The Economic Impact of Research and Extension on South Australian Viticulture 1983 - 2002

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Author(s) Black, I.D. and Dyson, C.B.

South Australian Research and Development Institute
Entrance 2B Hartley Grove
Urrbrae SA 5064

Telephone: (08) 8303 9400
Facsimile: (08) 8303 9403
http://www.sardi.sa.gov.au

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Author(s):	I.D. Black (SARDI Principal Economist) and C.B. Dyson (Consultant Statistician)
Reviewers:	Andrew Manson (PIRSA Corporate Strategy and Policy) Dr Elton Li (University of Adelaide) Dr Mike McCarthy (SARDI Horticulture)
Approved by:	Dr Pauline Mooney, Director, Research and Development
Signed:	
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Executive Summary

At $2.7 billion gross value of production when wine making is included, viticulture is easily the most important crop driving economic activity in SA. It is estimated in this report that SA viticulture is currently serviced by $11M worth of research and extension (R&E) annually (inclusive of all institutions) for a grape growing industry whose farm gate value is approximately $720M. The R&E figure includes approximately $3M of R&D in SARDI plus some extension from PIRSA Rural Solutions SA (the figure includes both State Government and external funding). There is a need for accountability in the allocation of government funds in research and development and to clearly demonstrate acceptable returns on such investment. That need motivates this report.

Total factor productivity (TFP) decomposition and profit models were used to assess the impact of R&E on the three zones of South Australian viticulture – the Central cool climate zone, the Riverland warm climate zone and the South-East cool climate zone. The table below shows that lagged research and extension (REL) has provided an excellent return on investment, particularly for the Riverland. The explanation for this greater impact in the Riverland is probably the large research resource allocation by SARDI, CSIRO and the Victorian Department of Primary Industry for development of irrigation technology and techniques.

Internal rates of return (IRR) and benefit cost ratios (BCR) of lagged research and extension (REL) for SA viticulture zones

Zone	TFP Model		Profit Model	
	IRR	BCR	IRR	BCR
Central	42%	52:1	43%	59:1
Riverland	47%	76:1	48%	85:1
South-East	41%	52:1	44%	66:1
South Australia [a]	45%	53:1	46%	58:1

[a] Results from overall regressions.

When quality improvements in grapes are incorporated in the measure, TFP improvement in SA viticulture from 1983 to 2002 was assessed to be 2.3 percent. This is about the same as for Australian broadacre agriculture (2.5 percent). However, the same measure is only 1.0 percent without grape quality improvements. Given the marked reduction in TFP change with and without quality improvement, the regional IRR and BCR results using the data that does not incorporate grape quality improvements was relatively high (specific results shown later). This may reflect an emphasis in R&E on yield improvements in the first 10 years of the review period rather than on quality improvements, which were emphasised in the second 10 years of the review period.

From a socio-economic perspective, the bias towards greater impact of R&E in the Riverland has probably been beneficial. Given the lower profitability of viticulture in the Riverland compared to the cool climate zones shown in this report, which is due to lower grape prices, this bias has allowed more Riverland growers to remain viable through productivity improvement than would otherwise be the case.

The R&E intensity for SA viticulture is 1.6 percent, which is quite low compared to that for SA broadacre agriculture (3.9 percent). Even if there were diseconomies of scale in R&E investment for viticulture, considerably more R&E investment would be warranted before the levels of return would be reduced to a level commensurate with risk on a diversified R&E investment portfolio.

1 Introduction

The viticulture industry in South Australia produced an average $720M gross value of production worth of grapes in the 2002-2004 vintage seasons. After a period of rapid expansion in the 1990s, the crop is now second only in value to wheat in South Australia. If value added by wine making is also included ($1,940M) then viticulture is easily the most important farm enterprise driving economic activity in SA (most wheat is exported unprocessed). It is estimated in this report that SA viticulture is currently serviced by $11M worth of research and extension annually (inclusive of all sources). This figure includes approximately $3M of R&D in SARDI plus some extension from PIRSA Rural Solutions SA (the figure includes external funding). There is a need for accountability in the allocation of government funds in research and development and to clearly demonstrate acceptable returns on such investment. That need motivates this report.

Ex-ante and ex-post benefit-cost analysis and econometric analysis provide quantitative tools for these exercises. In examining the impact of research and extension on an industry, the authors' view is that econometric analysis is the superior tool because it relies mainly on historical data from statistics collection agencies, thus largely eliminating the need to exercise subjective judgements about the impact of particular research and extension (R&E) programs and projects when using benefit-cost analysis techniques.

Unfortunately, historical data sets are often insufficiently detailed for econometric analyses of small industries. Data sets may be problematical even for larger industries such as viticulture.

This report provides econometric analyses of the impact of R&E on the three zones of South Australian viticulture (Map 1):

- the *central cool climate zone* consisting of the Barossa, Eden and Clare valleys, the Adelaide Hills, the Adelaide Plains, McLaren Vale, Langhorne Creek and geographically associated newer viticulture regions,
- the *Riverland warm climate zone* and
- the *South-Eastern cool climate zone* consisting of the Coonawarra, Padthaway and geographically associated newer viticulture regions.

This zoning reflects different production systems, between the Riverland and the cool climate zones (the Riverland system is much more dependent on irrigation), as well as higher yields due to higher temperatures in the Riverland.

In conducting the analyses considerable judgement had to made in modifying particular data sets, and these methodological considerations are detailed in Section 2. These modifications of the historical data sets means that subjectivity once again becomes a concern, although not on the scale of that involved in many benefit-cost analyses.

The impact of research and extension[1] (R&E) on South Australian viticulture might be questioned because the unmodified data show that grape yields have been decreasing - Figure 1.

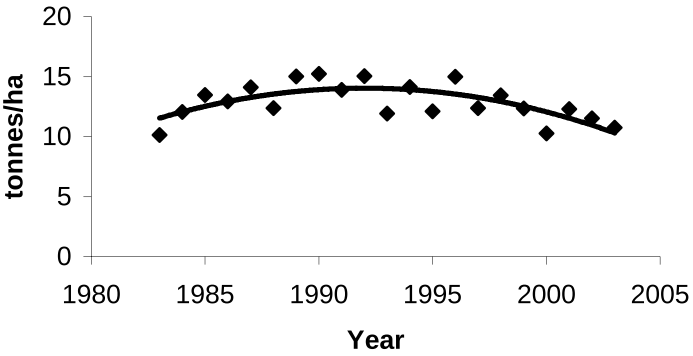


Figure 1. Yield of vines in SA

Figure 1 serves as a means to introduce the major deficiencies in the unmodified production data that are available for an econometric analysis of industry performance. Yields per bearing hectare take no account of the proportion of young bearing vines in the industry – vines take several years to reach their full bearing potential and the production data needs to be modified accordingly. At a disaggregated, zone by variety level, a further deficiency becomes apparent: varietal yields in individual zones fluctuate very considerably from year to year, particularly in the two cooler climate zones, and these fluctuations needed to be treated sensibly in order to avoid misleading results from statistical analysis. Figure 1 also conceals a third trend that has contributed to reduced yields: The growth in area planted to grapes in the cooler, relatively low yielding regions of the state has exceeded that of the high yielding Riverland. Hence, an aggregation of yield data across both the cool climate regions and the Riverland over time is likely to produce a downward trend in yields. In addition, most of the high yielding varieties in the Riverland have been replaced with lower yielding varieties better suited for bottled wine.

R&E primarily impacts productivity improvement in an industry and productivity improvement consists of growth in outputs less growth in inputs over time. In viticulture, growers trade off yield for quality and therefore a critically important consideration in an assessment of R&E

[1] Included in “extension” is Government agency extension activities, private consulting, technical advice to growers by agribusiness and “implied” technical advice by wine companies to growers through company technical officer inspections of vineyards, newsletters, clauses in contracts, etc (the advice is “implied” to avoid legal liability).

impact on viticulture is the improvement in quality of grapes reaching the winery[2]. The available statistics on production and price do not allow differentiation in grape quality within a given variety. Quality improvement plays a very large part in the productivity improvement of the industry and special measures, described in Section 2, were implemented in order to account for this factor.

