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Statistical analysis of Total Factor Productivity (TFP) for lamb industry

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1. Background

ABARE has supplied MLA with a yearly Total Factor Productivity (TFP) index for the years 1988/89 to 2006/07 as a measure of Australian lamb industry performance. The index suggests that the productivity gain over the period has risen only by 0.22% per year. This is different to the assumption made by Agtrans in the recent study of the R&D investment study for the lamb industry. The Agtrans assumption of a 1.6% per annum productivity gain was based on previous TFP estimates published by ABARE that used data only up to 2001/02.

2. Terms of Reference

1. Calculate correlation coefficients between TFP, an annual SOI index and a trend variable representing the series of years commencing 1988/89.
2. Fit simple linear regression lines as TFP as f (SOI) and f (year).
3. Fit multiple linear regression equations as TFP as f (SOI and year).
4. Repeat 2 and 3 above with final year omitted (2006/07) from analysis
5. Repeat 2 and 3 above for period 1988/89 to 2001/02 to match with Agtrans assumptions in earlier report.
6. Report on R^2 for each equation, coefficients for trend and SOI in each equation, and significance of coefficients.
7. Calculate performance coefficients using average year-on-year percentage increase method for periods up to 2006/07, 2005/06 and 2001/02.
8. Provide comments on implications for use of TFP.

3. Data used

The data used in the analysis are shown in Table 1. Sources of the data are in footnotes.

Year	TFP Index (a)	Year Number	SOI index (b)
1988-89	1	1	+ 15.07
1989-90	1.16	2	+ 1.57
1990-91	1.17	3	- 2.73
1991-92	1.14	4	- 10.53
1992-93	1.27	5	- 6.08
1993-94	1.27	6	- 7.00
1994-95	0.99	7	- 13.75
1995-96	1.16	8	+ 0.32
1996-97	1.18	9	+ 5.12
1997-98	1.21	10	- 13.75
1998-99	1.28	11	+ 11.78
1999-00	1.41	12	+ 6.90
2000-01	1.34	13	+ 8.43
2001-02	1.32	14	- 2.52
2002-03	1.02	15	- 8.97
2003-04	1.32	16	+ 0.68
2004-05	1.22	17	- 6.18
2005-06	1.27	18	+ 1.07
2006-07	0.89	19	- 8.28

(a) Total Factor Productivity index as supplied by ABARE to MLA. For analyses this series was transformed by a natural log function.

(b) SOI index is the average monthly SOI (Southern Oscillation Index) for July to December from Long Paddock web site – the first half of each financial year. Many studies have shown SOI is more highly correlated with a range of production measures than is simple totals of rainfall. Also ABARE use SOI rather than rainfall in their regional modelling. This series was transformed by a natural log function. To avoid negative numbers, the log transformations were made on (SOI +20).

4. Results

It is understood that the preferred method by ABARE to express TFP gain over time is to fit a trend line to the data series. The coefficient of the trend variable is then the slope of the fitted line and this is considered the average gain each year over the period and is usually expressed as a percentage gain.

Coefficients for ten equations were estimated in the current exploratory analysis.

(1) Log TFP as f (Year) for all observations

LN (TFP) = 0.1452 + 0.00226 Year (t for Year coefficient is 0.44 which is not significant at 90%; R^2 is 0.011).

(2) Log TFP as f (Year, Log (SOI+20)) for all observations
LN (TFP) = -0.1140 +0.00251 Year +0.0914 LN (SOI+20) (t for year coefficient = 0.513, not significant and t for LN (SOI+20) is 1.67 which is not significant at 90%; R^2 is 0.158).

(3) Log TFP as f (Year) for observations up to 2001/02 only.
LN (TFP) = 0.06187 + 0.0162 Year (t for Year coefficient is 3.11 which is significant at 99%; R^2 is 0.45).

(4) Log TFP as f (Year, Log (SOI+20)) for observations up to 2001/02 only
LN (TFP) = 0.04851 + 0.0157 Year +0.0401 LN (SOI+20) (t for year coefficient = 3.01 which is significant at 99% and t for LN (SOI+20) is 1.03 which is not significant at 90%); R^2 is 0.50).

Equations 3 and 4 show that omitting the past five years of data increased the productivity gain from around 0.23%-0.25% per annum up to 1.57% to 1.62% per annum.

