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An Analysis of Productivity growth in Western Australian Agriculture

Nazrul Islam
Department of Agriculture and Food, Western Australia

AN ANALYSIS OF PRODUCTIVITY GROWTH IN WESTERN AUSTRALIAN AGRICULTURE*

by

Nazrul Islam

Agriculture Western Australia
and
Economic Research Centre, UWA

Address for correspondence:

Economic Research Centre (ERC)
Department of Economics
The University of Western Australia
Nedlands WA 6907
Phone 08-9380-2931
Fax 08- 9380-1073
email **nislam@ecel.uwa.edu.au**

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ABSTRACT

The objective of this paper is to analyse productivity growth of Western Australian broadacre agriculture. For the period 1977/78 to 1997/98, the growth of aggregated outputs, inputs and the total factor productivity (TFP), of broadacre agriculture in WA is estimated by applying a non-parametric approach. The productivity performance of WA agriculture is compared with that of other Australian states. An attempt is made to identify the factors, which may explain productivity growth in WA agriculture. TFP growth in WA agriculture is estimated to be 4.2 percent p.a.. Compared to other Australian states, only South Australian agriculture has experienced a higher rate of productivity growth. Within WA, the wheat-sheep zone has the highest TFP growth of 4.7 percent p.a.. Among the broadly defined industry groups, the crop industry experienced the highest TFP growth of 6.6 percent p.a.. Besides the influence of seasonal conditions, the transfer and adoption of new technologies appear to have a positive impact on the TFP growth in WA agriculture.

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1. INTRODUCTION

For Western Australia, the economic prosperity of the rural community and the living standards of farmers rely heavily on the growth of the state's farming sector. The growth in the farming sector in turn depends on the resource base, such as land, and productivity growth. However, most industry analysts point to a declining resource base for broadacre farming in WA, associated with increasing salinisation and acidification. The enhancement of farm-level productivity is important, therefore, for the growth of the agricultural sector and the rural economy.

WA agriculture is predominantly export oriented and in fact exports about 75 percent of its produce (Islam, 1999). Nevertheless, it is still a small player in the world market, comprising only about .6 percent of the total world agricultural trade. As a result, WA farmers accept world market prices and are exposed to their fluctuations. Added to this is the fact that increases in commodity prices have been relatively slow, compared to rapid increases in the prices of inputs. This has given rise to a situation where the prices received relative to the prices paid by farmers (i.e. the farmers' terms of trade) are declining (Chisholm, 1992). Furthermore, rapid technological improvements such as the emergence of hybrid and genetically modified (GMO) crops, as well as genetically engineered food products, and advances in transportation and communication systems, are taking place in many competing countries. This technological progress is having a significant impact on increasing the production capacity of these countries and reducing their production costs. Moreover, in some cases, their farm production is subsidised. The FAIR Act and the Export Enhancement Program in the United States, and the Common Agricultural Policy (CAP)[1] in the European Union are a few examples of these subsidies. Accordingly, rapid technological progress in these countries, coupled with production subsidies, has enabled them to supply their products at lower prices and emerge as stronger competitors in international markets. Faced with this situation of increased international competition, a declining resource base and a deterioration in the farmers' terms of trade, the challenge for the agricultural sector in WA is to enhance and sustain farm-level productivity growth so as to remain competitive in international markets. The importance of productivity growth in Australian agriculture, has been emphasised by researchers and policy makers (see, e.g., McKay, Lawrence and Valstain, 1982; Wall and Fisher, 1987; Mullen, *et al.*, 1995; Mullen and Cox, 1996; Coelli, 1996; Islam, 1995; and Productivity Commission, 1996 and 1999).

[1] Now known as the Agenda 2000.

Productivity growth depends, to a large extent, on the progress and application of technologies which are generated through research and development (R&D) activities. Historically, agricultural R&D activities in Australia relied heavily on government funding support[2] (Mullen *et al.*, 1996). This has been the case not only in Australia, but also in most other developed economies such as the US, Canada, and the UK. In WA, Agriculture Western Australia is the largest government agency providing funds for investment in agricultural research. Its goal is to maintain sustainable growth in the productivity of the state's agriculture sector. It does this by undertaking most of the agricultural R&D activities in the state.

However, in recent years, Agriculture WA has had to face the challenge of achieving its goal under increasingly tight budget conditions. In order to formulate the R&D investment policy of the agency, information on the productivity variation across industries and farm units, as well as on the causes of variation is vital. Such knowledge is crucial for identifying constraints to productivity growth and for understanding the needs of the rural industries in WA. Moreover, knowledge of the productivity performance of different agricultural industries in WA may provide insight into their capacity to cope with the challenges they encounter, as well as into their future growth potential.

In the literature on WA agriculture on empirical research, the estimation of productivity variation across farm units and the identification of its determinants, have been relatively neglected. To fill in this gap, this paper aims to analyse the productivity growth performance of a number of agricultural industries in WA for the last two decades. The study also makes an attempt to investigate the causes of differences in productivity growth through time, and across industries in WA agriculture.

The paper is organised into five sections. Having introduced the paper in Section 1, in Section 2 some literature on methods of productivity measurement is briefly reviewed. In Section 3, the data and the productivity measurements are summarised. The section also presents estimates of the productivity growth for the period 1977/78 to 1997/98. In Section 4 an attempt is made to identify the factors contributing to the growth discussed in Section 3. The paper is concluded in Section 5.

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[2] The underlying principle behind the involvement of the public sector is that because of an inability to internalise positive externalities, small individual farmers are expected to under-invest in agricultural R&D activities (Inglis, 1995).

2. MEASURES OF PRODUCTIVITY GROWTH

Conventionally, productivity is simply measured by the ratio of outputs to inputs and productivity growth is measured by taking the difference of growth in outputs and inputs. However, the productivity of a business unit, say a farm, is measured on the basis of its ability to produce a profit maximising or cost minimising level of output by using the best combination of resources, including labour and capital. As a farm usually produces more than one output in combination with its management and other inputs, measuring its productivity is a complex task. Inputs and outputs are not necessarily homogeneous across time or firms, in terms of their units and qualities. The heterogeneous characteristics of these commodities make it difficult to aggregate them and to compute the total output and total input indices. In this section some literature on the methods of productivity measurement is briefly reviewed to select a suitable method for the present study.

The existing approaches to measure productivity growth can be classified into two groups: parametric and non-parametric. The least-squares econometric production and stochastic frontier production function models are examples of the first category and the traditional Tornqvist-Theil (TT) or Christensen and Jorgenson (1970) total factor productivity (C&J TFP) index and data envelopment analysis (DEA) are examples of the second group[3].

The parametric methods, based on cost or profit functions, have been used less frequently in Australian agricultural studies. Studies by McKay, Lawrence and Valstain (1982), Fisher and Wall (1990), Mullen, *et al.*, (1995), Mullen and Cox (1996), Coelli (1996), and Ahammad and Islam (1999) fall under this category. However, the non-parametric methods, particularly the TT or C&J TFP[4] index number approach have been very popular and extensively applied in Australian agricultural studies. To appreciate the popularity of the TT approach a brief discussion on a few commonly used index number approaches and their relationship with economic theory is presented.

[3] See Coelli *et al.* (1998) for a detailed discussion about the distinctions between these methods.
[4] In the rest of the paper we have used TT and C&J TFP interchangeably.

2.1 Index number approaches[5]

Index numbers play a major role in three areas of productivity measurements: (a) In the computation of output and input index numbers. These index numbers in turn are used to compute TFP index numbers. (b) Index numbers take an indirect role in generating data that are required for productivity measurements using both the parametric and non-parametric approaches. (c) Index numbers also help to deal with the problems of a panel data in measuring the price and quantity variables over time and space. In the literature on productivity measures, disagreement centres around the choice of an index number procedure to aggregate outputs and inputs (Christensen, 1975; Mullen and Cox, 1995, and 1996). We begin our discussion by presenting a short overview on the properties of the traditional index number approaches, to help understand the relative merits of different approaches.

Laspeyres (LA), Paasche (PA), Fisher Ideal (FI), and Tornqvist-Theil (TT) indices are the commonly used traditional index number approaches. The underlying functional relationship for both the LA and PA indices are linear. This means that, these two indices assume that all factors of production are perfect substitutes and inputs are used in fixed proportions. For a linear production function these indices are exact. The difference between these two indices is that the LA price index uses the base period quantities as weights, whereas, the PA index uses the current period quantities as weights. These two indices represents two extremes, one placing emphasis on base period quantities and the other on current period quantities. The indices tend to diverge when price relatives exhibit a large variation. If the price variation is zero then they coincide.

The FI index (Fisher, 1922) is the geometric mean of the LA and PA indices which lies between the two extremes. It has a number of useful statistical and economic properties. Diewert (1992) shows that the FI index is exact for a production technology which is of quadratic[6].

The TT price index is defined as the weighted geometric mean of the relative prices, with weights given by the average of the value shares in two adjacent periods. This index can be written as:

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5 The discussion in this part of the section is largely based on Coelli *et al.*(1998).

6 Because of many other useful properties the word 'ideal' is added after Fisher and the index is well know as the 'Fisher Ideal' index.

$$P_t = \prod_{i=1}^{N} \left[p_{it} / p_{i,t-1} \right]^{\overline{w}_{it}}, \quad (1)$$

where P_t is the price index; p_{it} and $p_{i,t-1}$ represent the price of the i^{th} component in periods t and t-1, respectively; and $\overline{w}_{it}$ is $(w_{it}+w_{i,t-1})/2$, the simple average of the value share ($w_{it} = p_{it}q_{it}/M_t$, where $M_t = \sum_{i=1}^{N} p_{it}q_{it}$ and q_{it} is the output quantity) of the i^{th} component in periods t and t-1. This price index is usually applied in log-change form, so that it is a weighted average of the logarithmic price changes and provides an indication of the overall growth rate in prices. The same approach is used to calculate a quantity index. Quantity changes are measured in two ways – direct and indirect. In the direct method, the overall quantity change is measured from individual commodity specific quantity changes such as $q_{it}/q_{i,t-1}$.

The indirect method, takes into consideration the fact that there are two components that make up the value change over the periods t-1 and t, price and quantity. Accordingly, if price changes are measured directly then quantity changes can be indirectly calculated by discounting the value change for price change. The indirect measure is usually applied for comparing quantity changes over time. The remarkable feature of this indirect measure is its practical applicability in terms of using the value aggregates, after being adjusted for price changes over time, as aggregate quantities or quantities of composite commodities.

The PA-price index and LA-quantity index are dual to each other implying that together they decompose the value index. The FI index for prices and the FI index for quantities together form a dual pair. This means that the indirect FI-quantity index, obtained by deflating the FI-value index with FI-price index, will be exactly the same as the direct FI-quantity index. Therefore, the FI index has the 'factor reversal test' property.

However, the TT index does not have the property of self-duality[7] because it involves the geometric mean in its calculation. This index is exact for a production technology which can be represented by a translog transformation function. The characteristic of a translog transformation function is that the second order coefficients are equal across time or firms. Both the FI and TT indices are called superlative indices (Diewert, 1992) as their respective quadratic and translog

7 Self-duality means that if the quantity index is derived indirectly by using the direct price index then it will not be different from the direct quantity index. In the TT index, the indirect quantity index will be different from the direct quantity index.

functional forms are flexible[8] in nature. However, none of the index number approaches discussed above satisfy the transitivity[9] property but the FI and TT indices satisfy the time-reversal test[10].

There are two theoretical approaches to measuring TFP growth which satisfy the transitivity property. One is referred to as the Malmquist TFP index and the other is the modified TT approach discussed in Caves, Christensen and Diewert (1982). Under this CCD approach, one way to measure productivity change is to compare the change in output growth from a given level of inputs used under the current technology, with the output growth that could be achieved under a given reference technology using the same level of inputs. The CCD approach forms the basis of the Malmquist TFP approach. The Malmquist approach is based on the concept of output distance function. An output distance function considers a maximal proportional expansion of outputs under a given level of inputs.

From a practical point of view, a problem of choice arises as to which approach should be used if the direct and indirect approaches lead to different estimates of quantity changes. As suggested by Allen and Diewert (1982), the choice of an approach should depend on the type of data available, the variability in the price and quantity relatives as well as the theoretical framework used in the comparison of quantities.

The other concern surrounding choice is the reliability[11] of the underlying index. The literature suggests that the relative variability in the price and quantity ratios provides a useful clue as to which index is more reliable. If quantity ratios relative to price ratios are less variable, then a direct quantity index is suggested, and if the price relatives are less variable compared to quantity relatives, then an indirect quantity index is prescribed. However, under certain conditions direct output and input quantity indices, based on TT index formula, are theoretically superior (Diewert, 1976 and 1983; and Caves, Christensen and Diewert, 1992). Diewert (1992) concludes that as the FI and TT indices both provide reasonable approximations to the 'true' output and input quantity index numbers in most empirical applications where time series data are involved, both formulae yield very similar numerical values for the TFP index.

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8 A function is called flexible if it provides a second-order approximation of any arbitrary function.

9 The transitivity property relates that a direct comparison of a price index betwen periods t and s yields the same index as an indirect comparison through a period r. For example, the transitivity test requires that Pst = Psr × Prt where s, t and r are any three periods.

10 For two periods s and t the time-reversal-test satisfies: Pst = 1/Pts. That is, a price comparison between s and t yields the same index as an inverse price comparison between t and s.

11 Reliability of an index number depends on the degree of relative variability in price and quantity ratios.

Having introduced a number of commonly used index number approaches we turn our discussion to a review of Australian studies related to agriculture.

2.2 Approaches used in selected Australian studies

In Australian research, the TT index procedure is the most widely used method (Lawrence and McKay, 1980; Beck *et al.*, 1985; Males *et al.*, 1990; Mullen and Cox, 1994 and 1995; and Mullen *et al.*, 1995; Islam, 1995; Strappazzon *et al.*, 1996, and Coelli, 1996). In Table 1, the objectives, study locations, study periods, data sources, methods applied and estimated productivity growth of these studies are summarised. Column 6 of the table indicates that the TT index method have been applied in almost all studies. The argument for the appropriateness of the TT index is that, it is suitable for most production situations where production structure is not linear, inputs and outputs are not perfectly substitutable and the underlying functional form is nonhomothetic translog (i.e. the bundles of inputs cannot be compared directly between two production levels). As mentioned above, this functional form provides a second-order approximation (Diewert and Wales, 1987). The principal advantage of this index is that it is not based upon simplistic linear production assumptions as are the LA, PA and other index procedures. However, the disadvantages associated with this index are that it is not as intuitive as the other indexes to interpret and requires extra data on the prices of each of the inputs and outputs for all the years under consideration (See Christensen, 1975 for concepts and measures of agricultural productivity in using the TT index). There are also concerns that, because it assumes constant returns to scale and translog functional form, estimates of productivity growth based on the TT index may be biased (Coelli *et al.*, 1998).

Mullen *et al.* (1995) and Strappazzon *et al.* (1996) have reported and applied a number of alternative measures of productivity which relax these restrictions. Using data on Australian agriculture, they have compared productivity growth rates by applying the following methods.