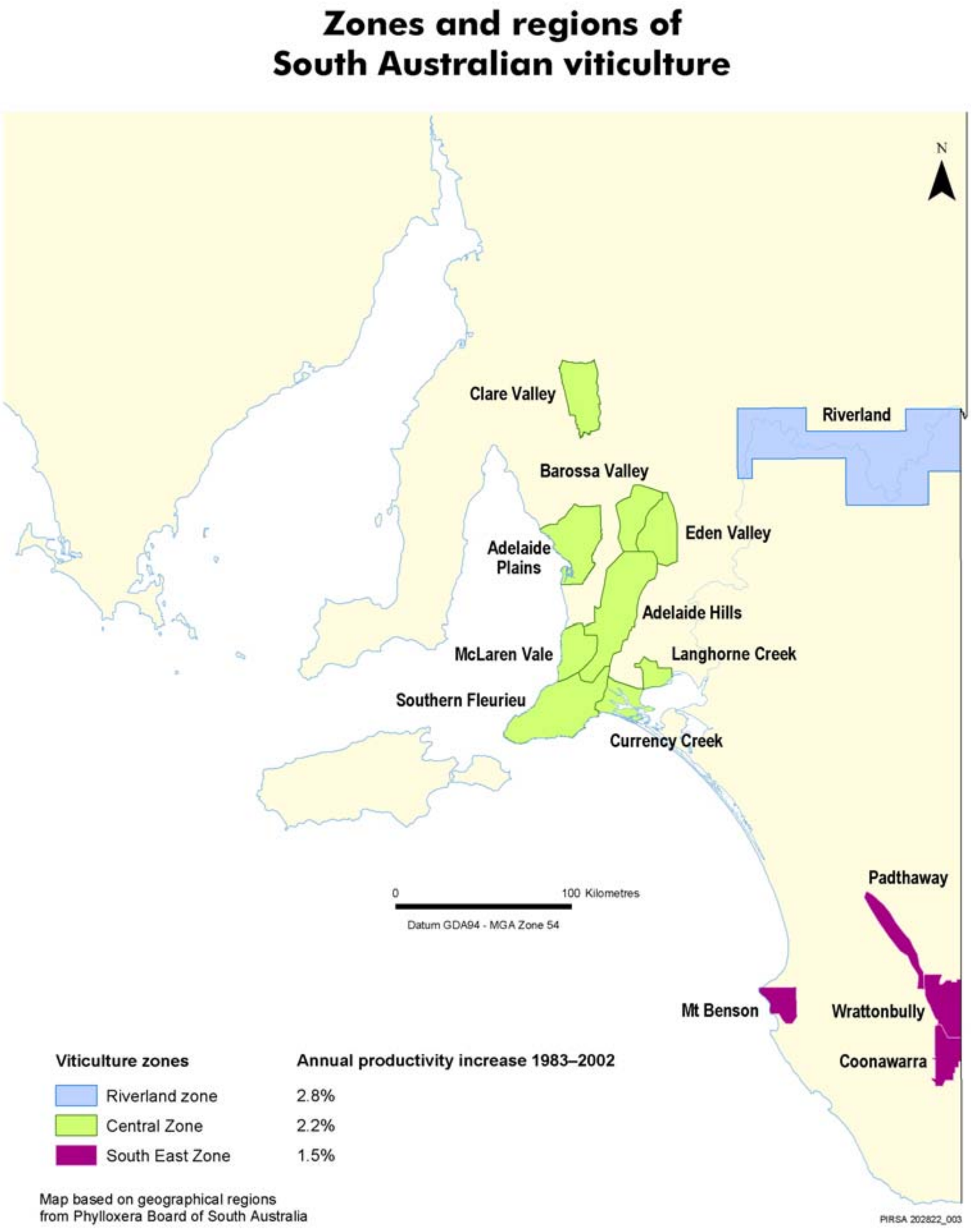
The second part of the productivity improvement equation, in addition to output change, is growth in inputs. Unfortunately, there is no historical data series available on industry costs that would enable a direct assessment of growth in inputs. Fortunately, however, viticulture dominates fruit growing in South Australia, so the ABS financial statistics for this sector of primary production were used as a proxy. Clearly, the necessary use of such data is less than ideal in terms of constructing an accurate input series.

An analysis of the impact of research and extension on viticulture also involved the construction of a proxy series for R&E. Essentially, this series had to be constructed from scratch and, again, the fact that a proxy is not readily available is less than ideal because it then involves some subjective decisions in proxy construction, which are detailed later.

The reader will adduce from the foregoing that the task of assessing the impact of R&E on South Australian viticulture has proved challenging (and interesting). Fortunately, however, the analyses show that R&E has had a large positive influence on the industry (see Summary). Therefore, even if the error associated with the estimated benefits is relatively large, the conclusion is beyond doubt.

[2] Table grapes and dried grapes form a very small portion of grape production in South Australia.

Map 1


Zones and regions of
South Australian viticulture
N
Clare Valley
Riverland
Barossa Valley
Eden Valley
Adelaide
Plains
Adelaide Hills
Langhorne Creek
McLaren Vale
Southern Fleurieu
Currency Creek
0
100 Kilometres
Datum GDA94 - MGA Zone 54
Padthaway
Mt Benson
Wrattonbully
Coonawarra
Viticulture zones
Annual productivity increase 1983–2002
Riverland zone
2.8%
Central Zone
2.2%
South East Zone
1.5%
Map based on geographical regions
from Phylloxera Board of South Australia
PIRSA 202822_003

2 Data aggregation and manipulation

The primary building blocks of an econometric analysis of the impact of R&E on an industry are time-series estimates of *outputs*, *inputs* (thus forming an estimate of productivity growth) and of *lagged R&E* impacting that productivity growth. In addition, *education* of the industry workforce participants, a proxy for human capital, can be used as a TFP decomposition model explanatory variable, as can viticulture *terms of trade*. The period of review was 1983-2002. In addition to the TFP decomposition model employed, a second approach involving a profit model was also examined. This involved deriving a *profit* index.

Estimates of both outputs and inputs were on a bearing hectare basis. For outputs, this was the most convenient platform on which to conduct the modifications to raw grape yield, as detailed below. For inputs, this basis was necessary to minimise the errors associated with the necessity of using a cost data series that incorporated other forms of fruit growing in SA.

Outputs

In terms of outputs, the data manipulation described in this section would largely not have been necessary if appropriately disaggregated grape quality categories with corresponding prices, that was consistent in terms of quality categories over time, could have been used to create a Divisia index. By this means, the critically important improvements in grape quality over time would have been captured. Unfortunately, this form of categorisation (by quality and price within the specific grape variety by defined geographical area) is lacking in ABS, and more recently the SA Phylloxera Board, price and production data.

Quantity and regional aggregation

Detailed data on bearing and non-bearing hectares and tonnes of each variety produced by vintage were available from ABS in all years of the review period under ABS regional definitions and later from the Phylloxera Board for grape-growing regions of South Australia. The ABS regions were:

"Yorke and Lower North", encompassing the Clare valley region;

"Adelaide" and "Outer Adelaide", encompassing the Barossa and Eden valleys, the Adelaide Hills, the Adelaide Plains, McLaren Vale, Langhorne Creek and geographically associated newer viticulture regions;

"Murraylands", encompassing the Riverland; and

"South East", encompassing the Coonawarra, Padthaway and geographically associated newer regions.

In addition, ABS data for all but 3 years was available at Hundreds level. Although there were some difficulties associated with data at this level (a very small level of production was attributed to absentee owners in city localities, for example) it was possible to get production and area by variety at wine growing region level for each year, with considerable input into proper attribution and management of the data (and with the assistance of the Phylloxera Board data for the missing years).

Conveniently, however, one of the ABS regions, "Yorke and Lower North", isolates one recognised wine-growing region – the Clare Valley. It was thus possible in an exploratory analysis to test whether or not regional level analysis might prove useful in isolating individual regional differences in the impact of R&E. Ordinary least squares (OLS) total factor productivity decomposition analysis involving "Yorke and Lower North" as a region separate from "Adelaide" plus "Outer Adelaide" indicated somewhat indecisive and unstable results for "Yorke and Lower North" as shown by the high coefficient of variation. This was probably due to the relatively small level of production as well as the influence of variable climate at flowering on grape yields and the results were, in any case, little different from those of "Adelaide" and "Outer Adelaide" combined. For this study, therefore, it was decided to treat "Yorke and Lower North" plus "Adelaide" plus "Outer Adelaide" as one viticulture zone.

Thus, there are three viticulture zones in this study (Map 1):

- the *central cool climate zone* consisting of the Barossa, Eden and Clare valleys, the Adelaide Hills, the Adelaide Plains, McLaren Vale, Langhorne Creek and geographically associated newer viticulture regions,
- the *Riverland warm climate zone* and
- the *South-Eastern cool climate zone* consisting of the Coonawarra, Padthaway and geographically associated newer viticulture regions.

Grape prices

Detailed region by variety price data (per tonne basis) was only available from the inception of the Phylloxera Board data series (1992). In addition, the earlier years of that series provided only partial region by variety price coverage. ABS only provides total value of grapes produced, on a statewide basis. Nevertheless this ABS data set, together with total tonnes of grapes produced, provides a broad guide to annual changes in price, on an average price per tonne basis. South

Australia operated a two-category minimum price scheme from 1981 until 1987 inclusive, and in 1992 and 1993[3]. The two categories were "Riverland" and "Other" and prices were for the main varieties of grapes grown. A check of average value using these data showed that it substantially agreed with the ABS calculated "average price per tonne" data and therefore these minimum price scheme data were used for the years until 1987. Using the ABS statewide price per tonne data as a guide, varietal price data was interpolated for the 1988-1991 vintages.

Grape categories

There are a large number of grape varieties grown in SA. However, only a few dominate production. In order to reduce the work of data manipulation to a manageable level, it was decided to concentrate on those varieties that constitute a large part of production.

<u>Red varieties</u>: Shiraz and Cabernet Sauvignon dominated production throughout the period (they represented an average 41 percent and 32 percent in the 2000-2002 vintages, respectively). In addition, Merlot represented 9 percent of the production over those vintages (in 1982 there was virtually no Merlot grown in SA – it is not recorded in ABS statistics until 1985). The red grape categories chosen were therefore Shiraz, Cabernet Sauvignon, Merlot and "Other".

<u>White varieties</u>: At the beginning of the period Riesling was the most important variety grown in the cool climate zones, and produced a significant portion of the production in the Riverland. Overall, it represented an average 14 percent of SA white grape production in the 1982-1984 vintages and 8 percent in the 2000-2002 vintages. Although sultanas and some high yielding white varieties dominated production in the Riverland at the beginning of the period, they were insignificant in the cool climate zones. By contrast, Semillon and Sauvignon Blanc were significant in the cool climate zones throughout the period but were insignificant in the Riverland at the beginning of the period. Chardonnay now forms a large portion of SA white grape production, but was insignificant at the beginning of the period (42 percent in the 2000-2002 vintages, 1 percent in 1982-1984). In order to impose consistency across zones a consideration in choosing categories was that they (1) represented a significant level of production in all zones, particularly towards the end of the review period, and (2) production was sufficient to reduce very large fluctuations in both production and price between vintages in the cool climate zones. For these reasons sultanas and the high yielding white varieties grown in the Riverland (1), and Semillon and Sauvignon Blanc (2) were not analysed as individual varieties. The final white grape categories were therefore Chardonnay, Riesling and "Other".