(5) Log TFP as f (Year) for observations up to 2005-06 only (omitting last year)
LN (TFP) = 0.1054+0.00823 Year (t for Year coefficient was 1.94, significant at 90% level; R^2 was 0.19).

(6) Log TFP as f (Year, Log (SOI +20)) for observations up to 2005-06 only (omitting last year)
LN (TFP) = -0.0801 + 0.00789 Year +0.0664 LN (SOI+20) (t for Year coefficient was 1.96, significant at 90% level; t for LN (SOI+20) coefficient was 1.55 which was not significant at 90%; R^2 was 0.30).

Equations 5 and 6 show that the last year of data (2006/07) has a significant effect on
the trend coefficient. The effect is additional to the seasonal extent captured by the SOI index.

(7) Log TFP as f (Year) for all observations from 1989/90 (omitting first year)
LN (TFP) = 0.1838 - 0.0006 Year (t for Year coefficient was 0.12, not significant at 90%; R^2 was 0.001).

(8) Log TFP as f (Year, Log (SOI +20)) for observations from 1989/90 (omitting first year)
LN (TFP) = -0.1895 - 0.00225 Year + 0.14109 LN (SOI+20) (t for Year coefficient was 0.49, not significant; t for LN (SOI+20) coefficient was 2.76 which was significant at 95%; R^2 was 0.34).

Equations 7 and 8 show that the base year for the data (1988/89) has a significant effect on the trend coefficient.

The hypothesis that the rate of productivity gain (additional to the seasonal change approximated by the SOI term) has changed since 2001/02 was tested in the next two equations. A dummy variable was included to represent the years up to 2001/02 (dummy variable = 0) and after 2001/02 (dummy variable =1,2,3,4,5) and the two LN functions fitted again. Results were:

(9) Log TFP as f(Year, Dummy) (all observations)
LN (TFP) = 0.0694 – 0.0617 DUMMY + 0.0147 Year (t for year coefficient was 2.26 which is significant at 95% and t for DUMMY is 2.60 also significant at 95%. R^2 was 0.31).

(10) Log TFP as f(Year, Dummy, Log (SOI+20)) (all observations)
LN (TFP) = -0.1895 – 0.0579 DUMMY + 0.0142 Year (t for year coefficient for YEAR is 2.28 which is significant at 95% and t for DUMMY is 2.56 also significant at 95%, and t for LN (SOI+20) is 1.66 which is near significant at 90%); R^2 is 0.41).

By including the dummy variable the slope of the trend line for all observations changed significantly from a gain of 0.23% per annum (all years) to 1.47 % per annum up to the change in slope in 2001/02 (equation 9). With the SOI term included the slope changed from 0.25% per annum (all years) to 1.42% per annum up to the change in slope in 2001/02 (equations 2 and 10). This suggests there was a change in the trend line in 2001/02 additional to the seasonal change approximated by the SOI term. Given the limited data, the most likely hypothesis is that the trend is zero since 2001/02 but it should be borne in mind that may simply reflect that the seasonal indicator is not very precise.

Other ways of calculating productivity gain: year on year % gain
(11) Year on Year Gain derived from the index (all data)
The year on year percentage gain in the TFP index could be used to calculate the annual gain. This averages out at 0.44% per annum.

(12) Year on Year Gain derived from the index (omitting 2006/07 year)
The average year on year percentage gain was 2.22% per annum when the 2006/07 year was omitted, a significant increase.

(13) Year on Year Gain derived from the index (omitting 1988/89 year)
Excluding the 1988/89 year, the rate of gain was -0.48% per annum. If both the first and last year were taken out the average gain was 1.36% per annum.

(14) Year on Year Gain derived from the index (up to 2001/02 only)
When only the years up to 2001/02 were included, the average year on year gain was 2.66% per annum.

Average gain over period
An alternative approach is to calculate the average index over the period compared to the base year.

(15) Average of the Index (all data)
The average of the TFP index over the period was estimated from Table 1 as
1.201 (excludes base year of 1.0). On average, therefore, in any year over the period, the average productivity index was 20.1% more than the base year. The index ranged from 0.89 to 1.41 across the 18 years, excluding the base year.