1. Traditional index number approaches, i.e. LA, PA, FI, and TT approaches which were introduced above.

TABLE 1

AUSTRALIAN STUDIES ON MEASURING AGRICULTURAL PRODUCTIVITY GROWTH

Author(s)	Study objectives	Country/State/ Region/Industry	Study period	Data and sources	Methods applied	Productivity growth rate (percent p.a.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lawrence and McKay (1980)	Analysing the extent and nature of productivity changes	Australian wheat-sheep industry	1952/53 to 1976/77	Australian Sheep Industry Survey (ASIS) data, Bureau of Agricultural Economics	• Tornqvist-Theil (TT) or Christensen and Jorgenson (C&J TFP)	2.9
Beck *et al.* (1985)	Examining the productivity changes	Australian wheat-sheep zone	1952/53 to 1982/83	Australian Agricultural and Grazing Industry Survey (AAGIS), ABARE	• Fisher Ideal Index (FI)	2.7
Males *et al.* (1990)	Examining the changes in input, output and productivity growth.	Australian broadacre agriculture	1977/78 to 1988/89	Productivity data set, ABARE	• TT or C&J TFP	2.2
Islam (1995)	Investigating inputs, outputs and productivity changes in WA agriculture	Wheat-sheep zone	1977/78 to 1993/94	Productivity data set, ABARE	• TT or C&J TFP	3.8
Mullen and Cox (1995) and Mullen *et al.* (1995)	Estimating the relationship between several measures of productivity and research expenditure	Australian broadacre agriculture	1953/54 to 1987/88	AAGIS, ABARE	• TT or C&J TFP	2.3
					• Caves, Christensen and Diewert (CCD)	2.2
					• Chavas &Cox (C&C)	1.8
					• Translog cost function (COST)	1.6

(continued on next page)

TABLE 1 (Continued)

Authors	Study objectives	Country/State/ Region/Industry	Study period	Data and sources	Methods applied	Productivity growth rate (percent p.a.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Coelli (1996)	Investigating productivity growth in WA agriculture	WA Wheat-sheep zone	1953/54 to 1987/88	AAGIS, ABARE	• TT or C&J TFP	2.7
Mullen and Cox (1996)	Comparing alternative measures of productivity growth including TT	Australian wheat-sheep zone	1953/54 to 1993/94	AAGIS, ABARE and Productivity data set, ABARE	• FI ,	2.5
					• C&J TFP (mix index)[a]	2.5
					• C&J TFP Direct Price	2.5
					• CCD	2.5
					• C&C	2.6
					• COST	2.4
Strappazzon *et al.* (1996)	Measuring differences in TFP under different methods	Australian all broadacre	1977/78 to 1993/94	All broadacre data, ABARE	• FI	2.7
					• TT or C&J TFP	2.6
					• Laspeyres (LA)	3.0
					• Paasche(PA)	2.3
					• C&C	2.3
					• Malmquist index	-0.8

Note: [a]The C&J TFP mix index is computed from direct input and implicit output quantity indices and by adding a scale adjustment factor.

2. A scale adjusted version of the C&J TFP index suggested by Caves, Christensen and Diewert (1982). In the CCD approach, the constant returns to scale assumption is relaxed by adding a scale adjustment factor. Mullen and Cox (1996) added these scale adjustment factors in their C&J TFP index.

3. A non-parametric measure developed by Chavas and Cox (1994) is based on distance functions. The advantage of the C&C method is that the imposition on the production technology of a particular functional form such as translog is avoided. Hence, it generalises further the measurement of productivity.

4. A Malmquist productivity index requires the computation of output distance functions for observation periods with reference to technology periods. This approach requires linear programming solutions for the computation of a distance function. Malmquist index measures can be used to decompose measured changes in efficiency into technical progress and catchup efficiency when panel data are available. Strappazzon *et al.* (1996) have used this approach and applied it to the Australian broadacre data for the period 1977/78 to 1993/94 for comparing productivity growth with other measures.

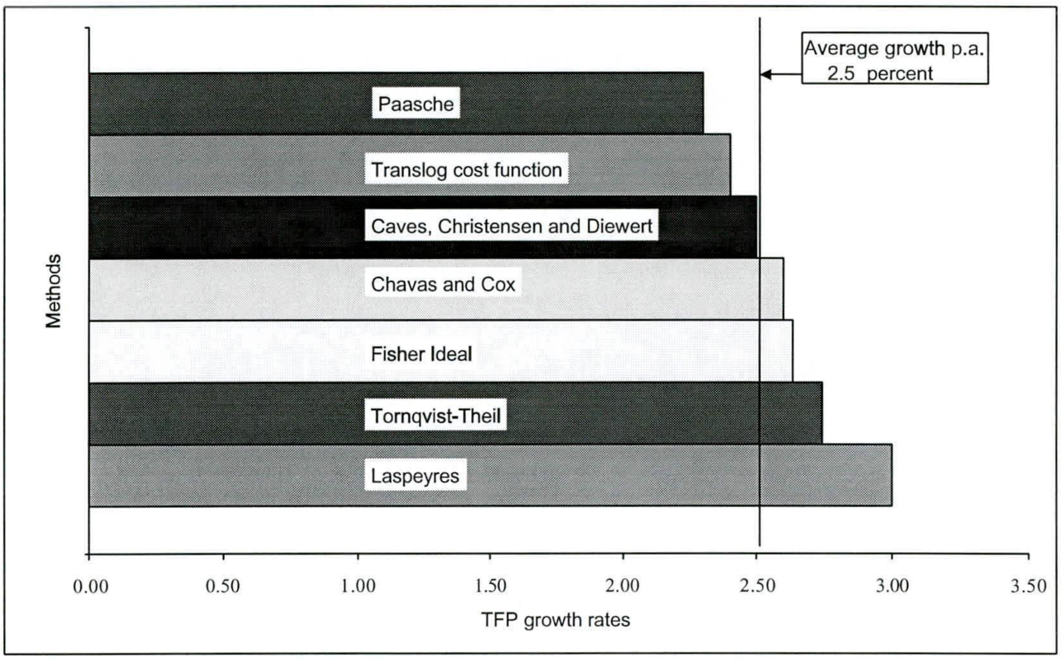
5. A translog cost function is a parametric measure. Mullen and Cox (1996) specified and estimated a translog cost function to take account of the returns to scale and bias in technical change.

An investigation of Column 7 in Table 1 reveals that the growth estimates of the studies using different approaches did not vary remarkably. For instance, in the studies by Mullen and Cox (1995) and Mullen *et al.* (1995), where they have used broadacre agriculture data for the period 1953/54 to 1987/88, the growth estimates measured by different approaches varied between 1.6 to 2.3 percent. Similarly, Mullen and Cox (1996), by extending the data series to 1993/94 and by applying similar approaches, experienced an even smaller divergence (2.4 to 2.6 percent) in the estimates of productivity growth. With the exception of the Malmquist approach, similar results were found by Strappazzon *et al.* (1996) (Table 1). The Malmquist productivity index has given a negative growth rate over the study period whereas the growth measures for the same data set from other indices range between 2.3 to 3.0 percent. One possible explanation advanced by Strappazzon (1996) for this erratic result is the fact that Malmquist index does not use prices to 'weight' commodities.

A simple statistical analysis of the growth estimates given in column 7 of Table 1 reveals that the TFP growth of Australian broadacre agriculture is distributed around the mean[12] of 2.5 percent p.a. with a very small standard deviation of .4. In Figure 1, a graphical illustration on the average growth for each category of methods reveals that all growth estimates are close to the mean while the PA and LA estimates lie on the two extreme ends of the mean.

FIGURE 1

TFP GROWTH IN AUSTRALIAN BROADACRE AGRICULTURE MEASURED BY DIFFERENT METHODS



2.3 The approach selected for this study

The review of productivity measures and empirical studies presented above suggests that parametric and non-parametric approaches differed in the extent to which they imposed structure on the nature of technology relating to biasness, returns to scale, and functional form. Each of the approaches have weakness and strengths. For example, for all the non-parametric approaches it is not possible to measure the level of statistical significance for their growth estimates. This is an important drawback as it is difficult to compare growth estimates from two non-parametric

[12] In this mean the Malmquist TFP growth rate of -.8 is excluded considering it to be an outlier.

approaches in terms of their goodness of fit. On the other hand, parametric methods provide information on statistical goodness of fit but they need data with a large number of observations to overcome the degrees of freedom problem. In the context of Australian agriculture, such a data base is not readily available.

Comparing the FI and TT indices, in line with Diewert (1992), Mullen and Cox (1996) have preferred the FI index because the TT index, although widely used, does not pass the factor reversal test. Diewert (1976 and 1983) and Caves, Christensen and Diewert (1982), however, suggest that the direct output and input quantity indices, based on the TT method are theoretically superior under certain conditions. The studies above lead to the conclusion that a choice between the TT and FI methods, needs to be made as to whether a direct-quantity and implicit price or an indirect quantity and direct price indices should be used.

Despite the marginal disadvantages of the TT approach compared to the FI index outlined above, we have applied the TT or C&J TFP approach for the following reasons:

1. The productivity data set provided by ABARE is in index form. ABARE applies the TT method to the Australian annual farm survey data in compiling the productivity data set.
2. In order to apply other methods, the available data will have to be reconstructed which imposes sever restrictions in terms of time and resources.
3. As most of the previous studies (including the Productivity Commission, 1999) have used the TT method, its application makes the results of this study comparable with those cited in early studies.
4. As evident in Table 1 and Figure 1, the TFP growth measured by the TT method does not differ much from those measured by other methods such as FI and CCD methods.

Hence, we have used the TT method. For our empirical estimation of the TFP growth in WA broadacre agriculture, we have used the following TT index formula. In log form the TFP index can be expressed as

$$\ln(TFP_t/TFP_{t-1}) = \sum_{i=1}^{N} \bar{R}_{it}\ln(Y_{it}/Y_{i,t-1}) - \sum_{j=1}^{K} \bar{S}_{it}\ln(Y_{jt}/Y_{j,t-1}) \quad (2)$$

where Y_i is the i^{th} output quantity; $\bar{R}_{it}$ is $\frac{1}{2}(R_{it} + R_{i,t-1})$, the average of the output revenue share ($R_{it} = P_{it}Y_{it}/N_t$) of the i^{th} output component in period t and t-1; $N_t = \sum_{i=1}^{N} P_{it}Y_{it}$; P_{it} is the price of i^{th} output; X_{jt} is the j^{th} input quantity; $\bar{S}_{it}$ is $\frac{1}{2}(S_{it} + S_{i,t-1})$, the average of the input cost share ($S_{it} = P_{jt}X_{jt}/K_t$) of the j^{th} input component in period t and t-1; $K_t = \sum_{j=1}^{K} P_{jt}X_{jt}$ and P_{jt} is the price of j^{th} input.

3. ESTIMATES OF PRODUCTIVITY GROWTH IN WA AGRICULTURE

In this section, growth in inputs, outputs and productivity of WA broadacre agriculture are estimated and compared to that for other Australian states. The TT indexing method discussed in Section 2 and the farm productivity data set discussed below are used for the growth estimation. Within WA, the outputs, inputs, and TFP growth are estimated for WA climatic zones and broadly classified industries. Our estimates are also compared with the findings of earlier studies.

3.1 The data set

The database used to estimate the productivity growth in WA agriculture is the 'farm productivity data' of the Australian Bureau of Agricultural and Resource Economics (ABARE, 1999). This data series contains average farm level output and input data for a period of 21 years (1977/78 to 1997/98) and is based on ABARE's annual farm surveys of broadacre and dairy industries[13]. ABARE provides data for:

- Total broadacre (farms with 200 or more sheep) by states;
- Western Australian broadacre by three climatic zones ;
- Western Australian broadacre by five ANZSIC industries; and
- Western Australian dairy industry.

The broadacre and dairy industries relate mainly to certain types of commodities and are based on the Australia New Zealand Standard Industry Classification (ANZSIC) (ABS, 1993). These ANZSIC industries are: Crops, Livestock-crops mixed, Sheep, Beef, Sheep-beef and Dairy.[14] Under the classification of climatic zone, broadacre agriculture is divided into three main zones: high-rainfall, wheat-sheep, and pastoral zones. The agricultural characteristics of these zones and

[13] A list of variables and a note on the data set are given in Islam (1999a).

[14] Farms assigned to a particular ANZSIC industry class have a greater proportion of their output chracterised by that class (ABARE, 1997). This means that farms in an industry class also produce other commodities in addition to the major output suggested by the industry name. See Islam, (1999) for further information on the farming activities included in each of these industries.

industries are described in Islam (1999). In this study, except the WA dairy industry all other broadacre data sets are used.[15]

The composition of the input and output variables in the data sets for the climatic zones and industry classifications are more or less the same as in the total broadacre data set. There are price and quantity variables for 12 outputs and 27 inputs. Where quantity variables were not available, ABARE derived them by deflating the farm survey data with ABARE's appropriate price-paid and price-received indices (ABARE, 1995). The prices used were farm gate prices.

For the purpose of comparing productivity growth across Australian states, WA climatic zones and commodity industries, these variables were grouped into one composite output and one composite input by using the TT index method mentioned in Section 3. However, for the subsequent analysis for WA agriculture these composite outputs and inputs are decomposed into six output[16] and three input groups. A general description on the measurement of the output and input groups for the total broadacre data set is given in Appendix A.

3.2 WA broadacre agriculture

The movement of the output, input and productivity indices and their growth rates for WA broadacre agriculture are presented in Figure 2. The output, input and TFP indices are given in Table B1 of Appendix B and the decomposed quantity indices of six output and three input components are given in Tables B2 and B3 respectively, of Appendix B.

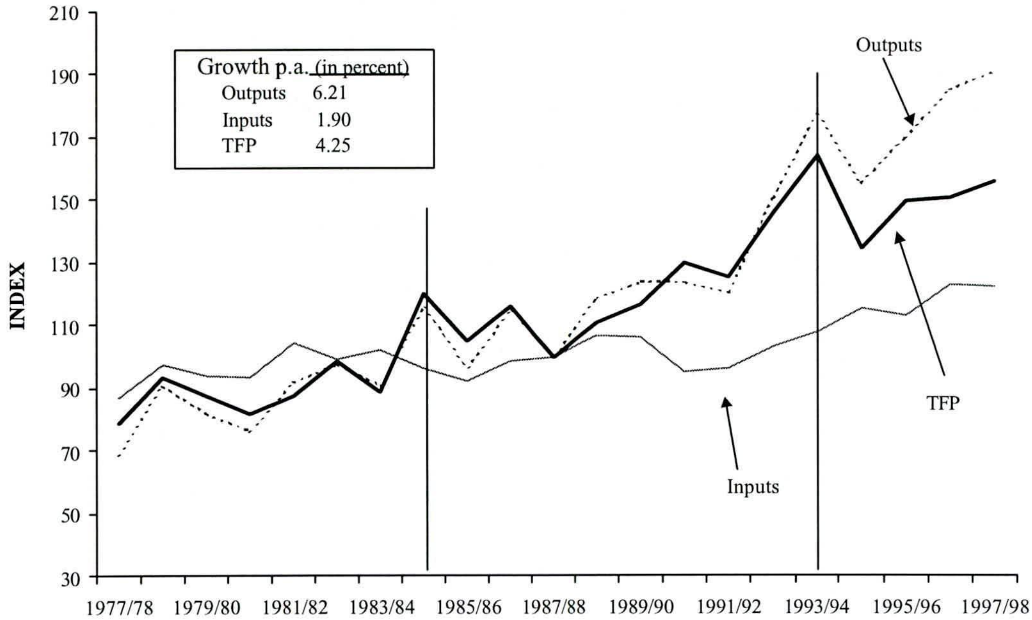
Figure 2 indicates that over the 21 year study period, except for a few marked declines from 1984/85 to 1985/86, and from 1993/94 to 1994/95 (as indicated by the two vertical lines), the TFP in WA broadacre agriculture has been increasing at an average rate of 4.2 percent p.a. with a standard deviation of 13.1 (Table 2). Input use per farm has been more or less flat until 1991/92 but since then it has been slowly increasing. For the total period the annual average growth rate of total input is estimated at 1.9 percent with a relatively smaller standard deviation of 6.2 (Table 2). The annual average output growth is estimated at 6.2 percent with a standard deviation of 14.7 (Table 2). The movement of the output index appears to have followed closely the movement of the TFP

[15] The dairy industry is not included in this paper because its data set is separate and different from the broadacre data set. However, a productivity analysis for this industry has been done separately and its results can be obtained from the author on request.

index (Figure 2). Given that the input growth has been slow, the TFP growth appears to have been contributing significantly to the output growth in WA broadacre agriculture.