[3] We are indebted to Geoff McLean, PIRSA, for providing the historical records of these data. Geoff was the SA Department of Agriculture representative on the Wine Grape Prices Committee.

Initial yield manipulation

Yields per bearing hectare take no account of the proportion of young bearing vines in the industry – vines take several years to reach their full bearing potential and the production data needs to be modified accordingly. At a disaggregated, zone by variety level, a further deficiency becomes apparent: varietal yields in individual zones fluctuate very considerably from year to year, particularly in the two cooler climate zones, and these fluctuations needed to be treated sensibly in order to avoid misleading results from statistical analysis.

For each grape category by zone raw yields were manipulated over the review period. Raw yields were modified according to the area of young bearing vines contributing to production (young vines do not produce as high a yield as mature vines), and for atypical growing seasons. The example chosen to illustrate the problem of atypical growing seasons and the procedure to overcome it is Shiraz in the South-East zone.

Figure 2 shows the raw yield data for Shiraz in the South-East:

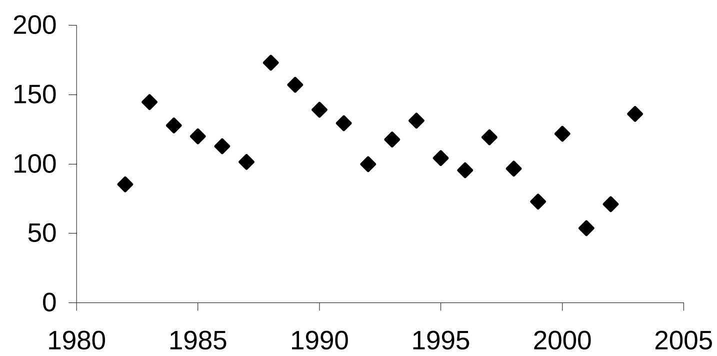


Figure 2. SE raw Shiraz yield, 1992 = base 100

Figure 2 illustrates large differences in yield between seasons. The differences are mostly unrelated to rainfall which is, in any case, mitigated by irrigation (1982 and 2002, drought years, may have influenced the low yields in those seasons). The erratic nature of the yields is due mainly to conditions at flowering time in cool climate regions. Cold and wet conditions at flowering markedly reduce yields (M McCarthy, pers. comm.). Because there is no convenient proxy for climatic conditions at flowering time that could be used as a covariate in a statical analysis, the procedures discussed below were implemented in order to reduce the erratic variation in yields through time.

Table 1 shows the raw yield data in Figure 2 in tabular form together with columns for the two corrective measures taken to manipulate these raw data: non- bearing ha lagged two years (1992 = base 100) and unusual years. By inspection of Figure 2 it can be seen that some years have unusually low or high yields. These years were assigned 1 (low yield) or –1 (high yield). The model used can be represented as:

(1) $$CY = RY + aUY + bLNBha$$

Where:

CY Corrected yields

RY Raw yields

UY Unusual years

LNBha Lagged Non-bearing ha, and

a and *b* are coefficients to be estimated in a regression analysis.

The four columns provided data for the regression analysis, the results of which are shown in Table 2.

Table 1: Data for Shiraz yields in the SE zone

Year	1992=100 Raw yield	1994=100 index (1992 lagged 2 years) Non-bearing ha	Unusual Years	Regression Analysis Corrected
1982	85.4	1.9	1	108.2
1983	144.5	1.9	0	144.6
1984	127.9	0.0	0	127.9
1985	120.1	0.0	0	120.1
1986	112.9	5.8	0	113.1
1987	101.5	0.0	1	124.2
1988	172.9	0.0	-1	150.2
1989	157.0	0.3	0	157.0
1990	139.0	2.9	0	139.1
1991	129.4	38.0	0	130.4
1992	100.0	179.3	1	127.4
1993	117.6	213.3	0	123.2
1994	131.2	100.0	0	133.8
1995	104.4	127.0	0	107.7
1996	95.4	584.6	0	110.6
1997	119.3	895.7	0	142.6
1998	96.8	679.4	0	114.4
1999	72.9	447.8	1	107.3
2000	121.8	488.4	0	134.5
2001	53.7	879.7	1	99.3
2002	71.2	370.3	1	103.5
2003	136.1	424.5	0	147.2

Table 2: Results of the regression analysis for Shiraz Yields in the SE zone

Regression Statistics	
Multiple R	0.89
R Square	0.79
Adjusted R Square	0.76
Standard Error	14.05
Observations	22

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	13740.93	4580.31	23.20	2.08E-06
Residual	18	3553.58	197.42		
Total	21	17294.52			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Year	0.139	0.764	0.182	0.858
Lagged non-bearing ha	-0.038	0.017	-2.288	0.034
Unusual Years	-40.291	5.917	-6.809	0.000

According to the coefficients for lagged non-bearing ha (*b*) and unusual years (*a*) shown in Table 2, the yields were therefore corrected by (1):

(1) $$CY = RY + 40.3 * UY + 0.038 * LNBha$$

The result is shown in the last column of Table 1 and in Figure 3.

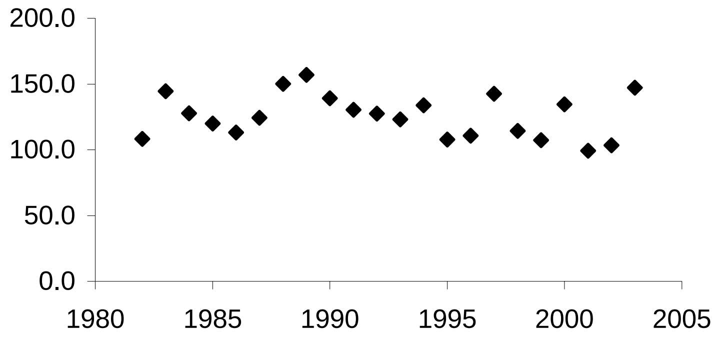


Figure 3. SE Shiraz Corrected Yields (1992 raw yield = base 100)

Following this individual grape category by zone manipulation, zone aggregate data were compiled using annual value of each category in the zone as weights.

Incorporating improvements in the quality of grapes reaching the winery

The available statistics on regional grape production provide information on quantity and value by grape variety over time. Data are not available on the quality of grapes reaching wineries in these categories. Grape quality is critically important in viticulture. Hence estimating productivity improvement, which forms the basis of the R&D impact study, will be inaccurate if grape quality improvements are not taken into account. An assessment of quality improvement over the 1980-2004 period was gained by five in-depth interviews of experienced industry participants, and we are grateful to the interviewees for providing their time[4]. Once this estimate of the value of grape quality improvement was obtained, the second step in the process involved converting this into a yield increase. This was carried out through use of an own-price elasticity of grape production in each region. This elasticity was obtained by use of a zone supply model – see below. By this means TFP calculations incorporating quality were obtained, the only differentiation in the outputs within a zone being between grape variety categories.

In summary there has been a considerable improvement in wine grape quality over the 1980-2004 period, both in the cool climate zones and in the Riverland, and it has been possible to gain a reasonable estimate of the monetary value of those improvements, as shown in the diagram. Although there was agreement about trends, there was some disagreement amongst the interviewees as to precisely how much improvement there has been. Figure 4 shows an average of the 1980 estimated zone relative quality (2004=100). There was, apparently, little difference in quality improvement between varieties, except possibly where clonal selections have had an impact on production of some varieties, especially Cabernet Sauvignon. Note that Figure 4 does not imply that quality in the zones in 2004 was equivalent.

[4] The interviewees were Dr Mike McCarthy, SARDI; Russel Johnstone, Orlando Wyndham; Vic Patrick, Beringer Blass; Peter Hayes, Penfolds; Bill Potts, Langhorne Creek grower. We would also like to acknowledge the contribution of Dr Jim Hardy, CRC Viticulture, and Mike McCarthy, who helped formulate the questionnaire that formed the basis for these interviews.

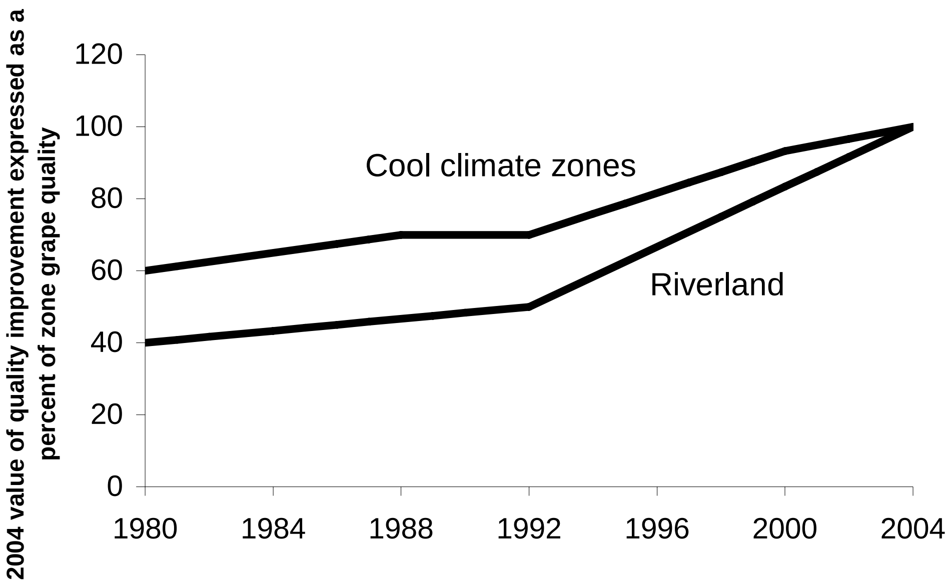


Figure 4. Quality improvement in SA Grapes 1980-2004

Combined with nominal prices, Figure 4 can be viewed as revealing the price that would have been set if there had been no quality improvement in that year. For this deficiency in the system example, if grape quality improvement in the Riverland was worth a nominal 3 percent between the 1993 vintage and the 1994 vintage, then if there had been no quality improvement the nominal value of grapes in 1994 would have been 3 percent less than the statistics reveal.

