513	128	2,500

Note: GSR is growing season rainfall and DSE is dry stock equivalent, *Index construction and model estimation*

The following steps were used to construct the indexes. Firstly, we clustered the data into three groups according to the level of growing season rainfall on each farm. The three categories of average growing season rainfall were (i) less than 275 mm (the low rainfall group), (ii) between 276 to 325 mm (the medium rainfall group), and (iii) more than 325 mm (the high rainfall group). Secondly, since the panel data were not balanced and some observations were missing, we used the complete data of only 50 farms for four intervals (i.e., 1st interval: 1998-2000, 2nd interval: 2001-2003, 3rd interval: 2004-2006, and 4th interval: 2007-2008) to form a balanced panel data of which 11 farms were the low rainfall group, 25 farms were the medium rainfall group and 14 farms were the high rainfall group. Thirdly, we constructed data for the estimation of sources of productivity change by grouping the production data into two output and four input variables.

The following approaches were used to form these input and output variables:

Crop output is constructed as the sum of production (tonnes) of all cereal enterprises for each farm; Cereal production was by far the dominant crop enterprise on all farms.

Livestock Output is a Fisher index of the quantity of livestock sold and the quantity of wool sold (kg). The quantity of livestock sold is measured as dry sheep equivalents (DSE) for the various classes and sheep and a conversion factor of 12 DSE applied to cattle. Prices for constructing the Fisher index number were derived by dividing cattle, sheep and wool revenues by their quantities sold.

Labour input is constructed as the annual sum of family, managerial and hired labour (in person-weeks);

Land input is effective land area or area of land utilized for crop and livestock production (in hectares);

Quantity of livestock capital is measured in DSE and was constructed as the sum of opening livestock numbers and live stock purchased minus the number of livestock sold.

Quantity of variable inputs is an index number constructed by summing annual farm expenditures over five categories: depreciation, building and machinery maintenance, fertilisers, sprays, livestock, materials, and fuel, and dividing each item by the relevant price index from ABARE (2010).

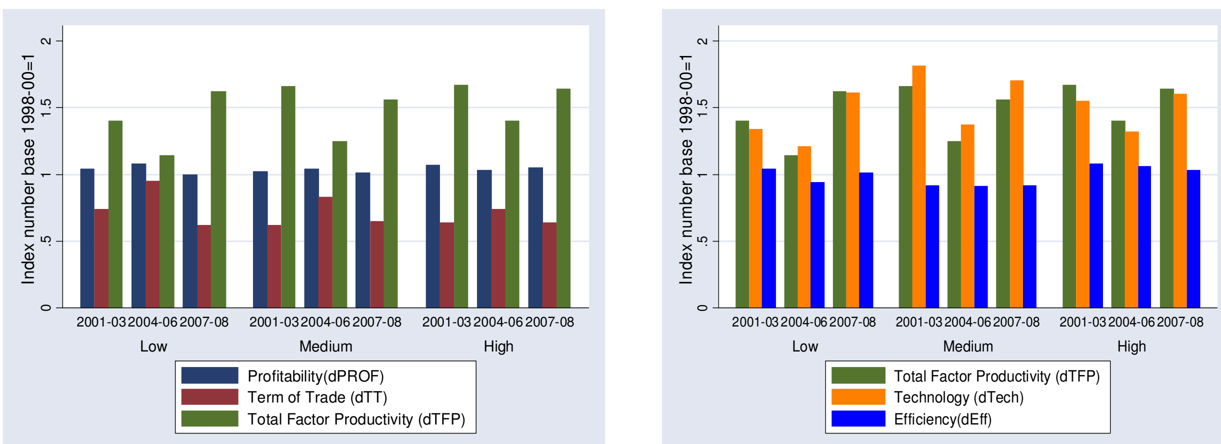
A summary statistics for these variables are presented in Table 1.

Finally, following O'Donnell (2008 & 2010), the Hicks-Moorsteen indexing method was used and the DPIN v.1 software developed by O'Donnell (2010b) was applied to measure and decompose profitability and productivity indexes and to estimate the sources of productivity change as specified in equations (2) to (6) for each group. In the software settings we have allowed both technical regress and progress over time and farms operating under variable returns to scale. We then estimated the sources of profitability, drawing on total farm income and total operating expenditure aggregates recorded in the dataset. Once productivity and profitability indices were estimated, the terms of trade index was estimated as a residual using equation (1).

3. Results and discussion

Profitability and productivity decomposition

Panel A in Figure 4 shows the changes in profitability (dPROF) and the components, terms of trade (dTT) and total factor productivity (dTFP). These measures are recorded for farms in each rainfall group and for each data period, using the 1998-2000 period as the base. Overall, profitability growth in all farm groups relative to the period 1998-2000 was more or less unchanged. The profitability index varied from 1.02 to 1.08. However, the sources of profitability were dominated by dTFP, with the dTT effect on dPROF being moderated by compensating changes in TFP. For example, the dTT for farms in the three rainfall groups improved for 2004-06 when dTFP decreased. As explained by O'Donnell (2010, p.550), "improvements in the *terms of trade* encourage technically efficient optimizing firms to expand their operations (further) into the region of decreasing returns to scale (and scope), with the result that increases in profitability are associated with falls in productivity". The opposite movement of dTT and dTFP change was also observed for 2001-03 and 2007-08, when the dTT decline was associated with an increase in dTFP.