If the index were to be assumed to increase gradually so that the average annual cost reduction was 20.1% for all years, then the gain would have to be about 2.11% per annum (2.1% times 19/2); this could be feasible to use, so long as the 2.1% per annum cost reduction is multiplied by the average production level over the period to get an estimate of the total cost reduction in each year. However, the method would still be sensitive to the choice of base year.

5. Summary

Table 2 shows the results for the ten equations.

Table 2: Parameters for the Ten Equations Fitted

Equation	Intercept	Year	LN(SOI+20)	DUMMY		R^2	Av % gain	Observations
1	0.1452	0.00226				0.01	0.23	all
		(t=0.44)						
2	-0.114	0.0025	0.0914			0.16	0.25	all
		(t=0.513)						
3	0.0619	0.0162				0.45	1.62	up to 2001/02
		(t=3.11)						
4	0.0485	0.0157	0.0401			0.50	1.57	up to 2001/02
		(t=3.01)	(t=1.03)					
5	0.1054	0.00823				0.19	0.82	up to 2005/06
		(t=1.94)						
6	-0.0801	0.00799	0.0664			0.30	0.80	up to 2005/06
		(t=1.96)	(t=1.55)					
7	0.1838	-0.0006				0.001	-0.06	from 1989/90
		(t=0.12)						
8	-0.1895	-0.00225	0.14109			0.34	-0.225	from 1989/90
		(t=0.49)	(t=2.76)					
9	0.0694	0.0147		-0.0617		0.31	1.47	all
		(t=2.26)		(t=2.60)			(to 2001/02)	
10	-0.1499	0.0142	0.0791	-0.0579		0.41	1.42	all
		(t=2.28)	(t=1.66)	(t=2.56)			(To 2001/02	

6. Implications

1. Equations 1 and 2 show that including all observations give a low rate of productivity gain, even if seasonal variation is allowed for. The variation in TFP explained is low and trend coefficients are not statistically significant.

2. However, equations 3 and 4 show that up to 2001/02 there was a strong real growth in productivity and although the SOI index influenced productivity gain positively, it was not overly important as a source of variation. These equations show that using data up to 2001/02 gave trend

coefficients of 1.57% to 1.62%, similar to the assumption made by Agtrans of 1.6%.

3. Equations 5 and 6 show that excluding the final year of the series (2006/07) resulted in a large increase in the average annual gain in productivity. This impact was probably an important part of the larger impact when the past five years were excluded (equations 3 and 4).

4. Similarly, excluding the first year of the series (Equations 7 and 8) resulted in the average rate of growth of productivity declining and, in fact, producing negative trend coefficients. The large increase in the index in the second year (from 1.0 to 1.16) is probably unduly contributing to the more positive gains reported in other equations. In general the impact of large changes in the first and last years would be less significant if they were mainly a seasonal effect and if the analysis had a good indicator of that. The concern is that the large increase in the first year of this series is anomalous as it was a time of such rapid adjustment following the end of the Reserve Price Scheme. For example, there could have been a rapid increase in the number of farms meeting the criteria of income from lambs of more than 20%.

5. Equations 9 and 10 show that there was a significant split in the series around 2001/02. The actual TFP and that predicted by equation 10 is shown in Figure 1 (the graph shows the actual TFP and the trend line estimated by removing the seasonal effect.). Hence it would not be advisable to use the 0.23%-0.25% gain calculated from all observations (Equations 1 and 2) over the 19 year period as the average gain for all years. Rather, the 1.6% average gain could be used up to 2001/02 and then a lower or zero rate of gain until a trend was confirmed. What this gain since 2001/02 should be is problematic as there are an insufficient number of years to be confident in any coefficient estimated. In addition the simple SOI index is not able to discriminate well between droughts of varying impacts on the industry.