<u>Technical reasons for grape quality improvement</u>

Better disease control, due to improved fungicide programs, better weather forecasting, timing of sprays and better coverage from improved spray machinery.

Mechanical harvesting, allowing timely and rapid harvesting in the evening and cool of the day, with improvements in the machines over the years gradually reducing damage to grapes and reducing harvested matter other than grapes.

Improved chemistry and colour, due to better matching of areas to be harvested at a particular time with sugar content, colour and phenolic ripeness.

Better vineyard siting, layout, canopy structure and irrigation and nutrition management, all leading to improved chemistry and colour whilst maintaining yields at desirable levels. In particular, the combination of *drip irrigation* and *regulated deficit irrigation* (RDI) has led to very significant improvements in chemistry and colour in the Riverland.

Release of better varietal clones has reduced alternate bearing problems in some varieties, Cabernet Sauvignon in particular, with a consequent improvement in the reliability of grape quality across seasons[5].

Economic incentives/disincentives for grape quality improvement

Until 1988, when minimum price schemes were dropped, there was no strong incentive to improve grape quality - wineries took grapes of widely differing quality at that price. In the Riverland in particular there was also no disincentive to switch to quality wine making grape varieties from high yielding grape varieties that were more suited to making bulk and fortified wine. Nevertheless, gradual improvements in disease control and harvesting machinery and timing improved grape quality over this period.

Cool climate regions: The initial penetration of overseas markets (1990-1993) led to wineries taking as many grapes as possible and without irrigation restrictions there may have been reduced quality in some batches. Since 1994, wineries have developed increasingly sophisticated payment incentives and spoilage disincentives for grape quality. These payment schemes, as well as technical officer inspections of vineyards, produced an increase in quality. Quality increases have declined over the 2002-2004 period, reflecting a satiation of the market for very high quality wine at the bottle prices asked.

Riverland: The rapid increase in wine exports in the 1993-2000 period led to payment scheme incentives for Riverland growers to improve quality to meet the demand for Australian bottled wine and improved cask wine. The change to drip irrigation and increasing adoption of RDI, along with other factors mentioned in the previous section, has enabled growers to increasingly meet these quality requirements.

In both the cool climate regions and in the Riverland: there was probably not as much quality increase as wineries would have liked in the 1994-2000 period because of the shortfalls in supply as export demand increased rapidly. However, as the relative position reversed in the 2001-2004 period the payment schemes have sent a strong economic signal to growers to improve quality and to expect somewhat lower returns at conventional quality standards.

Incorporation of grape quality improvements into the productivity improvement estimates

As stated by Alston, Norton and Pardey (1995, pp 132-133):

> If the quality of, say, horticultural products had risen over time, and the measure of the quantity of horticultural products had not been adjusted accordingly, we would be

[5] Some innovation has reduced grape quality: mechanical pruning in particular, although the negative effects of mechanical pruning on grape quality have been reduced over the years, as the management of this technique has improved.

understating the real growth in output, some of which was in the form of quality improvement.

The approach taken to incorporating grape quality improvements in productivity improvement was to use the price mechanism to arrive at a counterfactual yield per hectare in the absence of quality improvements. That is, if some of the increased inputs had not been used to improve quality, they would have been used to increase yield[6].

A supply model was used to arrive at an-own price elasticity for grapes for each zone:

$$Q_t = q(P_t, W_t, REL_t, EDU_t) \tag{2}$$

Where:

Q_t is corrected quantity of grapes produced in the zone[7] in year t,

P_t is nominal average grape price in the zone[8],

W_t is the ABARE index of prices paid by farmers,

REL_t is the index of lagged research and extension impacting viticulture in SA, a proxy for technology in use, and

EDU_t is an education index for viticulture in SA, a proxy for human capital

The log-log configuration was used. Education, *EDU*, did not contribute as an explanatory variable and interfered in the proper functioning of the three zone models in OLS analyses - when this term was included model explanatory power was weak and the coefficients on *P* and *W* were often incorrectly signed; hence it was dropped. Lagged research and extension (REL) was necessary for the proper functioning of the models – when this term was dropped model explanatory power was weak and the coefficients on *P* and *W* were often incorrectly signed. The results of the final configuration are shown in Table 3.

[6] The weakness of this counterfactual approach is that resources may have been used in differing proportions, i.e. more land may have been used in preference to increased inputs per hectare in order to produce the increase of unimproved quality grapes dictated by price.

[7] See "Initial yield manipulation" section, above. These yields in time *t* were then multiplied by bearing ha in time *t* to produce Q_t.

[8] Use of CPI indexed prices failed to produce a significant result in exploratory analysis.

Table 3: Own-price elasticity of grape production

Zone	Grape own-price elasticity	t value	Input price t value	REL t value	Coefficient of variation
Central	0.53	3.40***	-2.02*	3.06***	15.9%
Riverland	0.23	1.88*	-3.75***	6.56***	10.1%
South-East	0.57	2.73**	-0.76	1.74*	25.1%

*, **, *** Significant P< 0.1, 0.05 and 0.01 respectively (one tailed test).

The own-price elasticity in the Riverland zone was expected to be less than in the other two zones. Stricter yield restrictions in relation to yield potential were written into grape contracts in that zone, in order to improve grape quality (the yield potential in the Riverland is greater than the other zones because of a warmer climate and access to virtually unrestricted irrigation water).

The proportional grape price series shown in Figure 4 was then combined with the relevant elasticity to produce the quality adjusted yield, as shown in (4):

$$(3) \qquad Y_{Z(X)QA,t} = Y_{Z(X),t}\left(\frac{\propto_t \; P_{2004,Z(X),t}\,\varepsilon_{Q:P,Z(X)}}{\propto_b \; P_{2004,Z(X),b}\,\varepsilon_{Q:P,Z(X)}}\right)$$

Where:

$Y_{Z(X)QA,t}$ is the quality adjusted grape yield for zone X in time t

$Y_{Z(X),t}$ is the actual grape yield for zone X corrected for young bearing vines and unusual years – see (1)

$\propto_t P_{2004,Z(X),t}$ is the proportion of the 2004 zone price average quality grapes for that year would attract in 2004 (Figure 4)

$\propto_t P_{2004,Z(X),t}$ is the proportion of the 2004 zone price average quality grapes for the base year would attract in 2004 (Figure 4)

$\varepsilon_{Q:P,Z(X)}$ is the own-price elasticity of grapes in zone X

When adjusted for quality the yield series in Figure 3 becomes:

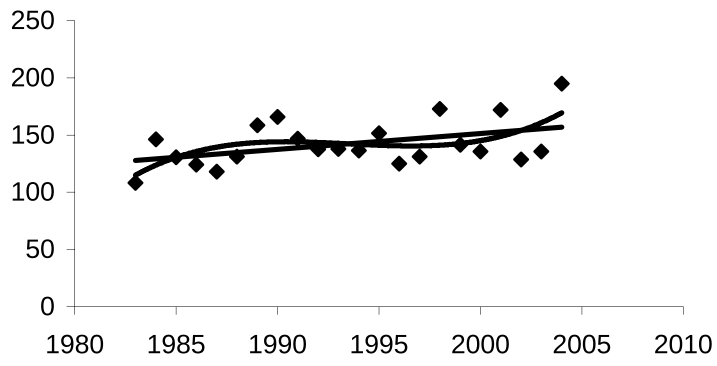


Figure 5. SE Shiraz Corrected Yields adjusted for quality (1992 raw yield = base 100)

A diagrammatic inspection of these data of corrected yields adjusted for quality, of the sort shown in Figure 5, show that the degree of dispersion of individual datum around a trend varied markedly between zones. The degree of dispersion was largest in the SE zone and smallest in the Riverland. This was confirmed by exploratory OLS analysis – there was wide divergence in the residual variance between zones. The divergence would be expected to be least in the Riverland because of its reliable warm climate and virtually unlimited available irrigation water. This divergence makes comparison of the zone results less secure. To ensure comparability between zones, curves were fitted to the corrected yields and the aggregated mean yields[9] in the SE and Central zones consisted of a combination of fitted and corrected yields (see e.g. Figure 5: in this case, because of some doubt about the relationship, two curves were fitted and the results meaned).

Zone:	*Corrected:fitted yield ratio*	*Residual variance in final analysis*
Riverland	1.0:0.0	0.00206
Central	0.7:0.3	0.00201
SE	0.4:0.6	0.00194

[9] The aggregate mean yield in each year (i.e. modified corrected yields multiplied by bearing ha in each grape category, producing a total counterfactual tonnage which was then divided by total bearing ha) formed an output index vector, **Q**, which was converted to 1983 = base 100.

(4) $$\mathbf{Q_t} = \left(\sum_{i=1}^{n} Y_{MCi,t} A_{i,t} \right) \Big/ \sum_{i=1}^{n} A_{i,t}$$

Where:

$Y_{Mci,t}$ is modified corrected yield of grape category *i* in year *t*, and

$A_{i,t}$ is bearing area (in ha) of grape category *i* in year *t*, and

n is number of grape categories.

Inputs

Unfortunately, there is no historical data series available on industry costs that would enable an indirect assessment of growth in inputs. Fortunately, however, viticulture dominates fruit growing in South Australia, so the ABS financial statistics for this sector of primary production were used as a proxy. Across the time series, it is estimated that the value of viticulture varied between 50 –70 percent of the total value fruit production in this ABS category. Clearly, the necessary use of such data is less than ideal in terms of constructing an accurate input series. After adjusting the data to the value of grape production in that year, the input data series was constructed on a unit area (ha) basis, in part to minimise the obvious error associated with the ABS "fruit growing" statistics sector- that of growth incorporating other fruit growing industries.