FIGURE 2

OUTPUTS, INPUTS AND PRODUCTIVITY TRENDS IN WA AGRICULTURE, 1977/78 TO 1997/97 (1987/88 =100)



Compared to those of the early studies in WA, our growth estimates seems to be larger. For example, Coelli (1996) estimated the output, input and TFP growth rates at 5.3, 2.6 and 2.7 percent p.a. respectively. He used the same TT method that we used. Reasons for this difference could be that the data he has used were for a different location (i.e. the wheat-sheep zone in WA) and time period (1953/54 to 1987/88). The other reason could be that he obtained these annual growth rates by subtracting one from the exponent to the coefficients of the time trends whereas we obtained the same by taking an average of the annual percentage changes in outputs, inputs and TFP indices.[17] However, the nature of the volatility of the output growth appear to be similar to that in this study.

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[16] The composition of outputs in a commodity groups is different from that in a corresponding ANZSIC industry. For example, the total output of the sheep commodity includes sheep and lamb for meat whereas the total output in the sheep industry classified by ANZSIC code, includes sheep, prime-lamb, wool and other commodities.

[17] Our approach to obtain the annual rate of growth was applied toCoelli's data and found that his output, input and TFP growth rates have changed to 6.8, 2.9 and 3.9 percent p.a. respectively. These growth rates are very close to those of the present study.

In both the present and Coelli's (1996) studies the volatility in the output growth is very high compared to input growth.

3.3 The six states

The output, input and TFP growth estimates of WA agriculture are compared with those of other Australian states[18] in Table 2. With respect to TFP and output growth, WA is second to South Australia where these growth rates are 6.5 and 7.3 percent p.a. respectively. The overall national TFP and output growth rates are 3.3 and 4.2 percent p.a. respectively. In terms of input growth, WA has the highest growth of 1.9 percent p.a. and Tasmania has the lowest growth of –.1 percent p.a..

TABLE 2

AVERAGE ANNUAL GROWTH IN BROADACRE AGRICULTURE IN AUSTRALIAN STATES, 1977/78 –1997/98

States	Outputs		Inputs		TFP	
	Growth % p.a.	SD	Growth % p.a.	SD	Growth % p.a.	SD
	(1)	(2)	(3)	(4)	(5)	(6)
Western Australia	6.21	14.68	1.90	6.17	4.25	13.10
Victoria	4.04	18.91	0.67	5.36	3.64	19.95
Tasmania	2.02	19.38	-0.13	12.23	1.71	10.44
South Australia	7.25	22.37	0.82	4.48	6.49	23.01
New South Wales	4.18	17.00	0.82	6.31	3.79	18.69
Queensland	4.18	14.84	1.40	7.95	3.16	15.29
AUSTRALIA	4.19	12.31	1.01	3.41	3.27	12.89

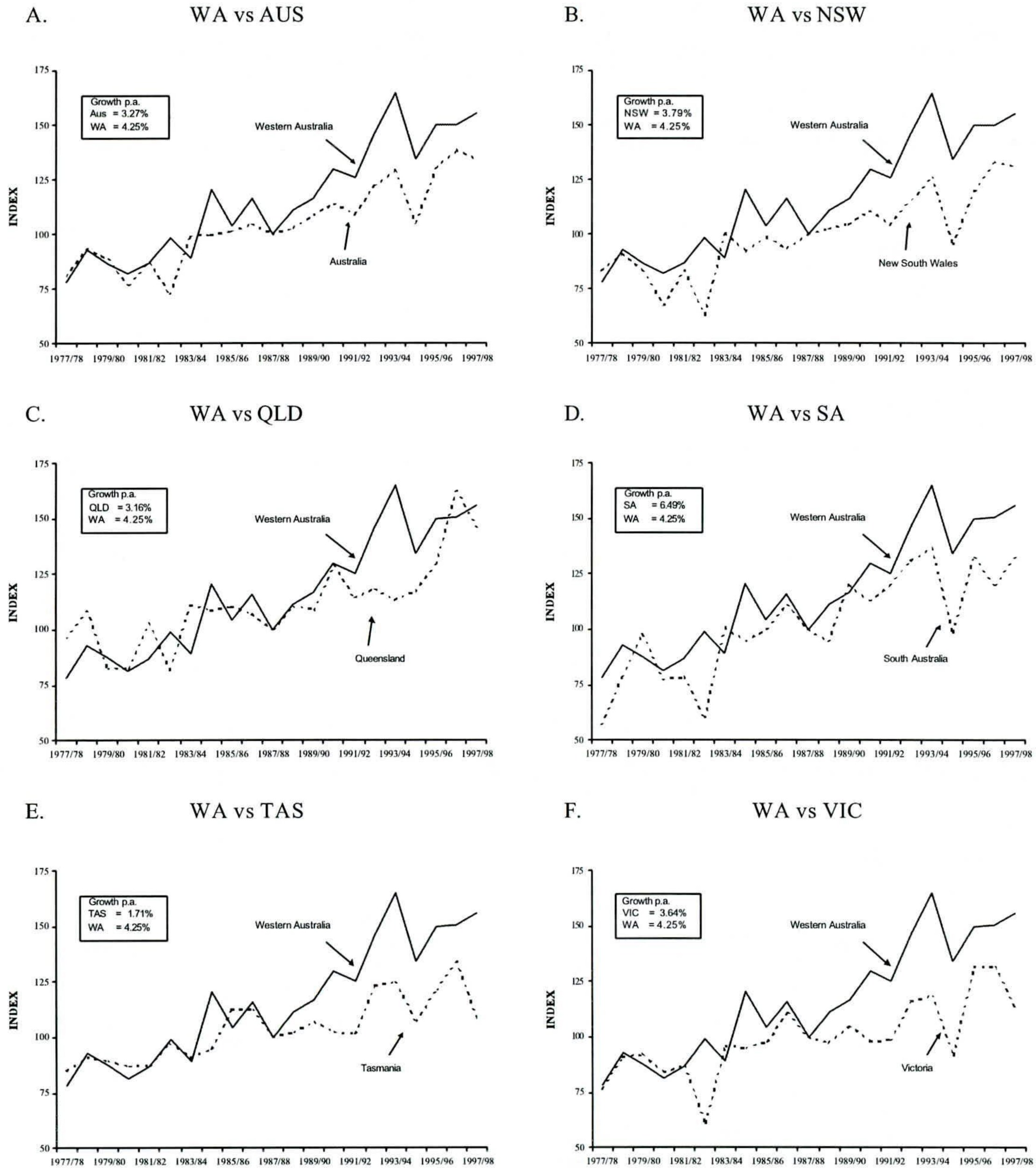
Note: The growth p.a. is obtained by taking an average of annual percentage changes in outputs, inputs and TFP indices. The SD is the standard deviation. Conceptually, the difference between the per annum growth in outputs (in column 1) and inputs (in column 3) should be equal to the corresponding per annum growth in TFP (in colimn 5). However, we notice that in most cases they are not equal. This discrepancy is mainly due to large variations in output and input indices.

A further examination of these growth estimates reveals that although SA's output and TFP growths have the highest value, the value of their standard deviations are also very high (22.4 and

23.0 respectively). This indicates that the total output and TFP growths in SA have been relatively volatile compared to WA. The relative volatility in the movement of the TFP index for WA agriculture is compared with those of the other Australian states in Figure 3.

FIGURE 3

TFP IN BROADACRE AGRICULTURE IN WESTERN AUSTRALIA AND OTHER AUSTRALIAN STATES, 1977/78 – 1997/98 (1987/88 =100)



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[18] The total outputs, inputs and TFP indices for individual Australian states are provided in Tables B1, and in B4 to B9 of Appendix B.

In general, the TFP indices for all the states have positive growth trends. However, the TFP growth in WA agriculture appears to have exceeded all the states particularly since 1987/88. As panel D shows, SA starts from a lower level than WA. Accordingly, despite the higher annual growth in SA, the level of productivity is still higher in WA than SA. Another interesting feature to note that since 1987/88, the TFP growth path for all other states except for Queensland and South Australia, more or less moved parallel with the TFP growth path for WA. As the composition of agricultural structure and physical environment are different from one state to the other it is difficult to explain clearly from Figure 3 why such a parallel movement exists and why the TFP growth in WA agriculture has been higher, particularly during the last decade. Establishing such an explanation for this phenomena is beyond the scope of this study.

The rest of this section is limited to the analysis of the growth performance of WA agriculture according to its climatic zones, and industry classifications.

3.4 Climatic zones

The growth rates and their SDs of outputs, inputs and TFP in the three climatic zones of WA broadacre agriculture are presented in Table 3. The TFP trends for these climatic zones are compared in Figure 4. It is revealed that the TFP trends and growth rates for the whole WA and its wheat-sheep zone are almost identical. They move closely together. This is perhaps to be expected as the share of the wheat-sheep zone is dominant (more that 80 percent) in the total gross value of agricultural production (GVAP) in WA.

Table 3 indicates that the growth rates of outputs, inputs and TFP are highest at 7.1, 2.4 and 4.7 percent p.a. respectively, in the wheat-sheep zone. The outputs and inputs growth are less volatile in this zone compared to the other two zones. The above results reconfirm a common view that the growth performance of broadacre agriculture in WA is almost entirely dependent on the growth performance of its wheat-sheep zone.

TABLE 3

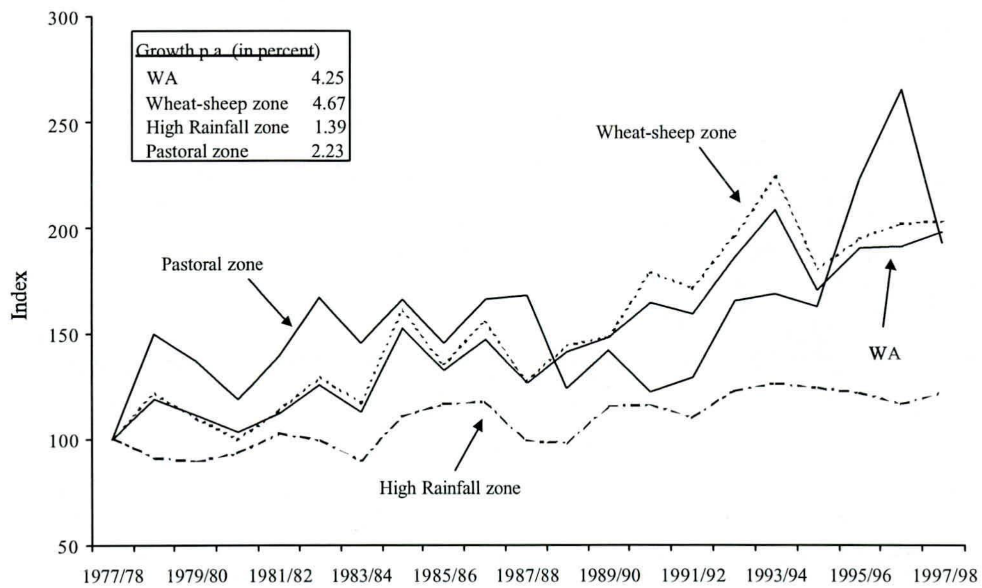
AVERAGE ANNUAL GROWTH IN BROADACRE AGRICULTURE BY WA CLIMATIC ZONES, 1977/78 –1997/98

WA Climatic Zones	Outputs		Inputs		TFP	
	Growth % p.a.	SD	Growth % p.a.	SD	Growth % p.a.	SD
	(1)	(2)	(3)	(4)	(5)	(6)
Wheat-sheep Zone	7.11	16.68	2.38	6.76	4.67	15.22
High-Rainfall Zone	3.28	16.79	1.76	12.92	1.39	9.28
Pastoral Zone	2.59	16.70	-0.01	21.01	2.23	20.56
Western Australia	6.21	14.68	1.90	6.17	4.25	13.10

Note: See the note to Table 2.

FIGURE 4

AGRICULTURAL TFP IN WA CLIMATIC ZONES, 1977/78-1997/98 (1977/78=100)



The estimated SDs of the average output and input growth indicate that, the output variability across the zones are almost the same but they are different for the input (Table 3). For the pastoral zone the SD for the input growth is 21.0, which is more than three times higher than that for the wheat-sheep zone and about two times higher than for the high-rainfall zone. For the wheat-sheep zone, the output growth is very high (7.1 percent p.a.). The TFP growth (4.7 percent p.a.) is also very high compared to that of the pastoral zone (2.2 percent p.a.). There has been a steady growth in input (2.4 percent p.a.) in the wheat-sheep zone compared to the negative average (-.01 percent p.a.) and highly volatile input growth in the pastoral zone. For the high-rainfall zone, the volatility in the growth of outputs and inputs are high but it is low in the TFP growth. The close movements of both the output and input indices may explain the low volatility of the TFP growth (see, panel C in Figure C1 of Appendix C).

3.5 ANZSIC industries

The growth performance of the broadly defined industries in WA Agriculture is assessed in Table 4 and Figure 5.[19] It is revealed in Table 4 that the crops industry has the highest TFP and total output growth of 6.6 and 10.3 percent p.a. respectively. The growth in input is relatively lower (3.3 percent p.a.). The TFP growth of this industry is volatile but it was steady until 1990/91. Since then it has slowed (see, panel A in Figure 5). The input growth of this industry on the other hand, declined until 1988/89 and then picked up steadily[20]. A very high SD of 30.3 indicates that the output growth of this industry has been highly volatile (Table 4).

The outputs, inputs and TFP growth in the sheep industry are almost the same as those in the beef industry (Table 4). However, farms producing both the sheep and beef jointly (sheep-beef) have experienced a highly volatile growth in outputs, inputs and TFP indices. There are a few extreme data points in the input index[21] which explain the highly volatile growth in the sheep-beef industry. Relatively less volatility is observed in the TFP growth in the sheep industry[22] except that its output index increased sharply from 1995/96 to 1996/97 and then dropped sharply in 1997/98. One reason for this could be that the number of sheep sold for meat soared in 1996/97 due to declining wool prices.

[19] The growth trends of outputs, inputs and TFP for individual industries are presented in Figure C2 of Appendix C.
[20] See, panel A in Figure C2 of Appendix C.
[21] See, panel D in Figure C2 of Appendix C.
[22] See, panel B in Figure C2 of Appendix C.