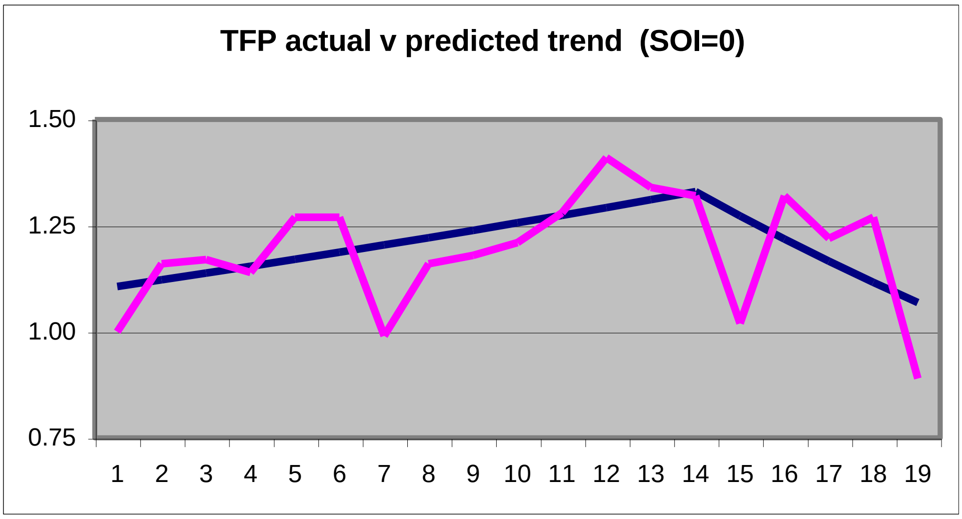

Figure 1: Actual and Predicted TFP using a Split Series

Year on Year % gain

6. The year-on-year % gain gave 0.44% for all data. However, the gain was 2.2 % per annum if the last year is taken out, and - 0.48% per annum if the first year was taken out. If both the first and last year were taken out the average rate of gain was 1.36% per annum.

Average index

7. If the average gain over the period is estimated and translated into a linear trend, then a higher % gain results. This is understandably the best diluter of the last year effects, but is a much coarser method and is still sensitive to the choice of base year. If used, it would require care, for example, by applying the productivity gain and any cost reduction to the average production over the period rather than to the production in individual years. However, while smoothing the year to year variability in TFP, the method would not be sensitive to any pattern of productivity changes over the period.

Taking out the climatic effect

8. The past five year decline in productivity gain could suggest that productivity-affecting factors such as technological change are influenced by the cumulative impacts of poor climatic years. If so, it may suggest that more needs to be done to develop new technology targeted at the poorer climatic years. However, there may be other factors involved in the apparent productivity gain decline. But the unusual rainfall pattern of the last five years may be relevant. Australian cropping areas have experienced eight years in a row of below average autumn rainfall. South-east Australia has experienced lowest on record autumn rainfall for the most recent eight-autumn period (Bureau of Meteorology analysis). The cumulative bioeconomic impacts are unlikely to be captured by a simple annual index such as the SOI.

9. Equations fitted without log transformations using YEAR, SOI, and YEAR x SOI interaction terms were very significant both in terms of R-squared and the significance of coefficients. The inclusion of the interaction term was based on a hypothesis that lamb industry productivity is now more highly responsive to seasonal variability than hitherto. In support of this hypothesis are the higher stocking rates, the heavier leaner lamb being produced, dependence on imported feed into the system, and possibly other factors. On the other hand the apparent decline in productivity may be simply part of the declining productivity growth in broadacre agriculture, mainly due to poorer climatic conditions in the past decade. Nevertheless the interaction term increased the goodness of fit of the positive trend line significantly.

   Taking out the impact of climate may be useful in sensitivity analyses to show the underlying improvement in technology produced. If livestock producers face increasingly variable climatic conditions in future, such approaches may be useful in benchmarking the success of industry adaptation strategies.

7. Recommendations

TFP is used for different purposes, in the main for describing the productivity gains made by different industries over different periods. The context of this current note is the estimation of the return to R&D investment over a period using a top down approach.

In this context, more attention needs to be given to understanding and incorporating into TFP analyses and TFP use:

- Seasonal climate impacts on TFP. The grain industry has used a relatively simple and routinely calculated moisture index for cropping areas that can be readily used to deseasonalise grain industry productivity measures and to give a better context to annual data. The equivalent capacity could be readily developed for the pastoral industries by adapting existing tools to the requirements of productivity analyses.
- The impact of choice of starting and end years is illustrated in this note. For the future, it would be worth investigating whether a base for analysis of a particular period should be one year or an average over some previous number of years.
- Methods other than the slope of trend line method for estimating average productivity gain over a period and the application of such parameters in producing broad cost reduction estimates for the impact of R&D are worthy of further analysis.