An examination of these ABS data showed large inter-year fluctuations, in part caused by the relatively small sample size (and were therefore manipulated through use of 3-year rolling means for the total of the inputs data series – see below). These fluctuations were particularly evident in the sub categories within these data. These cost data were converted to growth in inputs through use of the Tornqvist-Theil Divisia index, an index that is particularly suitable for logging the resultant data series (Alston, Norton and Pardey 1995, p. 128). The input classifications used were

"Purchases and selected expenses",

"Cash surplus" – used as a proxy for owner/operator and family labour,

"Net capital expenditure" – used as a proxy for machinery and infrastructure improvements, and

"Total value of selected assets" – used as a proxy for the improved capital value of land.

The "Cash surplus" category is particularly problematical because it captures temporary windfall profits. In addition, many vineyards are corporately owned – hence the returns are to investors. Nevertheless, an inspection of data for average vineyard size over the review period indicates that the average vineyard was small enough to be family owned and operated.

For Divisia index purposes, the above categories were matched with the appropriate ABARE price series or the Consumer Price Index in the case of "Total value of selected assets".

The resultant data series showed unacceptable fluctuations between years and these fluctuations were damped through use of 3-year centred rolling means. This input data series was applied across all zones. In the absence of more specific data, this appeared to be the most appropriate decision. However, the "Total value of selected assets" category becomes problematical when used in a zone context: much of the expansion of the Central and South-East zones would have been onto relatively low value grazing land whereas that in the Riverland would have been in replacing other irrigated crops on high value irrigated land with at least some appropriate irrigation infrastructure. This implies different rates of contribution by the improved capital value of land in an input index in the different zones.

The Tornqvist-Thiel input Divisia index was used in its dual form (i.e. inputs, *X*, were derived from deflating values of each category with the appropriate price index, *W*) to form the input index, with 1983 as base 100. Once *X* is derived, the formula is:

(5) $$\ln\left(XI_t^{DT} / XI_{t-1}^{DT}\right) = \sum_{i=1}^{m} \tfrac{1}{2}\left(S_{i,t} + S_{i,t-1}\right) \ln\left(X_{i,t} / X_{i,t-1}\right)$$

Where:

$X_{i,t}$ represents input *i* in year *t*,

$\ln\left(XI_t^{DT} / XI_{t-1}^{DT}\right)$ is the rate of change in the input Divisia index from period *t*-1 to *t*, and

$\frac{1}{2}\left(S_{i,t} + S_{i,t-1}\right)$ is the cost share of input *i* given by

(6) $$S_{i,t} = X_{i,t} W_{i,t} \Big/ \left(\sum_{i=1}^{m} X_{i,t} W_{i,t} \right)$$

Where:

$W_{i,t}$ represents input price *i* in year *t*.

Profit

A profit index, necessary for the use of the dual profit model that was employed in addition to the TFP decomposition model, was constructed by means of a real growth in revenue per ha index less real growth in selected costs per ha index. The real growth in selected costs per ha was used as total costs, which included the "Cash surplus" category, proved to be far too erratic to provide realistic input. The initial results were subject to a 3-year centred rolling mean transformation in order to reduce unrealistic perturbations in the series. The index was CPI-adjusted. The result is shown in Figure 6.

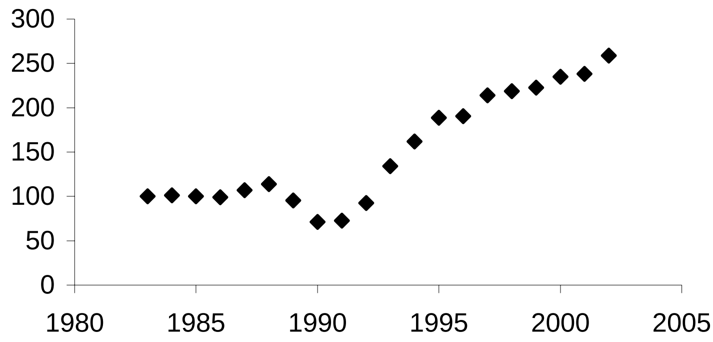


Figure 6. SA Viticulture profit/ha 1983 = base 100

Figure 6 generally reflects grape prices. Profitability was essentially unchanged during the 1983-1987 period because of the minimum price scheme. Profitability fell when the minimum price scheme stopped. This may not have been due to a drop in prices for desirable grape varieties. When the minimum price scheme was dropped, the wineries reduced the price of undesirable varieties as a strong incentive to Riverland growers to change to more desirable table wine varieties. As Riverland growers replanted/regrafted there would have been a number of years before the new plantings/graftings produced grapes, and hence profitability suffered during that period. Profitability increased rapidly when export demand for wine started to have an impact on the market, increasing prices from the early nineties.

Research and extension

A research and extension (R&E) index for viticulture in South Australia was constructed from interviews and records. All sources of formal research and development and of extension were included in the index. For research and development, these included SARDI and its predecessor the Department of Agriculture, The University of Adelaide, CSIRO and private corporate R&D in agrichemicals, fertilisers and machinery. This approach has the advantage of avoiding multicolinearity amongst individually included variables. As well, it admits the common-sense consideration that it would not be possible to accurately attribute the value of productivity gains between such a large number of sources of research and extension. For extension, these included PIRSA Rural Solutions and its predecessor the Department of Agriculture, private consulting, and part of winery technical officer activities. Initially the resources were counted as full time equivalents in all categories except private corporate R&D.

In the absence of specific records of viticulture R&E resources, SARDI and its predecessor the Department of Agriculture, PIRSA Rural Solutions, the University of Adelaide, private consulting and winery activity resources were drawn up from Dr Mike McCarthy's extensive knowledge of

R&E for the SA industry, and these data were informally checked using other information sources. It was assumed knowledge spill-ins to SA equalled spill-outs from SA in these categories. CSIRO Divisional annual reports, which contained summaries of their viticulture projects as well as staff lists, were consulted to gain an assessment of the resources devoted to viticulture by that organisation. A proportion of the CSIRO program was allocated to wine grapes, based on these project summaries, and a pro rata allocation then made to SA based on the value of grape production compared to the rest of Australia. Full time equivalent research/extension personnel was the initial unit chosen. These numbers were then doubled to take account of administrative and infrastructure support, and then multiplied by $75,000 (allowing for both salary and personal overheads) to come to a 2004-dollar figure.

Private corporate research and development was estimated using a percentage of machinery (2 percent), agricultural and veterinary chemical (5 percent) and fertiliser (2 percent) sales to SA viticulture, based on an idealised per ha budget for SA grape growing (Boon *et al.* 1999) The percentages are guided by OECD industry R&D data for 1991 (OECD 2003). An extensive discussion on why these percentages were chosen is contained in Black (2004, pp 83-84) for the broadacre agriculture industries. The reader is referred to that discussion for further detail. No reason was seen to vary the figures for viticulture at the end of the review period. However, these figures were progressively staged-in using a proportional approach. The reason was that it is believed that agribusiness played little part in R&D for SA viticulture early on – the value of chemical sprays and machinery in farm budgets was relatively small at the beginning of the period, and relied considerably on spillover technology initially aimed at other, larger industries.

Figure 7 shows the results from individual sources of R&E and Figure 8 shows the aggregate.

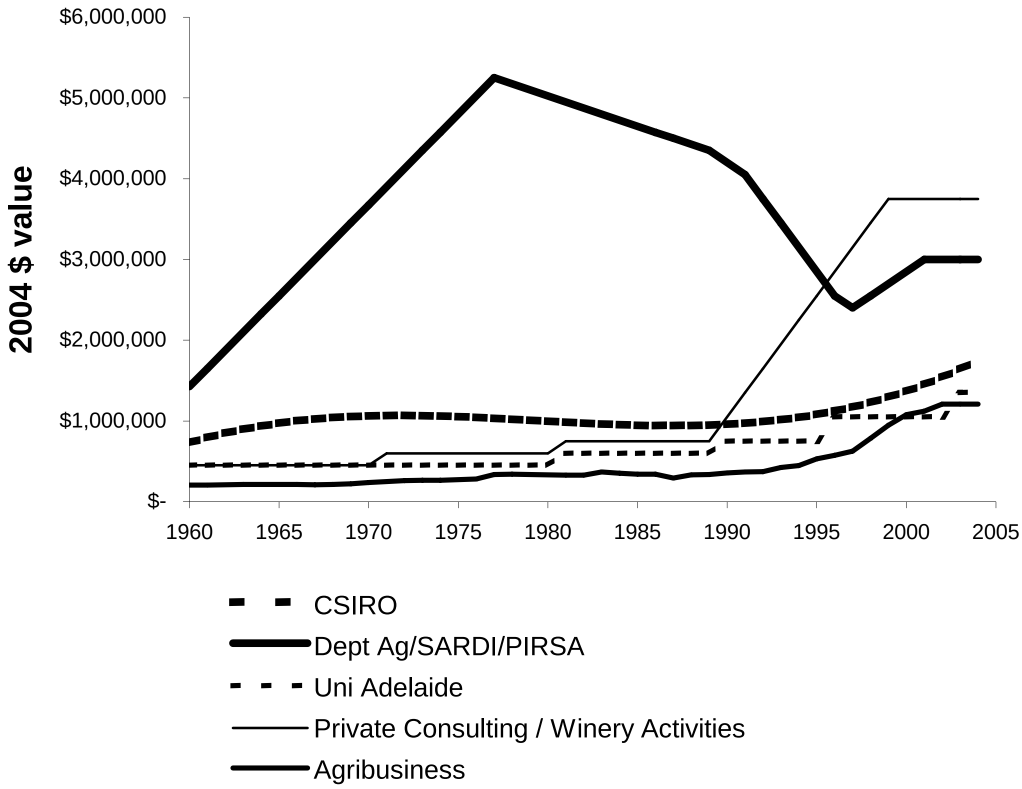


Figure 7. Value and sources of R&E for SA viticulture

The Department of Agriculture/SARDI/PIRSA resources reflect the initial strong build-up of resources in both research and extension in the 60s and 70s. A decline in resources followed in the late 70s and 80s, reflecting more stringent Government budgets as well as the relative decline in value of the viticulture industry. The sharp decline in resources in the early-mid nineties was due to the PIRSA withdrawal of extension resources from the industry. The partial recovery was due to increased external funding of SARDI research. Department of Agriculture/SARDI research suffered less dramatic changes in funding – a decline in Government funds was offset by an increase in external funding. CSIRO research resources reflected the value of the industry relative to other horticultural industries, to some extent. It is also clear from Figure 7 that there has been a considerable increase in private consulting activity and a very considerable increase in activity by the large wineries through their employment of technical officers used for vineyard inspections, technical specifications etc. This increase in resources partly reflects the withdrawal of PIRSA from extension (i.e. industry sources replaced those resources withdrawn by government) and partly reflects the expansion and increasing value of viticulture in the 90s.