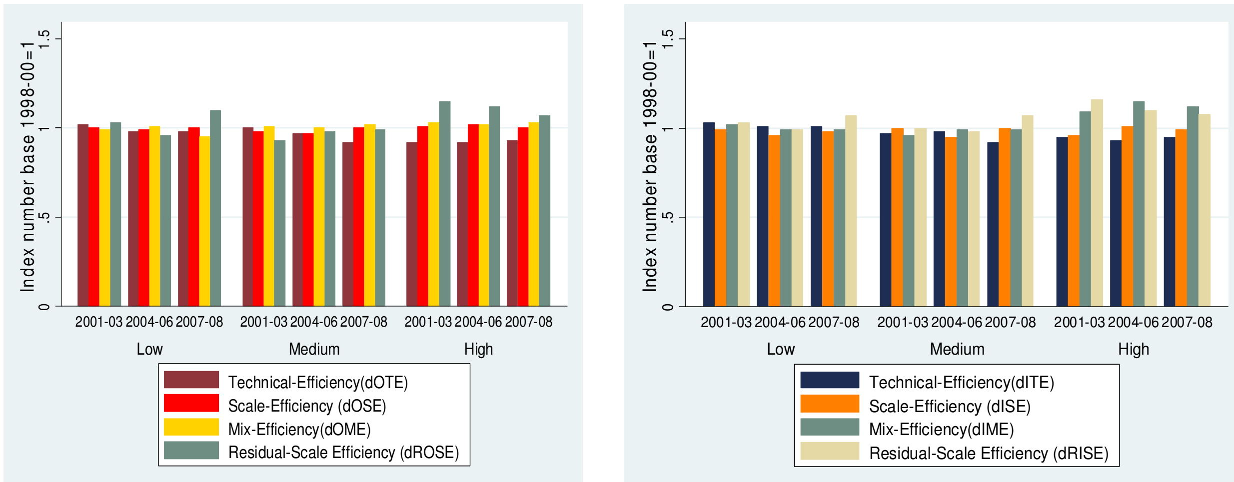
A. Profitability change B. Productivity change

Figure 4. Changes in profitability and productivity of farms in the three rainfall groups

Panel B in Figure 4 decomposes the total factor productivity changes (dTFP) relative to the period 1998-2000 into technical change (dTech) and efficiency change (dEff). Overall, TFP growth, relative to the 1998-2000 period, were high in 2001-03 and 2007-08. The TFP growth of farms in the low rainfall region was low in 2001-03 but caught up with the other groups in 2007-08. Importantly, in all groups and periods, technology change (dTech) was the main source of TFP growth. Whilst technical efficiency (dEff) also contributed to TFP growth, the differences in technical efficiency performance among farms in the three regions and across the three time periods were small.

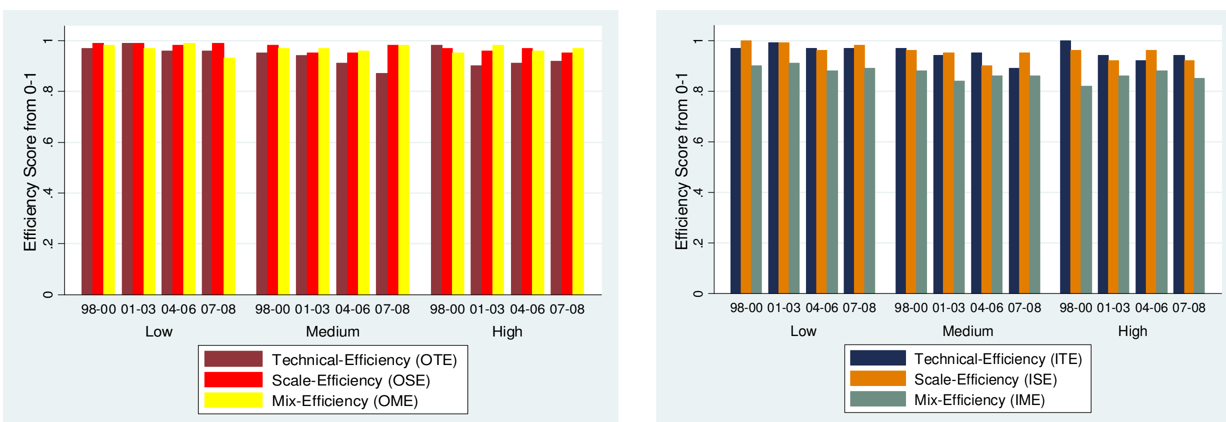
Efficiency changes and scores

The output and input oriented measures for the changes in efficiency categories (technical, scale, mix and residual) for the three farm groups in the three periods are presented in Panels A and B respectively in Figure 5 and the efficiency scores are displayed in Figure 6.