TABLE 4

AVERAGE ANNUAL GROWTH IN BROADACRE AGRICULTURAL INDUSTRIES IN WA, 1977/78 –1997/98

WA ANZSIC Industries	Outputs		Inputs		TFP	
	Growth % p.a.	SD	Growth % p.a.	SD	Growth % p.a.	SD
	(1)	(2)	(3)	(4)	(5)	(6)
Crops	10.33	30.30	3.32	17.63	6.62	20.46
Sheep	7.59	27.16	3.73	20.25	4.08	19.35
Beef	7.47	31.04	3.37	22.85	3.49	15.42
Sheep-beef	5.82	34.86	4.11	30.49	4.66	26.49
Livestock-crop mixed	4.59	13.71	1.87	10.71	3.00	11.09
Western Australia	6.21	14.68	1.90	6.17	4.25	13.10

Note: See the note to Tables 2.

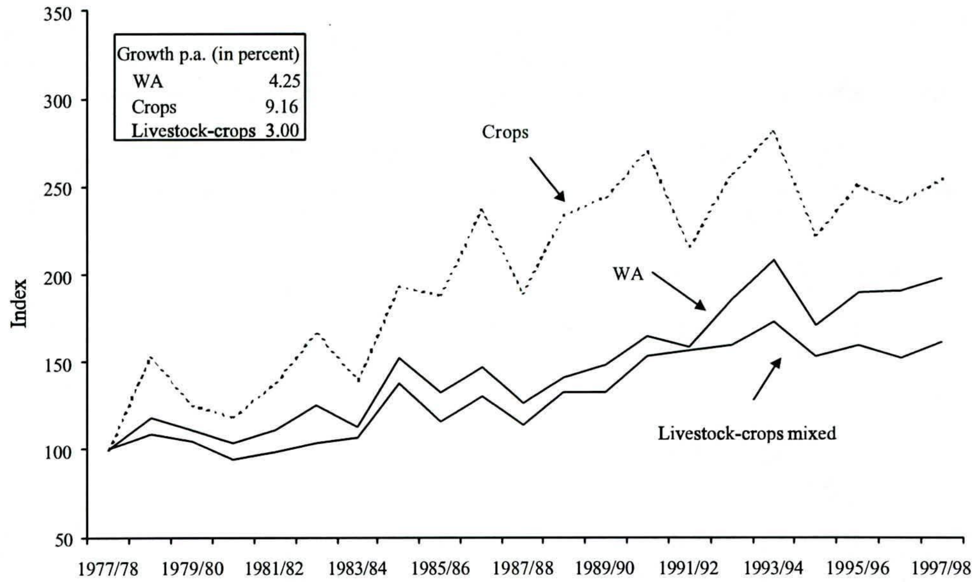
Based on the analysis above it is difficult to make an assessment as to why some industries have performed better than others. Also, it is difficult to ascertain which industry has contributed the most to the overall performance of WA broadacre agriculture. To ascertain such contributions, much more elaborate data[23], and the application of more sophisticated methods than those used in this study are required. However, in the following section we have made an attempt to assess the factors contributing to the growth performance of the overall broadacre agriculture in WA.

[23] Recently, Evenson *et al.*(1999) have measured productivity growth in Indian agriculture and assessed the contribution by several sources to that growth. They have used the crops sector data that covers all Indian districts – a total of 271 – for the period 1956 to 1987 with a total of 8,672 observations.

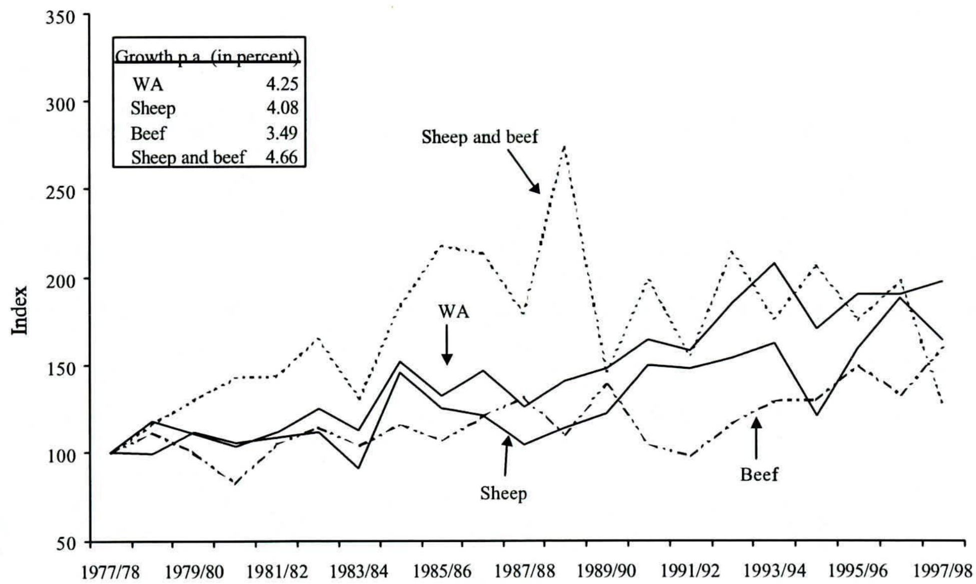
FIGURE 5

TFP IN WA AGRICULTURAL INDUSTRIES,
1977/78-1997/98 (1977/78=100)

A. Crops and livestock industries



B. Sheep and beef industries



4. FACTORS EXPLAINING PRODUCTIVITY GROWTH IN WA AGRICULTURE

Given the geo-climatic condition of a region, the productivity growth of its agriculture depends on a number of factors, ranging from technological changes to changes in market conditions (Evenson *et al.*, 1999). Being constrained by the limitations surrounding the available data described in Section 3, we adopt a simple analytical approach in explaining the sources of productivity growth in WA agriculture. Recall that we have measured the TFP trends by taking the ratio of the total output and total input indices and the TFP growth is residually measured by taking the difference between the growth of total output and total input (i.e. capital, labour and materials and services). Since to a lesser extent seasonal conditions influence input trends the productivity trends is likely to follow the path of the output trends, unless there is a change in technological factors. We observe in Figure 2 that the total input trend is relatively flat and less fluctuating over the data period. Hence, changes in output trends can be explained by the changes in the TFP trends. Conversely, changes in the TFP trends can be explained by identifying factors (other than inputs) affecting changes in the output trends.

To begin with, by examining the movement of the TFP index in Figure 2, we identify major changes in its trends. Secondly, based on these changes the total data period is segmented into a few sub-periods. For each of these sub-periods the TFP, input and output growth are calculated. Finally, by relating these to relevant historical events such as seasonal conditions, technological progresses,[24] and market conditions in WA agriculture we made an attempt to explain the productivity growth in WA agriculture.

4.1 Growth by sub-periods

If we refer back to Figure 2, it can be noticed that there were two major changes (sharp rise and fall) of the TFP index over the data period 1977/78 to 1997/98. The first sharp rise in the TFP took place in 1984/85 and then fell sharply in 1985/86. The second sharp rise took place in 1993/94 and then fell sharply again in 1994/95. We also noticed that during these two periods of major changes the output index closely followed the movement of the TFP index. These breaks are

[24] We have considered "R&D efforts' as a proxy for technological progress. Changes in infrastructure, skills, and institutions also affect productivity growth. Being constrained by data limitations we are unable to analyse their contributions to the productivity growth in WA agriculture.

marked by two vertical lines in Figure 2 and the total period is divided into three sub-periods. The first period is from 1977/78 to 1984/85, the second is from 1985/86 to 1993/94, and the third is from 1994/95 to 1997/98.[25] Based on a review of historical events such as seasonal conditions, technological progress and market situation, compiled in Table D1 of Appendix D, we try to identify reasons for the rise and fall of the TFP index in those two years of peak productivity growth.

Table D1 of Appendix D reveals that good seasonal conditions[26] prevailed right from 1980/81 to 1984/85. However, 1984/85 was an exceptionally good season with record levels of production. Similarly, in 1993/94 the seasonal conditions were also very good and a near record level of grain yields was achieved. The production of lupins for the first time exceeded one million tonnes and canola production nearly quadrupled from a low base. If we examine the seasonal conditions of the years 1985/86 and 1994/95 when the TFP index declined sharply, we find that there was low rainfall during those two years. This analysis perhaps suggests that the seasonal conditions might have been one of the main reasons for the sharp rise and fall in the total output growth and thereby affecting the TFP growth in WA agriculture. While changes in seasonal conditions to a large extent dictate the output trends, to a lesser extent they influence input trends. Productivity growth, measured residually by deducting input growth from the output growth, is therefore likely to follow the path of the output trends, unless technological factors also changed. In the next sub-section, we decompose the output growth by TFP and various input components to determine the net contribution of TFP to output growth.

4.2 A decomposition of output growth

Again, based on the two years of major changes discussed above, we divide the total 21 year period into three sub-periods: 1977/78 to 1984/85, 1985/86 to 1993/94 and 1994/95 to 1997/98. For each sub-period we decompose the total output growth into the growth of the TFP and three input components for further analysis.

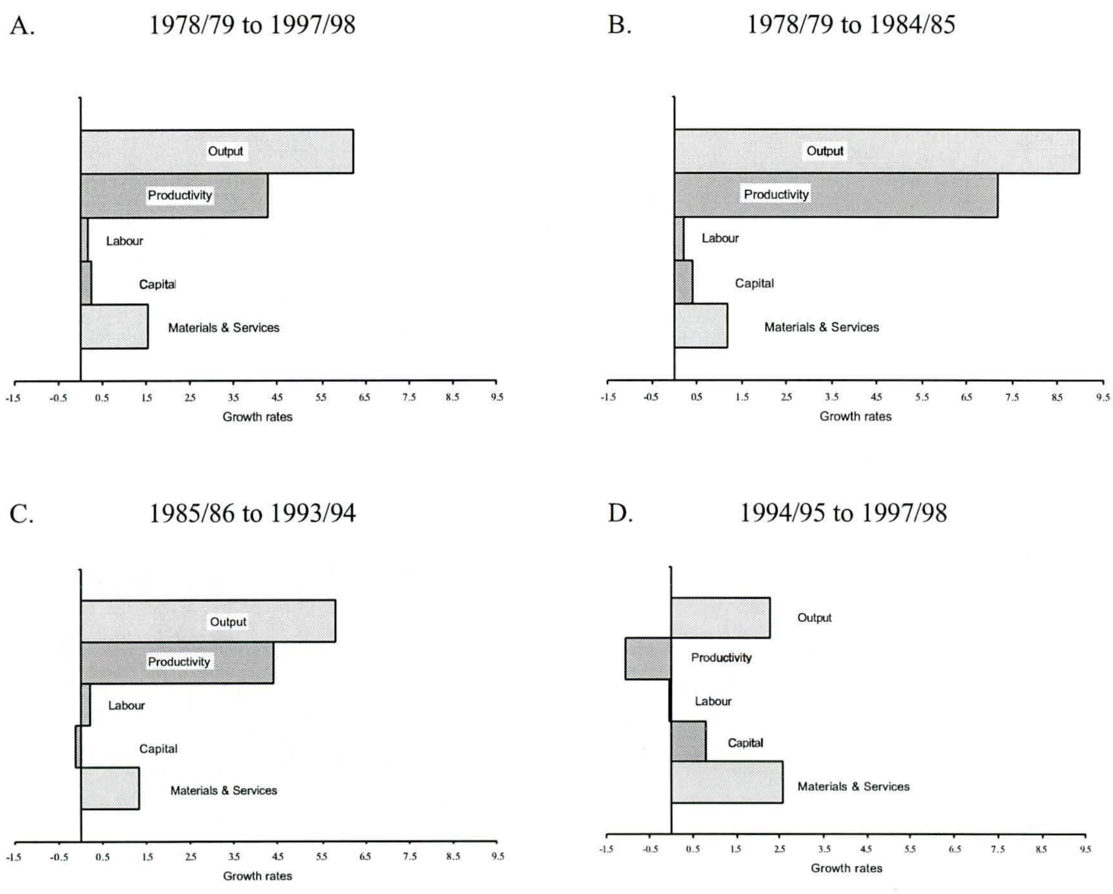
Panel A in Figure 6 reveals that, over the whole 21 year period, the output growth of WA agriculture stemmed primarily from improvements in productivity growth. There is, however, an

[25] With respect to major technological/structural changes in WA agriculture, these periods roughly correspond to the periods associated with the introduction oflupins in 1981/82 and the wool stockpile accumulation in 1990/91, as pointed out by RossKingwell and Ian Wilkinson of Agriculture WA.

exception for the recent sub-period between 1994/95 to 1997/98 (see, panel D in Figure 6). In this period the growth in TFP and labour input is negative whereas rapid growth is achieved in capital, and materials & services inputs, with the peak occurring in the last two years (see, Table B3 of Appendix B). Compared to the first and second sub-periods the output growth (2.3 percent p.a.) is also low in this time segment. One explanation as to why the TFP growth is negative is that, as output growth did not keep pace with input growth during the period, productivity of in situ capital and materials & services declined. A similar view is maintained by the Productivity Commission (1999).

FIGURE 6

CONTRIBUTIONS OF INPUTS AND TFP TO AVERAGE OUTPUT GROWTH IN WA BROADACRE AGRICULTURE, 1977/78 – 1997/98
(percent p.a.)



An investigation into the seasonal conditions and R&D activities (see, Table D1 of Appendix D) reveals that during this last segment, the seasonal conditions varied from low rainfall

[26] A 'good seasonal condition' can be described as a season with adequate rainfall and favourable weather conditions for the crops and livestock production and with no pest and disease outbreaks.

to a more or less satisfactory condition. Although there were pest and disease outbreaks, the area of production under the newly released wheat, canola and pulse crops expanded rapidly. A significant number of new cultivars and cereal crop varieties were released. Moreover, the organisational structure and management of the Agriculture WA[27] took a major turn to provide services to the WA agricultural sector.

The above situation gives an indication that seasonal factors along with pest and disease outbreaks may have lowered the output growth in this period. On the other hand, the expansion of the production area, changes in the provision of agricultural services and the adoption of new technologies may have contributed to the relatively higher growth in capital, and materials & services inputs. The full impact of these inputs on output growth is yet to be achieved. Hence, as productivity is residually measured, the lower output growth and the higher input growth gave rise to a negative productivity growth in this period. This finding supports the earlier explanation that, as output growth did not keep pace with the input (capital and materials & services) growth during the third sub-period, productivity declined.

As mentioned earlier, the output growth in the first segment (1978/79 to 1984/85) was very high (9.0 percent p.a.) and the productivity growth at a rate of 7.2 percent p.a., was the major contributor to this growth (see, panel B in Figure 6). For this period, Table D1 of Appendix D reveals that after experiencing a severe seasonal condition until 1979/80, an extremely good seasonal condition prevailed until the end of this sub-period. Many new technologies (including 'minimum tillage', release and the adoption of new wheat, oats and rapeseed varieties, a drop in livestock losses caused by annual rygrass toxicity disease, the provision of extension services through electronic media, soil conservation practices and so on) were introduced. It appears that despite the adverse seasonal conditions that prevailed during the early part of the segment, two main factors may be advanced to explain the high output and TFP growth in this period; the exceptionally favourable seasonal conditions in the later part of the period and the introduction and adoption of a significant number of new technologies.