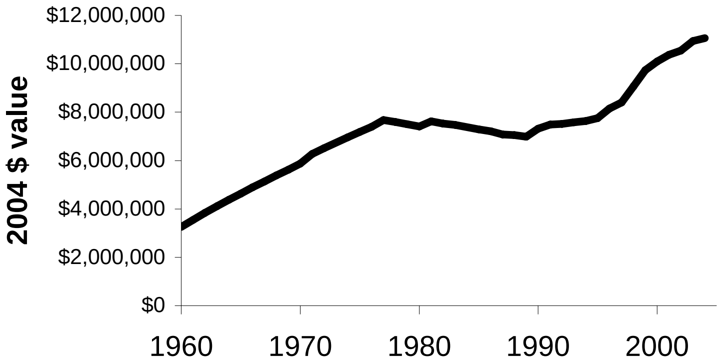


Figure 8. Total R&E Resources Impacting SA Viticulture

While Figure 7 shows an unrealistic short-term regularity in individual sources of R&E, the aggregate displayed in Figure 8 shows more realistic variation around a trend.

There is no general agreement amongst agricultural economists about the shape, magnitude and time of research and extension lag profiles within and between types of research and extension. Alston, Norton and Pardey (1995, pp 177-185) provide a full discussion on the topic. Typical finite lag structures that are used include the symmetrical and asymmetrical inverted V, the symmetrical and asymmetrical trapezoidal and a relatively simple polynomial. These and other *a priori* structures can be made more flexible by altering the weights involved to minimise the sum of squares in an analysis. In the absence of more specific guidance on the form of the lag structure, a 20 year time frame was chosen as it is a compromise between the very long lags associated with fundamental R&D, the relatively shorter lags associated with applied R&D and the short lags associated with extension. A 20-year asymmetric "inverted V" lag structure (Figure 9) was applied to the aggregate data and the result is shown in Figure 10.

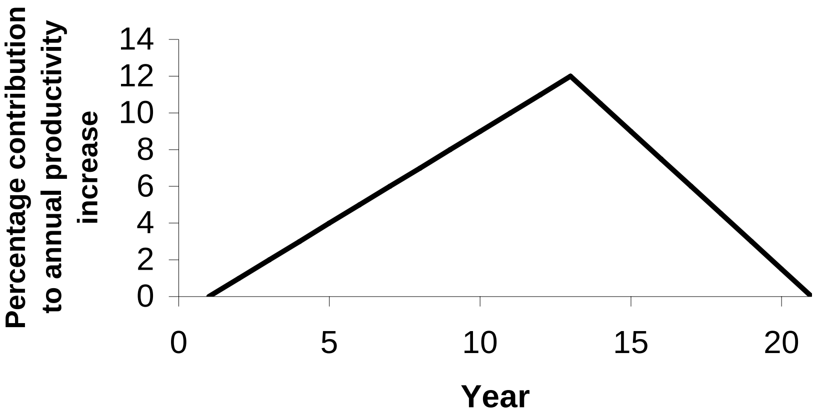


Figure 9. 20 Year Asymmetric Inverted V R&E Lag Structure

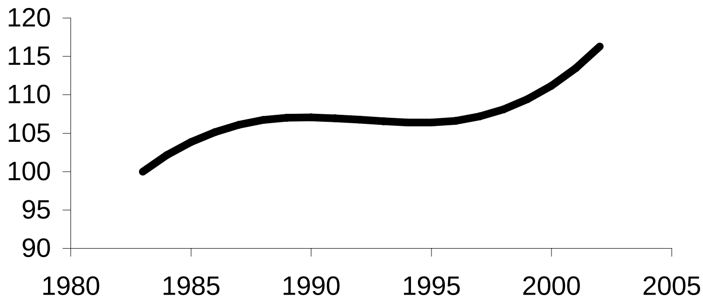


Figure 10. Lagged R&E resources for each year of SA Viticulture 1983-2002 (1983 = 100)

The shape of the curve in figure 10 is unusual in that it is relatively flat (note that the Y axis scale begins at 90) and sigmoid. At 1.6 percent for 2000-2002, research intensity for SA viticulture (current value of research and extension divided by current value of the crop) is low compared to the 3.9 percent for broadacre industries in the state (dryland crops, sheep and beef combined).

Education

Education is a proxy for human capital and can be used as an explanatory variable in econometric models. The series was based on the census figures for the education level of SA viticulture industry participants. The education index for each census year was calculated using (7):

(7) $$SAVEI_t = 1 + TIP_t / NTQIP_t$$

Where

$SAVEI_t$ is the SA viticulture education index in census year t,

TIP_t is total industry participants, and

$NTQIP_t$ is the number of industry participants that are not tertiary qualified.

A second order polynomial was fitted to the data (Figure 11) and the final index (1983 = base 100) was derived from the result. Curve fitting was necessary to provide annual estimates between census years. The second order polynomial was chosen because it is obvious, by examination of the data points in Figure 11, that this is the simplest polynomial that is consistent with the trend in these data.

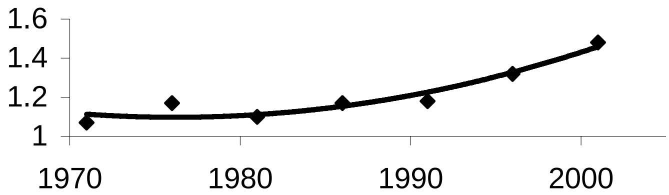


Figure 11. SA viticulture education index

Terms of trade

A zone viticulture terms of trade, used as an explanatory variable in the TFP decomposition model, was formed as a ratio of an index of the average zone grape price to the ABARE index of prices paid by farmers, converted to 1983 = base 100.

3 Models

Two models were chosen to assess the impact of R&E on SA viticulture regions – a total factor productivity decomposition model and a profit model. Two models were used in order to assess whether there was general agreement between the models in terms of results (microeconomic theory shows that these total factor productivity and profit models produce equivalent measures – see Alston, Norton and Pardey, 1995). By this means, more confidence can be placed in the conclusions from the analyses.

Total factor productivity decomposition model

The TFP decomposition model for each zone, or SA as a whole, is represented by (8):

$$TFP_{PRQX} = \frac{\mathbf{Q}_{PR}}{\mathbf{X}_{PR}} = f(REL, TOT, EDU) \tag{8}$$

Where:

TFP_{PRQX}	is the total factor productivity measure of perturbation-reduced **Q** and **X**.
$\mathbf{Q}_{PR}$	is a vector (grape categories) of perturbation reduced grape production,
$\mathbf{X}_{PR}$	is a vector of perturbation-reduced inputs (land, labour, variable inputs and plant and property infrastructure augmentation),
REL	is lagged research and extension,
TOT	is terms of trade index for SA viticulture, and
EDU	is an education index.

The derivation of these measures is described in Section 2, above.

Profit model

A parsimonious reduced-form profit model was derived from:

$$\Pi_{PR} = \pi(\mathbf{W}, \mathbf{P}, REL, EDU) \tag{9}$$

Where:

Π_{PR}	is profit measured as total revenue (**PQ**) minus the sum of expenditure on specified inputs (see Section 2, above), perturbation reduced,
P	is a vector of zone average grape prices, and

W is a vector of input prices, represented by The ABARE index of prices paid by Australian farmers.

Estimating Model

A generalised Leontief functional form was used as the estimating model and, after iterating configurations to ensure that the coefficients on the REL terms were highly significant[10], was finally configured as (10):

$$\Pi_{PR,t} = \sum_{z=1}^{3}\alpha_z \mathrm{d}_z + \alpha W_t + \sum_{z=1}^{3}\mathrm{d}_z \beta_z P_{z,t} + 2\sum_{z(i)=1}^{3}\sum_{z(j)=1}^{3}\beta_{ij}\left(P_{i,t}P_{j,t}\right)^{0.5} + 2\sum_{z=1}^{3}\gamma_z\left(W_t P_{z,t}\right)^{0.5} + \sum_{z=1}^{3}\mathrm{d}_z \varphi_z P_{z,t} REL_t \tag{10}$$

Using zone $z(i)$ grape price series, $P_{i,t}$, as an example, output supply equations were derived by the application of Hotelling's lemma:

$$\begin{aligned} Q_{z(i),t} &= \frac{\partial \Pi_t}{\partial P_{z(i),t}} \\ &= \beta_i + \sum_{z(j)=1}^{3}\beta_{ij}\left(\frac{P_{z(j),t}}{P_{z(i),t}}\right)^{0.5} + \gamma_z\left(\frac{W_t}{P_{z(i),t}}\right)^{0.5} + \varphi_{z(i)} REL_t \end{aligned} \tag{11}$$

From the configuration shown in (10), the elasticity of REL with respect to profit for zone *i* is:

$$\xi_{\Pi R,z(i)} = \left(\varphi_{z(i)} P_{z(i)}\right)\frac{REL_t}{\Pi_{PR,t}} \tag{12}$$

For SA as a whole, the model shown in (10) reduces to

$$\Pi_{PR,t} = \alpha_{SA} + \alpha W_t + \beta P_t + 2\gamma\left(W_t P_t\right)^{0.5} + P_t REL_t \tag{13}$$

[10] Configurations included use of

- the REL and EDU terms as individual items and
- the full suite of the interaction of these terms with prices,
- with or without association with regional dummies, as well as
- with or without dummies on the intercept and
- with or without input and output supply equations.