A. Output-oriented B. Input-oriented

Figure 5. Output- and input-oriented efficiency changes of farms in the three rainfall groups.



A. Output-oriented B. Input-oriented

Figure 6. Output- and input-oriented efficiency scores of farms in the three rainfall groups.

As seen from Figure 5, the output- and input-oriented efficiency changes of farms in three groups are slightly different and mostly invariant over the periods. However, the estimated mix and scale efficiency changes for farms in the high rainfall group are higher than other groups. This result suggests that farms in high rainfall region were more efficient in selecting combinations of inputs and outputs that achieved maximum productivity.

Figure 6 displays the output- and input-oriented efficiency scores of farms in the three groups. These scores are close to unity and invariant over the three periods. However, the output-oriented efficiency scores are greater than their input-oriented counterparts, especially the mix-efficiency scores. This finding is similar to that reported by O'Donnell (2010a).

It is possible to further decompose the data in Figure 4 (Panel B) to indicate the relative importance of differences in technical change (dTech), output-oriented technical efficiency change (dOTE), output-oriented mix efficiency change (dOME) and output-oriented residual scale efficiency change (dROSE). The importance of these factors in affecting change in total factor productivity (dTFP) is shown in Table 2. As stated earlier, in all groups and in all periods, technology change (dTech) is the main influence upon TFP growth. Between 68 to 100 percent of the positive change in TFP is attributable to technical change (dTech). Less frequent an influence on the change in TFP, and ranging from 8 to 28 percent is the residual scale efficiency change (dROSE). A relatively minor yet positive influence on the change in TFP, and often only at around 4 percent, is output-oriented mix efficiency change (dOME). Hence, led strongly by technical change, this set of factors (technical change, scale efficiency and mix efficiency) have driven the change in TFP observed across the sample of farms.

Table 2. Contributions to the change in TFP from technical change and efficiency components

		Low rainfall group			**Medium rainfall group**			**High rainfall group**		
		2001-3	2004-6	2007-8	2001-3	2004-6	2007-8	2001-3	2004-6	2007-8
dTFP	Rate	1.4	1.14	1.63	1.66	1.25	1.56	1.68	1.4	1.64
dTECH	%	87.2	95.5	85.9	98.8	100.0	97.2	75.3	68.1	85.7
dOTE	%	5.1			0.0					
dOME	%		4.5		1.2	0.0	2.8	4.1	4.3	4.3
dROSE	%	7.7		14.1				20.5	27.7	10.0

What might this mean in practice? It suggests a hugely important and beneficial role for new technologies, products and innovations that are the lifeblood of technical change. It identifies that scale efficiencies remain an important source of productivity gain for farm businesses. Results also suggests a minor beneficial role for the farm management task of selecting the mix of outputs and enterprises that underpin a farming system and that draw on a farm's set of inputs. However, the principal finding is importance of technical change in positively affecting TFP, and subsequently farm profitability.

Conclusion

This paper explores farm businesses' profitability and productivity in south-western Australia. The decomposition method of O'Donnell (2010a) was applied to farms in low, medium and high rainfall parts of the study region. The method allows the examination of how changes in farm input and output levels and their combination affect farms' profitability and productivity.

Farm business profitability remained more or less unchanged regardless of the investigation period or climate grouping due to the improvement in TFP being offset by recorded adverse changes in the terms of trade.

While improvements in technical efficiency contributed to total factor productivity growth, the differences in technical efficiency among farms in the three regions and across the three periods were small; except perhaps for farms in the high rainfall group.

The main finding was that technical change, rather than technical efficiency, was the main source of growth in total factor productivity. This finding applied to farms in all three time periods and in all three climate groupings. Moreover, growth in total factor productivity was found to be the major contributor to farm business profitability. It offset the adverse effect of changes in the terms of trade.

Between 68 to 100 percent of the positive change in TFP was found to be attributable to technical change. Less frequently, residual scale efficiencies and mix efficiencies (or scope economies) supplied 8 to 28 percent and 4 percent respectively of the improvement in TFP. So, largely technical change, followed then by scale efficiency and mix efficiency delivered the beneficial change in the TFP observed across the sample of farms.

The findings support the well-established view regarding the efficacy of scale economies. To a far lesser degree mix efficiencies also were revealed to be slightly important. However, the key finding was the major influence of technical change, rather than technical efficiency, in lifting farm profitability through improving farm TFP.

Farmers' ability to select and adopt best practices and innovations that lift their production possibilities is a main ingredient for technical efficiency. In other words, when farmers adopt best practice and innovations they move closer to the frontier. Education and training (including extension) can assist farmers in becoming more technically efficient. On the other hand technical progress is achieved through R,D&E expenditure which shifts the frontier. The results suggest that technical progress has been the main driver for farm profitability. This in turn highlights an important role for agricultural R,D&E, to create the innovations and knowledge from which technical change can spring. Because farm profitability is underpinned by technical change then generating innovations and information from which farmers can profit is clearly a sensible priority for all concerned. How to most cost-effectively identify and develop those innovations is an important but separate issue.

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