During the second sub-period 1985/86 to 1993/94 (see, panel C in Figure 6), the contribution of the TFP growth (4.1 percent p.a.) to the output growth (5.8 percent p.a.) is also high compared to the growth in inputs. However, the outputs and TFP growth are smaller than those in the first sub-period. The capital growth declined in this period. Again, the historical events indicate that the seasonal conditions were mostly average. Grain growers faced financial difficulties because

[27] Agriculture WA is the state government agency which provides most of the R&D services to the agricultural sector

of low grain prices. Returns from wool declined and a rapidly accumulating wool stockpile culminated in the lowering of the reserve floor price and termination of the Wool Reserve Price scheme. Sheep numbers increased to an excessive level and live sheep exports to Middle Eastern countries declined. These had a significant effect on the production of sheep in WA and on the cash-flow of sheep farmers. There was also a major outbreak of pests and diseases. In spite of all these unfavourable circumstances, a significant amount of R&D efforts were devoted during this period which, to a large extent perhaps, offset the adverse effects on output and productivity growth. For example, the program to support the specialist wool growers was stepped up by directing resources to a production and diversification campaign to assist wool growers adopt more cost effective production techniques and to identify opportunities to diversify from wool production to other forms of livestock and crop productions (see, Table D1 of Appendix D for more information).

The above analysis suggests that while the seasonal conditions played a major role in the fluctuations of the output growth, the productivity growth as a measure of technological progress, appears to have contributed significantly in maintaining a steady growth in WA agriculture. In the following sub-section we decompose the total output growth into the growth of six commodity components in order to identify reasons for variations in the contribution of these components to the total outputs in each sub-period.

4.3 The commodity composition of output growth

There is a general view among agricultural professionals that, in recent years a few new crop enterprises (such as pulses & oilseed crops) are contributing significantly to the total output and productivity growth in WA agriculture. To gain an understanding of the contribution made by traditional and new commodities to the total output growth and how their contribution varied over the 21 year period, we have decomposed the total output growth into the growth of six major commodity components. The same exercise is also performed by segmenting the data into three sub-periods as mentioned above. This analysis may give some indication of the effect of R&D efforts on the productivity growth of WA agriculture.

The results of the decomposed output growth are presented in Figure 7. The six output components are: cereals, pulses & oilseeds, sheep meat, beef, wool, and all other commodities

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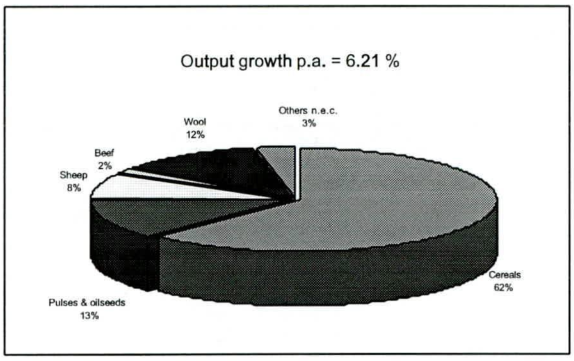
in WA.

which are not elsewhere cited (n.e.c.) (see, Appendix A for the composition of these output components).

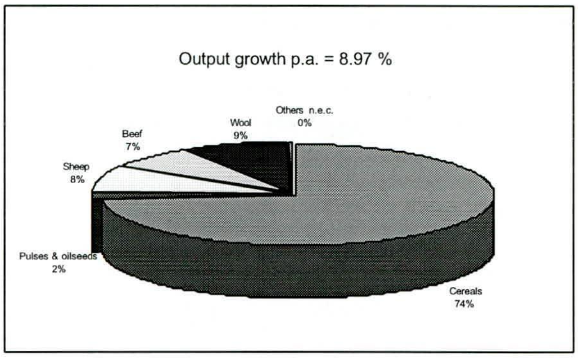
FIGURE 7

CONTRIBUTION OF MAJOR COMMODITIES TO OUTPUT GROWTH IN WA AGRICULTURE, 1978/79 – 1997/98

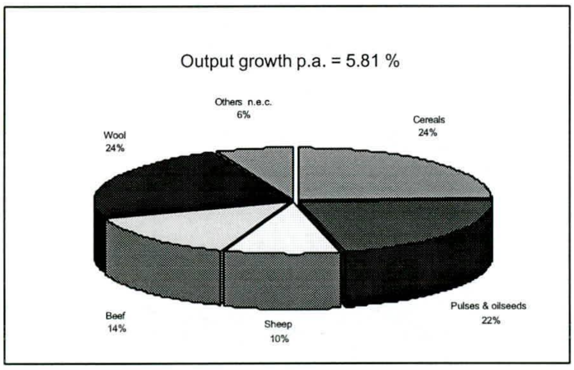
A. 1978/79 to 1997/98



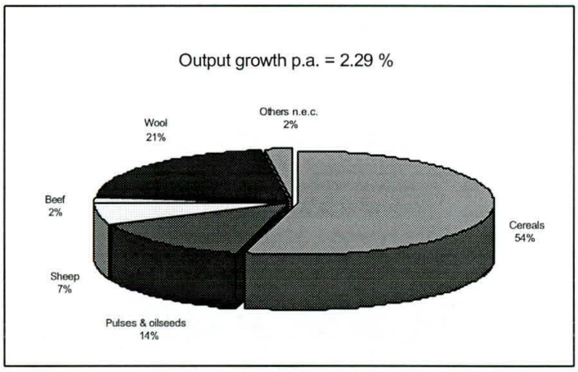
B. 1978/79 to 1984/85



C. 1985/86 to 1993/94



D. 1994/95 to 1997/98



Panel A of Figure 7 indicates that over the whole 21 period, cereals output contributed the most (62.0 percent) to total output growth. Pulses & oilseeds output contributed 13.0 percent and wool and sheep meat outputs jointly contributed 20.0 percent. In Panel B, for the first sub-period from 1978/79 to 1984/85, there was an absolute dominance by cereals output (74.0 percent) and the sheep meat and wool outputs jointly contributed 17.0 percent. Note that the contribution made by the pulses & oilseeds output was only two percent in this period. Relating these results to the historical events outlined in Table D1 of Appendix D, the R&D activities in this period are revealed as mainly cereals and sheep-wool oriented and the favourable seasonal conditions mainly benefited the cereal crops (i.e. mainly wheat). Given the share (about 50 percent) of the cereals industry in the

GVAP of WA agriculture, a little variation in its area and production is likely to affect the size of the total output growth. This appears to have happened in the second sub-period.

Analysis of the second sub-period from 1985/86 to 1993/94 gives a totally different picture (see, panel C, Figure 7). The contribution of cereals output declined sharply, to 24.0 percent, while the share of pulses & oilseeds jumped to 22.0 percent and wool and sheep output together also increased to 34.0 percent. As mentioned earlier, some adverse seasonal and market conditions prevailed in this period. This situation perhaps resulted in relatively lower output growth. It appears that the adverse situation has mainly affected the growth of the cereals component (see, panel C of Figure 7).

An investigation into the area and production statistics[28] of the cereal and pulses & oilseed crops indicates that during this second sub-period, the area under cereal crops declined by 1.8 percent p.a. compared to 3.8 and 2.3 percent p.a. increases in the first and third sub-periods respectively. Increases in the production of cereals were also low (2.1 percent p.a.) in this period compared to the first (14.3 percent p.a.) and third (5.7 percent p.a.) periods.

While the area and production of the cereal crops declined, they increased by 9.0 and 14.1 percent p.a. respectively for the pulses & oilseed crops in the second period. This has perhaps resulted in the increase of the relative share of the pulses & oilseed crops to the total output growth in this period. Historical events relate that the R&D activities in this period were mainly directed towards the production and marketing issues related to the pulses & oilseeds and the wool-sheep industries. Therefore, the increase in the share of pulses & oilseeds and wool-sheep output to the total output growth may be explained by an increase in the adoption of R&D technologies related to these industries. In other words, decline in the area under cereal crops in one hand and a technological boost to expand the pulses & oilseed crops on the other possibly have resulted in a decline in the share of cereals to the total output growth.

We have mentioned earlier that the total output growth was the lowest (2.2 percent p.a.) during the last segment of the study period. Of this low output growth, the Panel D of Figure 7 indicates that the share of the cereal outputs has moved up again and reached to 54.0 percent while the share of the pulses & oilseeds outputs has declined moderately from 22.0 to 14.0 percent. Increases in the area and production of the cereal crops seems to be the reason for the increase in the contribution of cereal outputs to the total output growth in this sub-period. Although the

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[28] Ian Wilkinson, Agriculture WA, South Perth, WA provided these statistics through personal correspondence.

contribution of the pulses and oilseeds outputs has declined to 14.0 percent, it is still much bigger than its share of 2.0 percent in the first sub-period.

The above analysis shows which component has contributed the most to the output growth, but it does not help to make a clear statement as to which commodity component has contributed the most to the productivity growth. Unless the productivity growth for each of the commodity components is measured we can not determine their relative contribution to the productivity growth in WA agriculture. Data limitations restricted us from doing this. Nevertheless, the above analysis seems to provide some indication that, seasonal influence aside, over the 21 period, the pulses and oilseed crops have been capturing progressively a bigger share in the total output growth and thereby contributing to the productivity growth. On the other hand, historical events suggest that the growth in the pulses and oilseed crops is the direct outcome of the R&D efforts in WA agriculture. Accordingly, this gives and indication that, besides the seasonal factors, the R&D efforts might have contributed the most to the productivity growth in WA agriculture.

5. SUMMARY AND CONCLUSIONS

In this paper, we have measured the productivity growth performance of WA agriculture for the period 1977/78 to 1997/98. The 'farm productivity' database of ABARE (1999) is used. The growth of aggregated inputs, outputs, and total factor productivity (TFP) is estimated for WA and the other Australian states by applying the Tornqvist-Theil index approach. These growth are also estimated for WA broadacre agriculture split by climatic zones and by broad industries. Following this, the total output growth was decomposed into TFP and various input components. The total output growth was also decomposed into six major output components. Finally, based on an analysis of historical events such as seasonal change, technology transfer and adoption and market conditions, an attempt was made to find some explanation for the variations in the productivity growth in WA agriculture.

Some key results of the paper are listed below:

- For the period analysed in this study, the aggregated outputs, inputs and TFP growth are estimated at 6.2, 1.9 and 4.2 percent respectively in WA broadacre agriculture. Inter-state comparisons of the growth in outputs and TFP reveal that in the rest of Australia (ROA), only South Australian agriculture, starting from a lower base experienced a higher rate of growth than WA agriculture.
- Among the climatic zones in WA, the wheat-sheep zone has the highest growth in inputs (2.4 percent p.a.), outputs (7.1 percent p.a.), and TFP 4.7 percent p.a.). The volatility in the movements of the input and output indices are less in this zone. This study reveals that the growth performance of WA broadacre agriculture is almost identical to that of the wheat-sheep zone.
- Among the broadly defined industry groups, the crop industry has the highest total output growth (10.3 percent p.a.) and TFP growth (6.6 percent p.a.). However, both the output and TFP growth rates are highly volatile.
- Our attempt to find explanations for the year-to-year fluctuations in agricultural growth reveals that seasonal conditions play a major role in WA agriculture. An investigation into relevant historical events suggests that seasonal influence aside, productivity growth

appears to have responded positively to the transfer and adoption of a significant number of new technologies.

In conclusion, WA agriculture grew at a faster rate than the ROA states combined. This is particularly true for the recent decade. The present study did not have the scope to examine why WA agriculture grew faster. Further research may provide an understanding of the growth differences between WA and the ROA. Such knowledge would help develop strategic policies and allocate R&D funds in WA agriculture.

The crop output component had the largest share in the total output growth. This is mainly because of sheer size of the crop output. However, the study indicates that in recent years the output growth of new enterprises such as pulses & oilseeds has been faster, and their share in the total output growth has also increased significantly. It is likely that this outcome has been achieved largely as a result of the transfer and adoption of new production technologies.[29] However, even though the contribution made by these new enterprises is increasing, the crop industry still remains the main contributor to output growth and, probably to productivity growth, in WA agriculture.

Finally, the descriptive approach we have used to explain the variation in productivity is mainly based on a review of the circumstances surrounding WA agriculture during the 21 year study period. It has been used to provide useful indicative information in explaining the productivity growth in WA agriculture. However from this approach, it is not possible to quantify the contribution of factors such as R&D expenditure to the productivity growth in agriculture. To quantify such contributions would require more elaborate data which are not readily available for WA agriculture. This could be a subject matter for future research related to productivity growth in WA agriculture.

[29] The literature suggests that there is always a lag between the R&D investment and productivity growth (Evenson *et al.*, 1999; and Pardey and Craig, 1989). In some cases it takes a few decade to get the full effect of R&D investment. However, it should be noted that in our analysis we have attempted to draw a relationship between productivity growth and the transfer and adoption of R&D innovations in hand, rather than drawing a relationship between productivity growth and R&D expenditure.

APPENDIX A

COMPOSITION OF OUTPUTS AND INPUTS

Input and output variables

There are price and quantity variables for 12 outputs and 27 inputs in the data set. Where quantity variables were not available, ABARE derived them by deflating the farm survey data with ABARE's appropriate price-paid and price-received indexes (ABARE, 1995). The prices used are farm gate prices.

For the purpose of comparing productivity performance across Australian states, WA climatic zones and commodity industries, these variables were grouped into one composite output and one composite input. The Tornqvist indexing procedure mentioned in Section 3 is used by developing a spreadsheet model using Microsoft Excel software. However, for the subsequent analysis for WA these composite output and input are decomposed into six output and three input groups.

The six output group are:

<u>Cereals</u> which include harvested amount of wheat, barley, oats, and sorghum crops.

<u>Oilseeds</u> which include harvested amount of pulses and oilseeds grains.

<u>Other crops</u> which includes all crops other than those mentioned in the cereals and oilseeds groups in the database[30].

<u>Meat</u> which includes quantity of sales and positive operative gains of sheep, lamb, beef-cattle and other livestock animals. The quantity data is provided in index form. Implicit prices for these items were calculated by deflating their respective values with quantity indexes.

<u>Wool</u> which is measured in kilograms of wool shorn. The wool price is calculated by deflating the value of wool shorn by the quantity.

[30] Except for other crops, quantities are measured intonnes. The implicit prices for cereals, oilseeds and other crops were calculated by deflating the values by their respective quantities. For the other crops quantity data is provided in index form.

Other farm income which is measured in index form and the implicit unit price is calculated by deflating the total farm receipt by the quantity index. In this study, this output group is labeled as 'Agriculture n.e.c.'.

The three input groups are:

Capital which is broadly defined to include land, plant and machinery, structures and livestock. The value for land and livestock (beef-cattle and sheep) is the opportunity cost of investing funds in those capital items. These are calculated as the average capital value (that is, the average of opening and closing values) multiplied by a real interest rate. The values for the plant and the structure capitals are the opportunity costs plus depreciation.

For land, the expected values of land which partly reflects the future productivity gains are not included. The quantity variable used for land is the area operated. For beef-cattle and sheep, it is the average of opening and closing numbers. For building and plant capital, it is the average value of capital stock deflated by the respective prices paid indexes for each. Unit prices of each of the capital items are calculated by dividing the values by the respective quantities of each.

Labour which consists of four items – owner operator and family labour, hired labour, shearing costs, and stores and rations. The value of owner operator and family labour input is imputed using weeks worked and an award wage. The value of hired labour is wages paid, and the values of shearing and stores and rations are expenditure. The quantity variables for owner operator, and family and hired labour are weeks worked. Expenditure deflated by a shearing price paid index is the quantity variable for shearing.

Materials and services which include purchases and positive operating gains of sheep, beef cattle and other livestock animals; purchases or user costs of chemicals, livestock materials, fodder, fertilizer, seeds, fuel, and other materials; and motor vehicle sundry costs, rates and taxes, administrative costs, miscellaneous livestock costs, contracts, repairs, and other services. Quantities of these inputs are provided in index form in the data base. Unit prices for these inputs are calculated by deflating the total value by their respective quantity indexes.