Estimators used

The TFP decomposition model parameters were estimated using the SUR (seemingly unrelated regression) methodology in SHAZAM V9, because REL and EDU were common explanatory variables in each zone model. The log-log configuration was used.

The profit model parameters were estimated using the NL (non-linear) estimator in SHAZAM V9.

Internal rate of return and benefit-cost ratio calculations

Internal rate of return (IRR) figures and benefit-cost ratios (BCR) for the two models are derived from the elasticity results, using the algorithms available in a spreadsheet[11].

In the case of the IRR calculations the average marginal increase in value of R&E[12] for each year, as shown schematically in Figure 10, was entered. This was followed by the value of viticulture productivity improvement that is attributable to R&E, using the elasticity derived from the model, in the final cell that went into the IRR algorithm calculation. It needs noting that this methodology provides a marginal increase calculation rather than an average calculation. The methodology is appropriate for decision makers assessing the value of an increase in R&D resources.

In the case of the benefit-cost ratio calculation, the cells in the spreadsheet corresponded with those of the IRR calculation except that a 7 percent cumulative discount rate was applied and the "payoff" final cell was divided by the sum of the R&E input cells, as discounted.

R&E was apportioned according to the 20-year average value proportions of each zone contribution to the total SA crop value. The implicit assumption in this approach is that R&E is neither completely flexibly applicable to each zone, with the priorities of research changing according to the value of viticulture in each zone in each year (implying an implausible prescience in research resource allocation decisions, given the lag involved), nor is it completely inflexible.

[11] Alston, Norton and Pardey (1995, p 201) provide details of the approach used for the IRR calculations. BCR calculations flow from the spreadsheet equivalent algorithm for the BCR.

[12] It was not possible to use year-by-year increments because, as can be seen from Figure 10, some marginal increments were negative. IRR calculations that include negative investment streams are not possible or may give incorrect results.

4 Results and discussion

Models assessment statistics

The Durbin-Watson autocorrelation statistic was satisfactory in all three zones for the TFP decomposition model.

After applying second-order autocorrelation correction across equations, the Durbin-Watson autocorrelation statistic was either satisfactory or fell into the inconclusive zone for the four equations used in the profit model (one profit plus three derived output equations). In addition, the estimated total profit and zone outputs (grape production, from the derived equations) were all correctly signed (positive) at every annual data point, thus conforming to microeconomic theory.

Productivity improvement

Table 4 shows total factor productivity increase estimates both with and without grape quality improvements. There is a considerable difference in the estimates, which illustrates the impact of incorporating improvements in quality in the TFP calculations. The estimates are low by broadacre industry standards if quality improvements are not taken into account. For example, Knopke et al. (2000) estimate a 2.5 percent rate of TFP growth for all Australian broadacre farms from 1978 to 1999. However, the estimate of 2.3 percent if quality is included is very similar to the broadacre farm estimate.

Table 4: TFP increase results for SA viticulture

Zone	Inputs increase p.a.	Quality incorporated outputs increase p.a.	Quality incorporated TFP increase p.a.	Outputs increase without incorporating quality p.a.	TFP increase without incorporating quality p.a.
Central	1.26	3.46	**2.20**	1.94	**0.68**
Riverland	1.26	4.03	**2.77**	2.48	**1.22**
South-East	1.26	2.80	**1.54**	2.00	**0.74**
South Australia	1.26	3.53	**2.27**	2.25	**0.99**

TFP decomposition model results

Table 5 shows the results from the TFP decomposition model. All three zone TFP:REL elasticities were highly significant. In addition, a comparison of the TFP figures and the REL figures show that they appear to be strongly correlated, adding further to the evidence that REL was a strong driver of productivity improvement.

Table 5: TFP model results and lagged research and extension (REL) elasticities for SA viticulture zones

Zone	TFP increase p.a.	TFP:REL elasticity	t ratio			CV[a]
			REL	TOT	EDU	
Central	2.20	1.77	3.65***	3.18***	-0.08	4.5%
Riverland	2.77	3.07	6.16***	-1.19	2.46**	4.5%
South-East	1.54	1.70	3.30***	-0.60	1.63	4.4%
South Australia	2.27	2.34	3.64***	4.47***	- [b]	6.4%

, * Significant, P<0.05, <0.01 respectively (one tailed test)

[a] Coefficient of variation

[b] EDU was not used in the SA regression as it did not contribute as an explanatory variable and interfered with the contribution of REL and TOT

Despite the fact that they only obtained significance in one zone each (TOT in the Central zone, EDU in the Riverland), both TOT and EDU were retained in all three zone models, in order to maintain models uniformity[13] (EDU also approached significance in the South-East zone). The explanatory power of the zone models was high, as shown by the low coefficients of variation.

There is some indication that TOT and REL interfered with each other in the statistical analysis or that they were "competing" explanatory variables. In the Central zone, the increase in the education index would be expected to be relatively high, because a lot of expansion in production capacity was in new, relatively small owner operated/managed vineyards in the Adelaide Hills. These new entrants to the industry would be expected to be relatively well educated – business and professional people starting a new business. In addition, much of the expansion in the Langhorne Creek area was in large vineyards run by qualified professionals. However, EDU did not approach significance in the Central zone, but TOT was highly significant, although with an unexpected positive sign. Previous work, in Australian broadacre agriculture, has shown that the sign on TOT in a TFP decomposition analysis is negative (Beck *et al.* 1985, Mullen and Cox 1995, Black 2004). The explanation for this negative sign is that when terms of trade have improved there is less pressure on growers to increase productivity in order to maintain profitability. Overall, in the Central zone, it could be that the new vineyards run by an influx of relatively well-educated new industry participants provided a strong impetus to improve productivity, but that TOT had stronger explanatory power for this improved productivity than EDU.

[13] The alternative approach is to drop variables that do not contribute to the explanatory power of the individual model.

In the Riverland, the increase in the education index would be relatively small because most expansion took place on small irrigation blocks as existing irrigated crop growers, whose formal education is thought to be relatively low, switched to viticulture in the 1990s. In the Riverland, however, EDU was significant but TOT, although correctly signed, was not. However, beginning in the early 1990s there was a considerable extension effort in the Riverland to educate growers to improve fruit quality. This effort came from well-educated large-winery technical representatives, and from R&E organisation employees at the behest of the large wineries, using seminars and field days. There was a much greater effort put into Riverland growers than into the cool climate region growers from these sources and using these techniques. By this means, the better education of these industry participants was plausibly translated into a significant impact in the Riverland.

In the South-East, the education of industry participants is thought to have always been relatively high, because a very large proportion of vineyards in that zone have always been run by qualified professionals or relatively well educated owner/operators. This may explain why EDU approached significance in this zone and TOT was not significant, although correctly signed: The large expansion in vineyard area in the South-East was always likely to use "state of the art" technology because of the relatively well educated industry participants in the zone, and therefore TOT was a minor consideration in productivity improvement.

One of the complicating factors in the analyses was that TOT was specific for each zone whereas EDU applied to industry participants across South Australia and was not zone specific, due to a lack of the necessary data at zone level. Zone model explanatory power may have improved if EDU had been zone specific and may have provided a more coherent set of results about the relative contribution of EDU and TOT in each zone[14].

[14] The log-log specification used in the analysis makes interpretation of the contribution of EDU particularly difficult as it implicitly assumes that the increase in REL and EDU is the same rate. In addition, although a positive sign on TOT is unusual, a higher TOT may mean that more private investment in R&E is possible, thus increasing productivity as a result. We are indebted to Eton Li for these comments.

Profit model results

Table 6 shows the results from the chosen profit model. It can be seen that the elasticity results are quite similar to those from the TFP decomposition models (Table 4). Therefore, there can be greater confidence in the conclusions from the study because they are not reliant on the findings from one model alone. The coefficient of variation for the derived (output) equations was high. However, these equations were assessed as necessary for the analysis because reliance on the profit equation alone produced a relatively low elasticity for the Riverland (Table 7) compared to the results for the four-equation model (Table 6) and the TFP decomposition model (Table 4).

Table 6: Chosen profit model results and lagged research and extension (REL) elasticities for SA viticulture zones: profit and output equations version

Zone	Profit:REL elasticity	T ratio REL	CV for profit equation	CV for output equations
Central	2.00	3.38***		18.0%
Riverland	3.33	4.59***	16.6%	20.2%
South-East	2.14	3.58***		16.2%
South Australia[a]	2.54	5.39***	8.4%	5.1%

[a] Results from overall regression

Table 7: Alternate Profit model results and lagged research and extension (REL) elasticities for SA viticulture zones: profit equation only model[15]

Zone	Profit:REL elasticity	T ratio REL	CV for profit equation
Central	2.01	4.90***	
Riverland	2.22	4.81***	5.4%
South-East	1.96	5.27***	

The relatively low elasticity of REL in the Riverland from the profit equation only version of the profit model (Table 7), compared to the results for the Riverland from the four-equation version of the profit model (Table 6) and the TFP decomposition model (Table 5), is a direct reflection of profitability of viticulture in the Riverland relative to the other two zones (Figure 12). From the early nineties, profitability in the Riverland has been consistently lower than in the cool climate zones, and this is a direct reflection of the price of grapes in the three zones, which is in itself a reflection of demand for grapes from these zones. In particular, profitability fell in the late nineties onwards in the Riverland, compared to the cool climate zones. A caveat to the analysis shown in Figure 12 is that the cost structure used was common across all zones (See discussion

[15] The configuration was the same as that described in (11). No autocorrelation correction was necessary for this model.

in Section 2). Cost increase in the Riverland may have been significantly less than in the cool climate zones over the review period.