Recent changes in the data series, 1977/78-1997/98

In the farm productivity data series for the period between 1977/78 and 1997/98 ABARE has made following changes in the measurement of variables as compared to the previous data series for 1977/78 to 1996/97 described in Islam (1999a).

- For inputs, a variable to account for insurance costs and returns was added[31].
- For outputs, changes were made in the measurement of wool and crop outputs. In the previous data series the wool quantity variable was measured as the kilograms of wool sold and the net wool receipts as it value variable. As in some later years substantial amounts of wool were held on farms at the end of the financial year, the wool quantity variable in the new series is measured as the quantity of wool shorn and its value variable is measured by multiplying the shorn quantity with the average unit price for that year

- For crops, quantity harvested for oats was replaced by a quantity variable derived by deflating the value of oats with its price index. In addition, data for oilseeds for the full 21 years are included in this series. Previously, in some cases there were zeroes for oilseeds in earlier years so it was added to other crop receipts. As in the later years with the big expansion in canola production there are quite significant dollar value occuring for this value in most states the oilseeds are therefore included as separate variable. For zeroes in the earlier years a vary small positive value was substituted to maintain a sensible price relationship between values and quantities.

- Some errors in the measurement of the 'other variables' were corrected. The value of this variable is now the ratio of returns to opening capita derived at the average farm level after weighting. Previously, the ratio was derived prior to weighting.

[31] For this report this variable was ignored as at the disaggregated levels they are expected to produce occasional negative numbers. This ignorance however will not affect the results significantly.

APPENDIX B

OUTPUTS, INPUTS, AND PRODUCTIVITY INDICES

TABLE B1

OUTPUT, INPUT AND PRODUCTIVITY GROWTH IN WA AGRICULTURE, 1977/78 TO 1997/98

Year	Outputs (index)	Annual output growth (%)	Inputs (index)	Annual input growth (%)	Total factor productivity (TFP) (index)	Annual TFP growth (%)
1977/78	100.00		100.00		100.00	
1978/79	132.42	32.4	111.91	11.9	118.32	18.3
1979/80	119.41	-9.8	107.74	-3.7	110.83	-6.3
1980/81	111.22	-6.9	107.55	-0.2	103.41	-6.7
1981/82	133.79	20.3	120.19	11.7	111.32	7.6
1982/83	142.16	6.3	113.60	-5.5	125.13	12.4
1983/84	132.22	-7.0	117.60	3.5	112.43	-10.2
1984/85	168.56	27.5	110.82	-5.8	152.10	35.3
1985/86	140.51	-16.6	105.84	-4.5	132.75	-12.7
1986/87	166.83	18.7	113.47	7.2	147.02	10.8
1987/88	145.71	-12.7	114.94	1.3	126.76	-13.8
1988/89	172.73	18.5	122.86	6.9	140.60	10.9
1989/90	180.28	4.4	121.90	-0.8	147.89	5.2
1990/91	179.93	-0.2	109.44	-10.2	164.41	11.2
1991/92	175.53	-2.4	110.46	0.9	158.91	-3.3
1992/93	219.44	25.0	118.31	7.1	185.48	16.7
1993/94	258.06	17.6	123.94	4.8	208.21	12.3
1994/95	226.50	-12.2	132.64	7.0	170.76	-18.0
1995/96	247.02	9.1	130.06	-1.9	189.92	11.2
1996/97	269.57	9.1	141.15	8.5	190.98	0.6
1997/98	278.16	3.2	140.68	-0.3	197.72	3.5
			1977/78 to 1997/98			
Mean	176.19	6.21	117.86	1.90	147.38	4.25
SD	53.70	14.68	11.05	6.17	33.50	13.10
			1977/78 to 1984/85			
Mean	129.97	8.97	111.18	1.72	119.08	7.21
SD	20.79	17.73	6.31	7.62	16.32	16.42
			1985/86 to 1993/94			
Mean	180.76	5.81	115.20	1.41	156.41	4.13
SD	34.57	14.95	6.28	5.94	24.64	11.32
			1994/95 to 1997/98			
Mean	255.86	2.29	133.70	3.32	191.52	-0.67
SD	20.19	10.07	7.31	5.22	13.70	12.39

Note: SD refers to standard deviation.

TABLE B2

OUTPUT QUANTITY INDICES OF WA AGRICULTURE, 1977/78 TO 1997/98

Year	Cereals	Pulses & oilseeds	Sheep meat	Beef	Wool	Others
1977/78	65.8	23.9	63.4	130.8	68.9	98.0
1978/79	100.9	27.9	91.9	150.1	81.8	73.6
1979/80	88.0	24.7	94.8	109.2	77.9	95.4
1980/81	73.2	33.0	85.4	105.6	87.4	73.2
1981/82	113.2	69.1	87.1	83.8	74.6	123.9
1982/83	127.6	61.3	85.8	81.5	80.1	111.3
1983/84	113.8	60.8	88.6	79.8	77.1	91.5
1984/85	173.4	36.1	94.6	79.6	88.2	110.0
1985/86	112.1	37.1	98.2	77.6	95.9	134.2
1986/87	140.8	91.1	108.1	81.1	109.0	101.0
1987/88	100.0	100.0	100.0	100.0	100.0	100.0
1988/89	131.6	104.9	114.7	103.8	115.6	108.5
1989/90	122.0	88.9	137.5	138.1	123.4	139.1
1990/91	133.5	93.3	83.1	112.8	128.4	140.5
1991/92	135.2	118.5	77.6	113.6	110.0	166.7
1992/93	178.7	144.0	96.5	153.5	126.6	160.8
1993/94	213.4	215.7	131.4	155.1	130.4	222.5
1994/95	169.1	213.2	135.7	151.1	112.6	246.2
1995/96	210.9	169.5	143.2	158.2	119.9	162.6
1996/97	241.9	251.0	148.5	120.6	100.6	243.3
1997/98	248.6	286.0	111.5	163.8	101.2	277.3
			percent			
Annual average change	10.09	19.33	4.58	2.67	2.56	8.54
Standard deviation	26.97	43.54	18.84	18.34	11.36	27.06

TABLE B3

INPUT QUANTITY INDICES OF WA AGRICULTURE, 1977/78 TO 1997/98

Year	Capital	Labour	Materials & services
1977/78	102.77	91.68	78.14
1978/79	111.16	101.16	89.63
1979/80	104.86	105.06	84.20
1980/81	104.41	102.86	85.05
1981/82	121.33	103.74	96.26
1982/83	110.35	102.95	92.19
1983/84	115.91	101.96	96.01
1984/85	111.16	93.26	90.15
1985/86	108.87	95.88	81.33
1986/87	115.81	102.57	87.59
1987/88	100.00	100.00	100.00
1988/89	106.10	105.66	108.05
1989/90	103.10	109.14	107.15
1990/91	105.38	105.53	84.15
1991/92	102.17	102.03	89.55
1992/93	101.54	100.72	104.93
1993/94	103.60	103.69	112.55
1994/95	110.10	101.25	125.01
1995/96	107.28	99.55	122.90
1996/97	114.08	102.54	137.03
1997/98	115.68	102.66	135.11
		percent	
Annual average growth	0.81	0.65	3.24
Standard deviation	6.71	4.28	9.79

TABLE B4

GROWTH IN OUTPUT, INPUT AND PRODUCTIVITY OF VICTORIAN AGRICULTURE, 1977/78 TO 1997/98

Year	Outputs (index)	Annual output growth (%)	Inputs (index)	Annual input growth (%)	Total factor productivity (TFP) (index)	Annual TFP growth (%)
1977/78	100.00		100.00		100.00	
1978/79	121.64	21.6	103.31	3.3	117.74	17.7
1979/80	123.41	1.5	102.99	-0.3	119.83	1.8
1980/81	119.12	-3.5	109.71	6.5	108.58	-9.4
1981/82	121.45	2.0	107.66	-1.9	112.81	3.9
1982/83	89.40	-26.4	113.03	5.0	79.09	-29.9
1983/84	124.69	39.5	100.67	-10.9	123.86	56.6
1984/85	116.98	-6.2	95.44	-5.2	122.57	-1.0
1985/86	129.18	10.4	101.84	6.7	126.85	3.5
1986/87	150.96	16.9	105.47	3.6	143.13	12.8
1987/88	127.85	-15.3	98.91	-6.2	129.25	-9.7
1988/89	131.39	2.8	104.73	5.9	125.45	-2.9
1989/90	131.72	0.3	96.80	-7.6	136.07	8.5
1990/91	121.07	-8.1	95.39	-1.5	126.92	-6.7
1991/92	114.54	-5.4	89.96	-5.7	127.32	0.3
1992/93	139.52	21.8	92.52	2.8	150.80	18.4
1993/94	150.99	8.2	98.32	6.3	153.57	1.8
1994/95	118.44	-21.6	99.82	1.5	118.66	-22.7
1995/96	176.30	48.9	103.86	4.1	169.75	43.1
1996/97	188.15	6.7	110.18	6.1	170.77	0.6
1997/98	163.41	-13.2	111.11	0.8	147.06	-13.9
			1977/78 to 1997/98			
Mean	131.44	4.04	101.99	0.67	129.05	3.64
SD	23.54	18.91	6.21	5.36	21.77	19.95
			1977/78 to 1984/85			
Mean	114.59	4.07	104.10	-0.50	112.07	5.67
SD	12.82	21.07	5.72	6.15	14.97	26.75
			1985/86 to 1993/94			
Mean	131.42	3.51	97.94	0.48	134.19	2.89
SD	12.69	12.05	5.01	5.79	11.18	9.11
			1994/95 to 1997/98			
Mean	159.46	5.22	104.66	3.13	151.96	1.76
SD	26.82	31.41	5.84	2.41	21.25	29.16

Note: SD refers to standard deviation.

TABLE B5

GROWTH IN OUTPUT, INPUT AND PRODUCTIVITY OF TASMANIA AGRICULTURE, 1977/78 TO 1997/98

Year	Outputs (index)	Annual output growth (%)	Inputs (index)	Annual input growth (%)	Total factor productivity (TFP) (index)	Annual TFP growth (%)
1977/78	100.00		100.00		100.00	
1978/79	113.89	13.9	105.71	5.7	107.74	7.7
1979/80	106.74	-6.3	101.47	-4.0	105.19	-2.4
1980/81	81.57	-23.6	79.80	-21.4	102.22	-2.8
1981/82	90.21	10.6	88.16	10.5	102.33	0.1
1982/83	132.69	47.1	115.58	31.1	114.81	12.2
1983/84	101.69	-23.4	95.32	-17.5	106.67	-7.1
1984/85	93.74	-7.8	84.10	-11.8	111.47	4.5
1985/86	120.43	28.5	91.11	8.3	132.18	18.6
1986/87	123.60	2.6	93.55	2.7	132.12	0.0
1987/88	95.40	-22.8	81.25	-13.1	117.42	-11.1
1988/89	97.90	2.6	81.52	0.3	120.10	2.3
1989/90	104.27	6.5	82.94	1.8	125.71	4.7
1990/91	105.30	1.0	87.48	5.5	120.37	-4.2
1991/92	99.83	-5.2	83.71	-4.3	119.25	-0.9
1992/93	121.27	21.5	84.15	0.5	144.12	20.8
1993/94	130.67	7.7	89.16	6.0	146.55	1.7
1994/95	120.72	-7.6	96.18	7.9	125.51	-14.4
1995/96	123.24	2.1	86.64	-9.9	142.24	13.3
1996/97	153.36	24.4	97.25	12.2	157.70	10.9
1997/98	107.29	-30.0	84.59	-13.0	126.84	-19.6
			1977/78 to 1997/98			
Mean	110.66	2.09	90.94	-0.13	121.93	1.71
SD	16.89	19.38	9.24	12.23	16.14	10.44
			1977/78 to 1984/85			
Mean	102.57	1.50	96.27	-1.05	107.20	1.75
SD	15.73	24.86	11.89	18.35	4.99	6.72
			1985/86 to 1993/94			
Mean	109.24	4.72	85.90	0.84	126.93	3.53
SD	13.44	14.73	4.21	6.43	11.62	10.25
			1995/96 to 1997/98			
Mean	127.06	-2.78	90.76	-0.71	139.77	-2.43
SD	16.96	22.59	5.68	12.62	13.64	16.94

Note: SD refers to standard deviation.

TABLE B6

GROWTH IN OUTPUT, INPUT AND PRODUCTIVITY OF SA AGRICULTURE, 1977/78 TO 1997/98

Year	Outputs (index)	Annual output growth (%)	Inputs (index)	Annual input growth (%)	Total factor productivity (TFP) (index)	Annual TFP growth (%)
1977/78	100.00		100.00		100.00	
1978/79	140.30	40.3	101.93	1.9	137.64	37.6
1979/80	178.16	27.0	103.65	1.7	171.88	24.9
1980/81	138.12	-22.5	102.18	-1.4	135.17	-21.4
1981/82	150.93	9.3	110.29	7.9	136.84	1.2
1982/83	110.31	-26.9	104.41	-5.3	105.64	-22.8
1983/84	167.47	51.8	95.03	-9.0	176.22	66.8
1984/85	161.03	-3.8	97.73	2.8	164.77	-6.5
1985/86	171.86	6.7	98.52	0.8	174.45	5.9
1986/87	191.83	11.6	98.75	0.2	194.26	11.4
1987/88	175.66	-8.4	100.84	2.1	174.20	-10.3
1988/89	161.53	-8.0	98.18	-2.6	164.52	-5.6
1989/90	219.47	35.9	104.90	6.8	209.22	27.2
1990/91	197.84	-9.9	100.44	-4.2	196.97	-5.9
1991/92	212.86	7.6	101.57	1.1	209.57	6.4
1992/93	237.76	11.7	102.85	1.3	231.17	10.3
1993/94	259.12	9.0	108.86	5.8	238.03	3.0
1994/95	180.55	-30.3	105.13	-3.4	171.73	-27.9
1995/96	241.95	34.0	104.98	-0.1	230.46	34.2
1996/97	237.91	-1.7	114.33	8.9	208.09	-9.7
1997/98	265.47	11.6	115.01	0.6	230.82	10.9
			1977/78 to 1997/98			
Mean	185.72	7.25	103.31	0.80	179.13	6.49
SD	46.30	22.37	5.24	4.48	40.24	23.01
			1977/78 to 1984/85			
Mean	143.29	10.73	101.90	-0.19	146.88	11.42
SD	27.18	30.44	4.60	5.61	28.67	33.18
			1985/86 to 1993/94			
Mean	198.90	6.24	101.26	1.26	195.72	4.70
SD	33.18	14.25	3.50	3.53	26.40	11.35
			1995/96 to 1997/98			
Mean	237.00	3.40	109.66	1.48	215.83	1.89
SD	33.59	26.87	4.83	5.25	27.09	26.74

Note: SD refers to standard deviation.