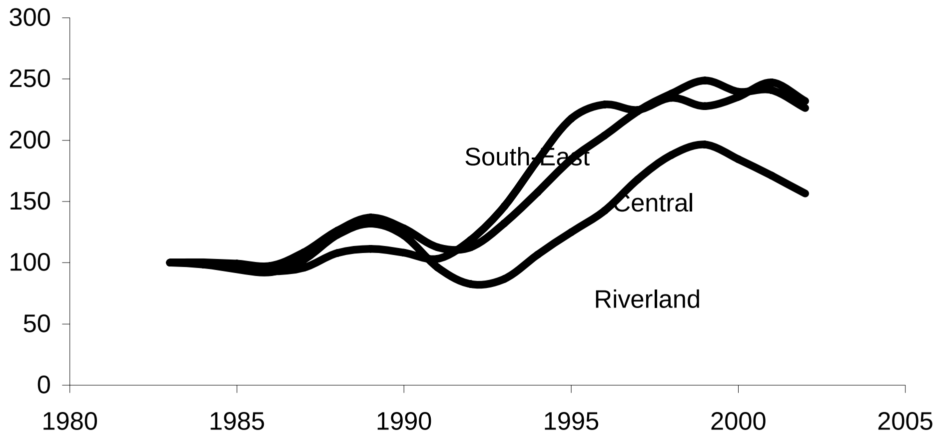


Figure 12. SA Viticulture zone profitability/ha 1983=100

The fact that the four-equation version of profit model (Table 6) produced a REL elasticity for the Riverland that was much closer to that of the TFP decomposition model than the one-equation version (Table 7) showed the necessity of using the output equations. This was despite the fact that the coefficient of variation for each equation in the four-equation system was considerably higher than the profit equation alone model (Tables 6 and 7). In the generalised Leontief (GL) format, differentiation of the profit equation provides volumes of output (in this case tonnes/ha of grapes) and these output equations were an important corrective for the profit equation in the system of equations approach. Hence, the GL format was justified.

Similarities and differences between regions

For both the TFP decomposition and chosen profit models, Table 8 shows that there was no significant difference between elasticities in the Central and South-East zones, but that both of these zones were significantly different from the Riverland. This confirms the obvious similarities and differences in the REL elasticity results shown in Tables 5 and 6.

Table 8: Probability of differences in lagged research and extension (REL) elasticities for SA viticulture zones

Comparison	TFP model	Profit model
Central Vs Riverland	0.042*	0.035*
Central Vs South-East	0.839	0.843
Riverland Vs South-East	0.032*	0.024*

* Significant, P<0.05 (two tailed test)

Table 9 shows a higher internal rate of return (IRR) and benefit-cost ratio (BCR) for the Riverland compared to the two cool climate zones because of the higher REL elasticity for the Riverland.

Table 9: Internal rates of return (IRR) and benefit cost ratios (BCR) of lagged research and extension (REL) for SA viticulture zones

Zone	TFP Model		Profit Model	
	IRR	BCR	IRR	BCR
Central	42%	52:1	43%	59:1
Riverland	47%	76:1	48%	85:1
South-East	41%	52:1	44%	66:1
South Australia [a]	45%	53:1	46%	58:1

[a] Results from overall regressions

Table 9 shows that R&E has been an excellent investment for South Australian viticulture. The returns on investment are considerably more than those for SA broadacre agriculture shown in Table 10 (Black 2004, p. 106, and unpublished results). As noted previously, the R&E research intensity for SA viticulture (1.6 percent) is very low compared to that for SA broadacre agriculture (3.9 percent). Even if there were diseconomies of scale in R&E investment for viticulture, considerably more R&E investment would be warranted before the levels of return on investment would be reduced to those for SA broadacre agriculture, which are considered quite acceptable in the mixed cropping/livestock production zones. The high rate of return for viticulture R&E is a result of the high elasticities compared to those for broadacre agriculture (Table 5 cf. Table 10): an average zone viticulture elasticity of 2.18 (TFP model) compared to an average 0.62 for broadacre agriculture zones.

Table 10: Internal rates of return (IRR) and benefit cost ratios (BCR) of lagged research and extension (REL) for SA broadacre agriculture zones: TFP model

Zone	TFP Model		
	IRR	BCR	REL elasticity
Low rainfall mixed cropping/livestock production	32%	13:1	0.74
High rainfall mixed cropping/livestock production	27%	8:1	0.72
High rainfall predominantly livestock production	21%	4:1	0.40

The zone results in Table 9 show that R&E has given a greater return in the Riverland than the two cool climate zones. This is the result of the higher REL elasticity in the Riverland compared to the cool climate zones (Tables 6 and 7). The average elasticity for the two cool climate zones was 1.9, across both models, compared to 3.2 for the Riverland. The explanation for this greater elasticity in the Riverland is probably the development of irrigation technology and techniques. Over a large number of years, there has been a considerable research effort into irrigation technology and techniques for viticulture from SARDI (and its predecessor the SA Department of Agriculture), CSIRO, and the Victorian Department of Primary Industry. The Riverland has been the primary beneficiary in South Australia because it uses irrigation to a considerably greater extent than the cool climate zones.

From a social perspective, the bias towards greater impact of R&E in the Riverland has probably been beneficial. Given the lower profitability in the Riverland compared to the cool climate zones (Figure 12), which is due to lower grape prices, this bias has allowed more Riverland growers to remain viable through productivity improvement than would otherwise be the case.

The fact that there was no statistical difference in the REL elasticity between the two cool climate zones (an average from the two models of 1.89 in the Central zone and 1.92 in the South-East) indicates that the technology in use and grape growing conditions in these zones are similar.

It needs to be noted that while credit for increased productivity in viticulture is reasonably attributable to R&D, credit for the increased value of the wine industry, and therefore viticulture, can be attributed to taste changes, increased purchasing power of consumers and overseas market penetration as well as R&D. These other factors contribute to the value of R&D by increasing the gross value of South Australian viticulture.

Impact of removing grape quality improvements on R&E measures

The models were also run on data that did not have quality improvements incorporated into the outputs. The results are shown in Table 11.

Table 11: Internal rates of return (IRR) and benefit cost ratios (BCR) of lagged research and extension (REL) for SA viticulture zones when grape quality improvements were not incorporated

Zone	TFP Model		Profit Model	
	IRR	BCR	IRR	BCR
Central	39%	36:1	42%	52:1
Riverland	46%	70:1	47%	79:1
South-East	37%	33:1	39%	43:1
South Australia [a]	38%	25:1	39%	30:1

[a] Results from overall regressions

Given the marked reduction in TFP change with and without quality improvement, shown in Table 4, the results shown in Table 11 compared to table 9 are relatively high, particularly for

IRR. They may reflect an emphasis in R&E on yield improvements in the first 10 years of the review period rather than on quality improvements, which were emphasised in the second 10 years of the review period. A second observation is that the separate SA regressions compared to the zone regressions shown in Table 11 returned results that were less than the zone average, in contrast to the results in Table 9 where the SA results were in the midst of the zone results, as expected. It could be that the changes in zone outputs without quality improvements over time were sufficiently different that the zone trends cancelled each other to the extent that the SA aggregate was not as strongly related to lagged R&E as the individual zone outputs. The result also possibly suggests that research may have been specifically targeted for each zone.

Summary

- Both the total factor decomposition and profit models showed high lagged R&E elasticities and resultant high rates of return on R&E for South Australian viticulture.
- The impact of R&E on the Riverland was greater than on the Central and South-East cool climate zones.
- The explanation for this greater impact in the Riverland is probably the emphasis on research and development for irrigation technology and techniques.
- Even if there were diseconomies of scale in R&E investment for viticulture, considerably more R&E investment would be warranted before the levels of return would be reduced to a level commensurate with risk on a diversified R&E investment portfolio.

References

ABS (various dates) 7000 series[16] (*Agriculture*), Australian Bureau of Statistics, Canberra. In addition, specific small area historical data purchased from ABS.

Alston JM, Norton GW and Pardey (1995) *Science Under Scarcity: Principles and Practice for Agricultural Research and Priority Setting.* Cornell University Press, Ithaca and London.

Beck T, Moir B, Fraser L and Paul P (1985) *Productivity Change in the Australian Sheep Industry.* Paper prepared for the 55th ANZAAS Congress, Monash University, 28th August.

Black ID (2004) *The Regional Impact of Research and Extension in Increasing the Productivity of South Australian Broadacre Agriculture: Results and Recommendations from Econometric Analyses.* SARDI Research Report Series No 61. South Australian Research and Development Institute, Adelaide.

Knopke P, O'Donnell V and Shepherd A (2000) *Productivity Growth in the Australian Grains Industry.* ABARE Research Report 2000.1 Australian Bureau of Agricultural and Resource Economics, Canberra.

Mullen JD and Cox TL (1995) The returns from research in Australian broadacre agriculture. *Australian Journal of Agricultural Economics*, **39**: 105-128.

[16] Often the data used occurred in several publications in the 7000 series and, where particular annual publications were missing in a series at the ABS Adelaide library, reference was made to other publications in the 7000 series that contained the same data. No records were made of the precise numbers in the series from whence individual data came. Generally, the series used were the publications specifically for South Australian agricultural statistics.