TABLE B7

GROWTH IN OUTPUT, INPUT AND PRODUCTIVITY OF NSW AGRICULTURE, 1977/78 TO 1997/98

Year	Outputs (index)	Annual output growth (%)	Inputs (index)	Annual input growth (%)	Total factor productivity (TFP) (index)	Annual TFP growth (%)
1977/78	100.00		100.00		100.00	
1978/79	102.74	2.7	94.34	-5.7	108.90	8.9
1979/80	110.64	7.7	110.31	16.9	100.30	-7.9
1980/81	85.68	-22.6	105.45	-4.4	81.25	-19.0
1981/82	98.03	14.4	97.89	-7.2	100.14	23.3
1982/83	76.72	-21.7	101.12	3.3	75.88	-24.2
1983/84	120.08	56.5	99.63	-1.5	120.53	58.8
1984/85	115.01	-4.2	104.32	4.7	110.25	-8.5
1985/86	127.65	11.0	107.97	3.5	118.23	7.2
1986/87	119.34	-6.5	106.80	-1.1	111.74	-5.5
1987/88	120.05	0.6	100.43	-6.0	119.54	7.0
1988/89	136.04	13.3	111.00	10.5	122.56	2.5
1989/90	139.04	2.2	110.83	-0.1	125.45	2.4
1990/91	137.94	-0.8	103.52	-6.6	133.26	6.2
1991/92	136.53	-1.0	108.75	5.1	125.55	-5.8
1992/93	149.71	9.7	107.96	-0.7	138.67	10.5
1993/94	169.60	13.3	112.06	3.8	151.35	9.1
1994/95	137.81	-18.7	120.10	7.2	114.75	-24.2
1995/96	163.34	18.5	113.68	-5.3	143.69	25.2
1996/97	175.53	7.5	109.93	-3.3	159.67	11.1
1997/98	178.56	1.7	113.47	3.2	157.37	-1.4
			1977/78 to 1997/98			
Mean	128.57	4.18	106.65	0.82	119.96	3.79
SD	28.39	17.00	6.25	6.31	22.42	18.69
			1977/78 to 1984/85			
Mean	101.11	4.69	101.63	0.89	99.61	4.48
SD	14.59	26.81	4.95	8.36	14.82	28.94
			1985/86 to 1993/94			
Mean	135.09	4.64	107.36	0.93	125.66	3.74
SD	16.21	7.28	3.69	5.43	12.56	5.94
			1994/95 to 1997/98			
Mean	164.97	2.24	113.85	0.44	145.36	2.68
SD	16.26	15.63	3.80	5.79	18.20	20.96

Note: SD refers to standard deviation.

TABLE B8

GROWTH IN OUTPUT, INPUT AND PRODUCTIVITY OF QEENSLAND AGRICULTURE, 1977/78 TO 1997/98

Year	Outputs (index)	Annual output growth (%)	Inputs (index)	Annual input growth (%)	Total factor productivity (TFP) (index)	Annual TFP growth (%)
1977/78	100.00		100.00		100.00	
1978/79	114.59	14.6	101.07	1.1	113.37	13.4
1979/80	105.13	-8.2	122.81	21.5	85.61	-24.5
1980/81	96.38	-8.3	112.15	-8.7	85.94	0.4
1981/82	136.32	41.4	127.52	13.7	106.90	24.4
1982/83	109.89	-19.4	128.88	1.1	85.27	-20.2
1983/84	141.72	29.0	121.70	-5.6	116.45	36.6
1984/85	155.02	9.4	136.78	12.4	113.34	-2.7
1985/86	152.47	-1.6	132.93	-2.8	114.70	1.2
1986/87	145.37	-4.7	130.92	-1.5	111.04	-3.2
1987/88	128.57	-11.6	123.88	-5.4	103.79	-6.5
1988/89	150.42	17.0	130.89	5.7	114.92	10.7
1989/90	146.42	-2.7	129.43	-1.1	113.13	-1.6
1990/91	156.83	7.1	117.27	-9.4	133.73	18.2
1991/92	142.04	-9.4	119.47	1.9	118.89	-11.1
1992/93	151.86	6.9	123.77	3.6	122.69	3.2
1993/94	145.27	-4.3	123.46	-0.2	117.66	-4.1
1994/95	144.48	-0.5	118.85	-3.7	121.57	3.3
1995/96	165.87	14.8	123.48	3.9	134.33	10.5
1996/97	193.49	16.7	114.97	-6.9	168.29	25.3
1997/98	188.92	-2.4	124.82	8.6	151.36	-10.1
			1977/78 to 1997/98			
Mean	141.48	4.18	122.15	1.40	115.86	3.16
SD	25.82	14.84	9.37	7.95	20.04	15.29
			1977/78 to 1984/85			
Mean	119.88	8.34	118.86	5.07	100.98	3.90
SD	21.63	21.92	13.29	11.05	13.58	22.44
			1985/86 to 1993/94			
Mean	147.43	-0.36	126.88	-1.04	116.39	0.76
SD	8.13	9.07	6.24	4.57	7.89	9.00
			1994/95 to 1997/98			
Mean	167.60	7.14	121.12	0.46	138.64	7.26
SD	23.24	9.98	4.11	7.05	21.16	14.73

Note: SD refers to standard deviation.

TABLE B9

GROWTH IN OUTPUT, INPUT AND PRODUCTIVITY OF AUSTRALIAN AGRICULTURE, 1977/78 TO 1997/98

Year	Outputs (index)	Annual output growth (%)	Inputs (index)	Annual input growth (%)	Total factor productivity (TFP) (index)	Annual TFP growth (%)
1977/78	100.00		100.00		100.00	
1978/79	116.96	17.0	102.25	2.2	114.39	14.4
1979/80	117.71	0.6	107.83	5.5	109.16	-4.6
1980/81	101.76	-13.6	107.91	0.1	94.30	-13.6
1981/82	119.49	17.4	111.73	3.5	106.95	13.4
1982/83	100.37	-16.0	111.94	0.2	89.67	-16.2
1983/84	130.42	29.9	107.13	-4.3	121.75	35.8
1984/85	133.62	2.4	109.49	2.2	122.04	0.2
1985/86	138.27	3.5	111.27	1.6	124.27	1.8
1986/87	144.22	4.3	112.54	1.1	128.15	3.1
1987/88	131.19	-9.0	107.21	-4.7	122.37	-4.5
1988/89	145.10	10.6	115.19	7.5	125.96	2.9
1989/90	151.30	4.3	113.50	-1.5	133.31	5.8
1990/91	148.33	-2.0	105.99	-6.6	139.94	5.0
1991/92	144.74	-2.4	108.01	1.9	134.00	-4.2
1992/93	164.63	13.7	109.96	1.8	149.72	11.7
1993/94	179.67	9.1	113.50	3.2	158.30	5.7
1994/95	152.26	-15.3	118.14	4.1	128.88	-18.6
1995/96	185.34	21.7	116.56	-1.3	159.01	23.4
1996/97	200.43	8.1	118.08	1.3	169.74	6.8
1997/98	199.02	-0.7	120.85	2.3	164.68	-3.0
			1977/78 to 1997/98			
Mean	143.09	4.19	110.91	1.01	128.41	3.27
SD	29.90	12.31	5.23	3.41	22.52	12.89
			1977/78 to 1984/85			
Mean	115.04	5.41	107.28	1.34	108.32	4.21
SD	13.26	16.97	4.23	3.11	12.03	18.30
			1985/6 to 1993/94			
Mean	148.11	3.57	110.67	0.48	133.81	3.04
SD	14.56	7.16	3.04	4.23	12.22	5.07
			1994/95 to 1997/98			
Mean	183.34	3.48	117.43	1.60	156.12	2.14
SD	19.50	15.52	2.68	2.27	15.92	17.59

Note: SD refers to standard deviation.

TABLE B10

COMPONENTS OF OUTPUT GROWTH IN WA AGRICULTURE, 1978/79 – 1997/98
(percent)

YEAR	Cereals	Pulses & oilseeds	Sheep meat	Beef cattle	Wool	Others	All output
1978/79	20.90	0.44	6.04	2.06	4.50	-1.53	32.42
1979/80	-5.69	-0.31	0.51	-4.32	-0.96	0.96	-9.82
1980/81	-7.28	0.79	-1.74	-0.42	2.84	-1.05	-6.86
1981/82	20.14	3.34	0.31	-2.12	-3.70	2.32	20.29
1982/83	6.32	-0.63	-0.20	-0.20	1.47	-0.50	6.25
1983/84	-5.59	-0.04	0.36	-0.15	-0.79	-0.77	-6.99
1984/85	24.89	-1.94	0.77	-0.02	3.07	0.72	27.49
1985/86	-20.38	0.26	0.41	-0.20	2.27	0.98	-16.64
1986/87	10.15	4.10	1.02	0.38	4.46	-1.38	18.74
1987/88	-10.71	0.29	-0.76	1.68	-3.14	-0.04	-12.66
1988/89	9.87	0.28	1.41	0.30	6.36	0.33	18.55
1989/90	-2.46	-0.82	1.60	2.46	2.59	1.01	4.37
1990/91	1.51	0.13	-1.56	-1.18	0.88	0.03	-0.19
1991/92	0.49	1.68	-0.30	0.08	-5.36	0.97	-2.45
1992/93	15.11	1.61	1.19	3.67	3.67	-0.25	25.02
1993/94	9.22	3.82	2.10	0.12	0.64	1.69	17.60
1994/95	-9.76	-0.11	0.24	-0.27	-3.10	0.77	-12.23
1995/96	12.10	-2.18	0.39	0.42	1.40	-3.08	9.06
1996/97	7.59	3.69	0.37	-1.66	-2.81	1.96	9.13
1997/98	1.41	1.44	-2.40	1.86	0.09	0.79	3.19
			1977/79 to 1997/98				
Mean	3.89	0.79	0.49	0.12	0.72	0.20	6.21
SD	11.85	1.81	1.73	1.75	3.16	1.31	14.68
			1977/79 to 1984/85				
Mean	7.67	0.24	0.86	-0.74	0.92	0.02	8.97
SD	14.18	1.63	2.43	1.99	2.86	1.36	17.73
			1985/86 to 1993/94				
Mean	1.42	1.26	0.57	0.81	1.38	0.37	5.81
SD	11.37	1.71	1.21	1.50	3.68	0.91	14.95
			1994/95 to 1997/98				
Mean	2.83	0.71	-0.35	0.09	-1.10	0.11	2.29
SD	9.47	2.48	1.37	1.47	2.21	2.20	10.07

Note: SD refers to standard deviation.

TABLE B11

COMPONENTS OF INPUT GROWTH IN WA AGRICULTURE, 1978/79 – 1997/98
(percent)

YEAR	Capital	Labour	Materials & Services	Total Input
1978/79	2.12	2.51	7.30	11.94
1979/80	-1.53	0.88	-3.34	-3.99
1980/81	-0.12	-0.45	0.75	0.18
1981/82	5.74	0.16	6.01	11.91
1982/83	-3.48	-0.13	-1.72	-5.33
1983/84	1.83	-0.18	1.89	3.54
1984/85	-1.61	-1.47	-2.76	-5.84
1985/86	-0.87	0.48	-4.10	-4.49
1986/87	2.42	1.33	3.39	7.14
1987/88	-3.73	-0.41	5.59	1.45
1988/89	1.96	1.04	3.99	6.99
1989/90	-0.98	0.60	-0.41	-0.80
1990/91	0.76	-0.68	-10.31	-10.23
1991/92	-1.02	-0.70	2.62	0.90
1992/93	-0.20	-0.27	7.66	7.19
1993/94	0.63	0.58	3.49	4.70
1994/95	1.86	-0.45	7.37	8.78
1995/96	-0.75	-0.30	-2.52	-3.57
1996/97	1.75	0.53	6.23	8.50
1997/98	0.42	0.02	-0.76	-0.32
		1978/79 to 1997/98		
Mean	0.26	0.15	1.52	1.93
SD	2.19	0.88	4.75	6.34
		1978/79 to 1984/85		
Mean	0.42	0.19	1.16	1.77
SD	3.07	1.24	4.20	7.67
		1985/86 to 1993/94		
Mean	-0.11	0.22	1.32	1.43
SD	1.85	0.75	5.52	5.95
		1994/95 to 1997/98		
Mean	0.82	-0.05	2.58	3.35
SD	1.23	0.43	4.95	6.25

Note: SD refers to standard deviation.

TABLE B12

INPUT, OUTPUT AND TFP GROWTH IN WA AGRICULTURE, 1978/79 – 1997/98, (percent)

YEAR	Total Input	Total Outputs	Total Factor Productivity
1978/79	11.94	32.42	20.48
1979/80	-3.99	-9.82	-5.84
1980/81	0.18	-6.86	-7.04
1981/82	11.91	20.29	8.39
1982/83	-5.33	6.25	11.58
1983/84	3.54	-6.99	-10.53
1984/85	-5.84	27.49	33.32
1985/86	-4.49	-16.64	-12.15
1986/87	7.14	18.74	11.60
1987/88	1.45	-12.66	-14.12
1988/89	6.99	18.55	11.56
1989/90	-0.80	4.37	5.17
1990/91	-10.23	-0.19	10.03
1991/92	0.90	-2.45	-3.35
1992/93	7.19	25.02	17.83
1993/94	4.70	17.60	12.90
1994/95	8.78	-12.23	-21.01
1995/96	-3.57	9.06	12.63
1996/97	8.50	9.13	0.62
1997/98	-0.32	3.19	3.50
	1978/79 to 1997/98		
Mean	1.93	6.21	4.28
SD	6.34	14.68	13.40
	1978/79 to 1984/85		
Mean	1.77	8.97	7.20
SD	7.67	17.73	16.16
	1985/86 to 1993/94		
Mean	1.43	5.81	4.39
SD	5.95	14.95	11.54
	1994/95 to 1997/98		
Mean	3.35	2.29	-1.06
SD	6.25	10.07	14.25

Note: SD refers to standard deviation.

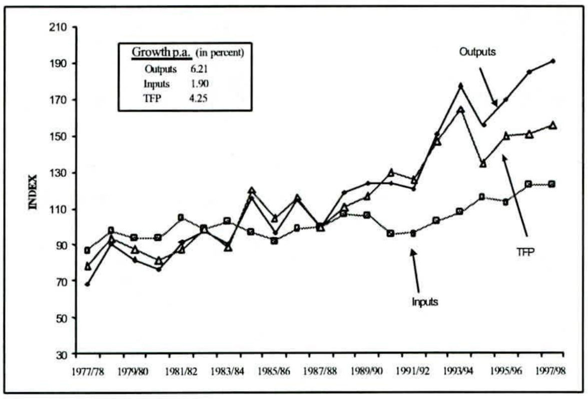
APPENDIX C

GROWTH TRENDS IN WA AGRICULTURE

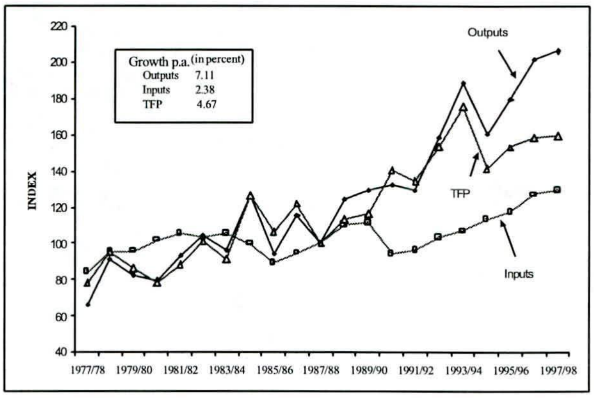
FIGURE C1

AGRICULTURAL OUTPUTS, INPUTS AND TFP GROWTH IN WA CLIMATIC ZONES, 1977/78-1997/98 (1987/88=100)

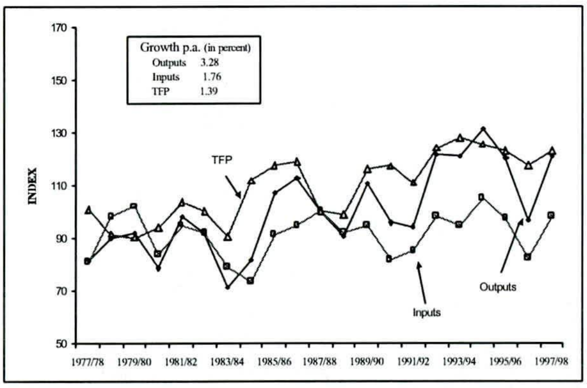
A. All Broadacre



B. Wheat-sheep Zone



C. High Rainfall Zone



D. Pastoral Zone

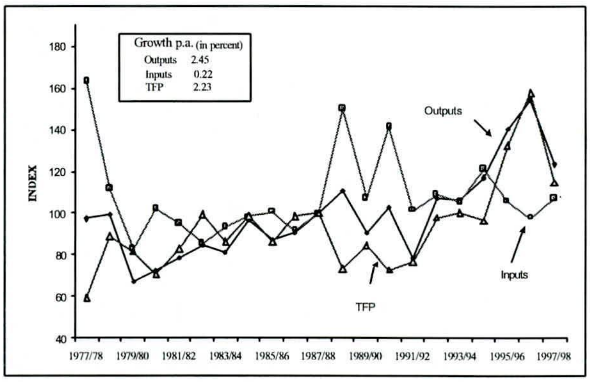
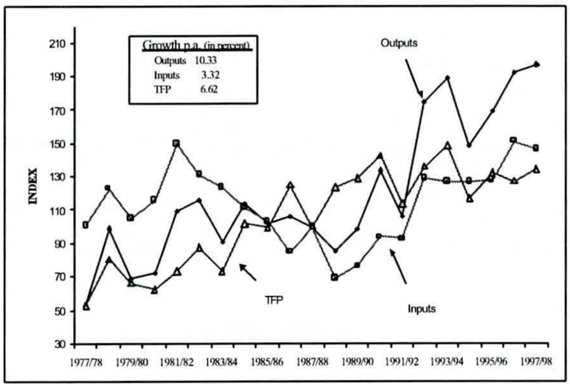


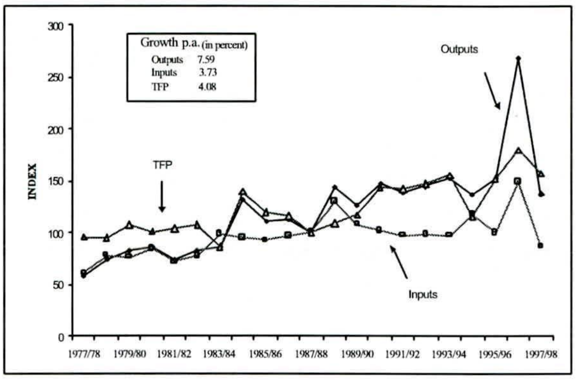
FIGURE C2

OUTPUTS, INPUTS AND TFP GROWTH IN WA AGRICULTURAL INDUSTRIES, 1977/78-1997/98 (1987/88=100)

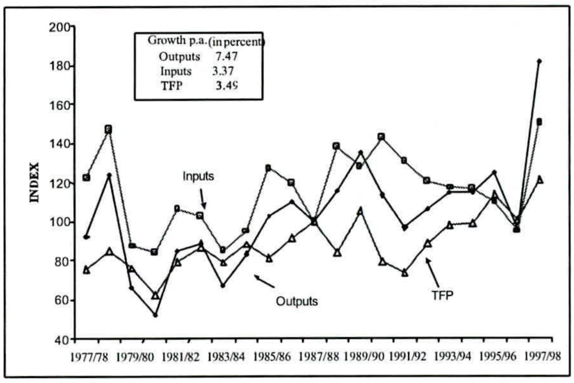
A. Crops



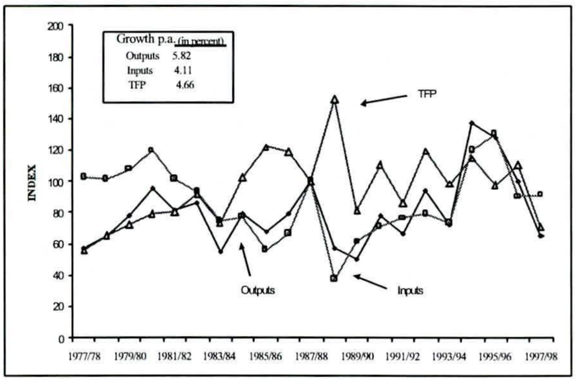
B. Sheep



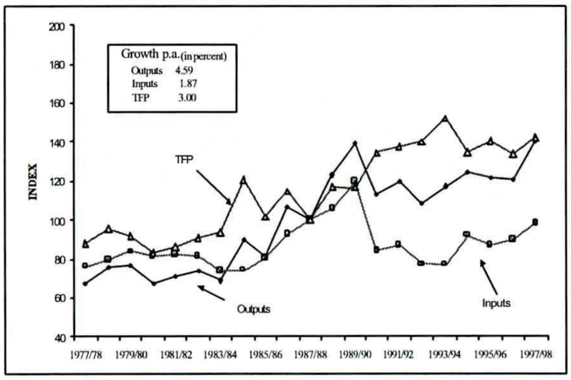
C. Beef



D. Sheep-Beef



E. Livestock-Crop Mixed



Appendix D

HISTORICAL EVENTS SURROUNDING WA AGRICULTURE

In Table D1, an overview of circumstances surrounding growth Western Australian agriculture over the period 1976/77 to 1997/ 98, is outlined. The Annual Reports (various issues from 1977 to 1998) of Agriculture WA are the main sources of information.

TABLE D1

AN OVERVIEW OF CIRCUMSTANCE SURROUNDING WA AGRICULTURE, 1976/77 TO 1997/98

Year	Seasonal and unfavourable events	Technological and favourable events
19976/77	• Drought year; • Yield declined: wheat - 21%, sheep and lamb - 10% and beef-cattle - 5%; and • Production declined: lupins - 75% and wool - 9%.	• Growth in demand for livestock products in the Middle East; • Release of a rust resistant variety of oats; and • The release of two new cultivars of subterranean clover.
1977/78	• Severe seasonal conditions (drought, hail storm, fire and cyclones); • The area affected by drought was greater than in 1976/77; • Crop losses increased further due to torrential rain and storms in eastern and south-eastern districts; • Further damage in February due to hail, wind and flood damage in the South-west and heavy rain and floods in the Eastern wheat-belt affected about 300 farmers; and • Further damage caused by fire, wind and rain associated with cyclone Alby.	• Due to successful extension activities undertaken by the WA Agriculture Department there was a dramatic drop in livestock losses caused by annual ryegrass toxicity disease; • Release and acceptance of 'Tincurrin' - the new soft wheat variety; • Release of 'Moore' - a new variety of oats; and • Release of 'Wesreo' – a new variety of rapeseed.

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TABLE D1 (continued)

Year	Seasonal and unfavourable events	Technological and favourable events
1978/79	• Drought conditions continued; • A total of 169 farmers were drought affected. Farmers in affected areas suffered greatly due to reduced crop yield, and in subsequent severely depleted incomes and were forced to sell livestock; and • Sheep population in the Northeastern wheat-belt declined dramatically.	• Overall, the wheat yield was slightly better than average this year.
1979/80	• Situation improved slightly compared to last year.	• Nothing remarkable.
1980/81	• A good seasonal year.	• A good winter rain and a record sowing of about six million hectares under wheat; • A record number of five new wheat varieties were registered; and • A new variety of feed barley, "Forrest"', was released.
1981/82	• The good season continued.	• A significant breakthrough occurred in research into animal disease; • Five wheat varieties registered last year were released; and • New herbicides and 'minimum tillage' technologies introduced.

(continued on next page)

TABLE D1 (continued)

Year	Seasonal and unfavourable events	Technological and favourable events
1982/83	• The good season continued.	• WA farmers sowed a record area to grains and produced more than seven million tonnes of grains, including wheat. This provided more than 60% of the national wheat crop as the Eastern states suffered from drought this year; • The Dry Land Research Institute at Merredin opened; • Farmers adopted 'minimum tillage' technology; and • Several other technological innovations took place in the area of crop breeding, and were adopted.
1983/84	• Good season continued.	• Introduction of the provision of extension services through electronic media and printed publications; • An interest in soil conservation was a major landmark in the year's activities; • The Agriculture Department assumed the management responsibility for 17 million hectares of land cleared for agriculture and 90 million hectares of pastoral land; • Major research on the problem of soil acidity undertaken; • Research directed at cash-crop rotation commenced on lupins and field peas and continued on pasture legumes;

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TABLE D1 (continued)

Year	Seasonal and unfavourable events	Technological and favourable events
1983/84 (continued)		• Breakthroughs occurred in sheep lice research, food technology adapting meat products for export, and making better use of animal skins; and • A major drive occurred in the program aimed at eradicating bovine tuberculosis from WA.
1984/85	• Good season continued; • High real interest was charged to farmers on borrowing, product cost increased fast and output prices were low; and • High cost and falling farm value led to reduced equity.	• It was a productive season on record; • The minimum tillage techniques for crop production were firmly entrenched in WA; and • Development of a modified seeding machine which combines the one pass advantage and reduced surface disturbance of minimum tillage, with enough soil disturbance to promote vigorous early growth.
1985/86	• Average season.	• Sheep lice eradication program intensified.

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TABLE D1 (continued)

Year	Seasonal and unfavourable events	Technological and favourable events
1986/87	• Good season; and • Grain growers faced financial difficulties because of low grain prices.	• Prices for wool and beef were good and there was a fall in production costs; • New farm management practices were introduced; and • New extension initiative was undertaken to bring into use by farmers all the available technological information in the possession of the Department of Agriculture as quickly as possible.
1987/88	• Good season; • Pesticide residues were found in beef; and • GVAP declined by 12 percent.	• Market prospects and prices in general were favourable; • The world market price increased moderately; • The wool market reaped the benefit from the recovery of wool price; • Lamb prices recovered strongly; and • Farm cost pressures eased due to the decline in interest rates and the relatively small increases in fuel costs and wage rates.
1988/89	• Average season.	• Nothing remarkable.

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TABLE D1 (continued)

Year	Seasonal and unfavourable events	Technological and favourable events
1989/90	• Average season; • Returns from wool declined and in June the rapidly accumulating wool stockpile culminated in the lowering of the reserve floor price; • Sheep numbers increased to excessive levels, and live sheep exports to the Middle East declined. These had significant effects on the turn-off of sheep in WA, and on sheep farmer's cash flow; and • There was major outbreak of a number of pests and diseases. Qeensland Fruit Fly, Footrot disease, Australian Plague Locust and Apple Scabe are a few examples.	• Grain prices increased slightly.
1990/91	• Falling grain and wool prices in the second half of 1990 foreshadowed major cash flow problems for farmers in 1991 and beyond; • The flock reduction scheme, the proposal for wool quotas, and finally the termination of the Reserve Price Scheme, together with falling demand and the wool stockpile overhanging the market, produced the most difficult time that most woolgrowers have ever experienced;	• The WA Government provided a guarantee on the price of wheat; • The release of 'Red Globe,' a superior variety of table grape and 'Pinky Lady', a new variety of apple; • The development of Sustainable Farming Systems was established; and • New varieties of oats and lupines were released.

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TABLE D1 (continued)

Year	Seasonal and unfavourable events	Technological and favourable events
1990/91 (continued)	• This coincided with falling grain prices as the subsidy war between the EC and the USA continued to depress world markets; • Financial returns from the live sheep trade to the Middle East remained depressed; and • Outbreaks of pests continued.	•
1991/92	• The season was satisfactory; and • Number of sheep and wool production declined slightly since the wool price crash.	• Wool and grain prices improved; • The recovery of wheat prices in the later part of 1991 removed the need for the price support guaranteed by the WA Government; • 'Merit' a new lupin variety, 'Narendra' a new canola variety, and 'Yilgarn' an oats variety for drier areas were released; and • The Agricultural Department's research innovation in sheepskin processing, Department in sheep skin processing was commercially adopted.
1992/93	• Generally good seasonal conditions; and • Wool prices continued to fall and for most producers, the returns from wool were below the cost of production; and	• The Agriculture Department stepped up its support for specialist wool growers by directing resources to a production and diversification campaign aimed at assisting wool growers to adopt more cost effective production techniques, and to identify opportunities to diversify from wool production to other forms of livestock production, and cropping;

(continued on next page)

TABLE D1 (continued)

Year	Seasonal and unfavourable events	Technological and favourable events
1992/93 (continued)	• Specialist wool producers, particularly in pastoral areas were under severe financial stress.	• The beef industry in north benefited from the improved productivity resulting from genetic improvement and better management practices; • Beef production from tagasaste significantly increased in the south; • The "Cadoux" variety (with a number of improved characteristics over existing varieties) of noodle wheat, intended for export to Japan, was released; and • The area under canola and production of canola continued to expand.
1993/94	• Generally good season throughout WA; and • The first year of the occurrence of the fatal livestock disease 'anthrax' in WA.	• The outbreak of the fatal livestock disease 'anthrax' was quickly controlled; • The outcome of the Uruguay round of the General Agreement on Tariffs and Trade was considered to have progressively improved market access internationally; • The market indicator climbed from its nadir early in 1993 and continued to make steady gains; providing the basis for a return to probability in the wool industry; • Grain yields were at near record levels;

(continued on next page)

TABLE D1 (continued)

Year	Seasonal and unfavourable events	Technological and favourable events
1993/94 (continued)		• The production of lupins for the first time exceeded 1 million tonnes and canola production nearly quadrupled from a low base to 44,000 tonnes; and • The release of a number of new pasture legumes, grains and fruit varieties were released.
1994/95	• Rainfall during the crop growing season was low.	• The season was notable for the production of an average of wheat grain (around 5.1 million tonnes) in a year of unusually low growing season rainfall; • Of particular significance was the quality of wheat crop; • A higher percentage of the crop was received into hard, noodle and high protein ASW segregations compared with the previous three years; • The GVAP for wool, canola and oats improved significantly; • Four new cereal varieties were released; • The Cadoux, released in 1992, continued to confirm its value to the industry as a high yielding wheat to produce white salted noodles;

(continued on next page)

TABLE D1 (continued)

Year	Seasonal and unfavourable events	Technological and favourable events
1994/95 (continued)		• Rapid adoption by growers led to the Cadoux variety being grown on 16% of the wheat area; and • The organisational structure and the management of the Department took a major turn to provide services to the sector.
1995/96	• Average seasonal conditions.	• The new cultivar 'Cadiz', belonging the pasture species 'pink serradella' was released; and • The 'Mundah', a new barley variety was released.
1996/97	• Satisfactory seasonal conditions throughout.	• Exceptional yields continued in the cereals sector; and • Expansion in the production area and improvements in the yields of canola and the new pulse crops.
1997/98	• Satisfactory seasonal conditions throughout.	• In nominal terms the GVAP reached to an estimated $4.3 billion from $3.1 billion in 1992/93; • Nine new cereal crop varieties were released; • The Grain Marketing Bill, 1997, was drafted and presented to State Parliament; and • 'TopCrop' continued to develop as the mechanism for promoting best practice grain farming systems to farmers.

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