CHAPTER 5

Agricultural Productivity Growth in Australia and New Zealand

John Denis Mullen

1. INTRODUCTION

Productivity growth in Australian agriculture has been an important source of wealth in Australia. The real value of agricultural production in Australia has been over $40 billion (2008 Australian dollars) per year since the late 1990s (Figure 5.1). If productivity has grown at a rate of 2% per year, as some estimates indicate, then about two-thirds of the value of production in recent years can be attributed to productivity growth since 1953. Productivity growth has been strong in Australian agriculture relative to other sectors of the Australian economy and relative to the agricultural sectors of other rich countries (Mullen and Crean 2007).

Recent data, however, suggest that productivity growth in at least some important sectors of Australian agriculture may be slowing. Public investment in agricultural research in Australia, always the predominant source of funding in Australia, has been falling for several decades. Other causes of the decline in the rate of productivity growth are a series of bad seasons extending back to 2001, which may, in part, be attributed to climate change.

The objectives of this chapter are as follows:

- To review productivity growth in the Australian agriculture, fisheries, and forestry sector as a whole relative to the Australian economy as an indicator

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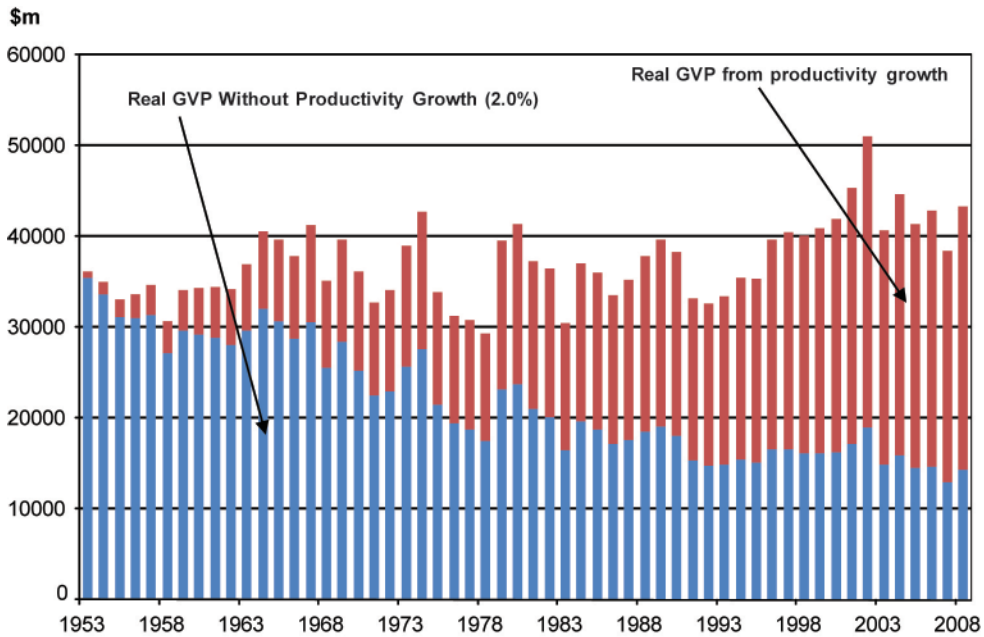

Figure 5.1. Value of productivity growth in Australia: 1953 to 2008

Source: Adapted from Mullen and Crean (2007) using data from 2003.

of the competitiveness of the sector domestically and internationally using value-added estimates of productivity growth from the Australian Bureau of Statistics (ABS). The performance of the agricultural sector within the New Zealand economy is also briefly reviewed.

- To review productivity growth within the cropping and livestock industries that comprise broadacre agriculture and within the dairy industry in Australia using gross output measures from farm survey data of the Australian Bureau of Agricultural and Resource Economics (ABARE).
- To assess whether productivity growth in agriculture has slowed and review potential sources of this slowdown.

2. AGRICULTURE IN THE AUSTRALIAN ECONOMY

The ABS uses national income accounting data to estimate and report value-added measures of productivity for sectors in the Australian "market" economy, in which the inputs are labor and capital.[1] Estimates of multifactor productivity

[1]In the value-added approach, the value of intermediate inputs is deducted from the gross value of output, and inputs are a correspondingly reduced set—often only labor and capital used in the sector.

(MFP) growth for the agriculture, fisheries, and forestry sector and other sectors are provided at five-year intervals from 1986 (Table 5.1) (ABS 2007).[2,3]

The agricultural sector has been ranked with the communication services sector and the finance and insurance sector as high-growth sectors in the Australian economy. Productivity in the Australian market economy grew at a rate of 1.2% per year

Table 5.1. Compound annual percentage change in value added–based MFP, market sector industries

	1985–86 to 1990–91	1990–91 to 1995–96	1995–96 to 2000–01	2000–01 to 2005–06	1985–86 to 2005–06
			percent		
High					
Communication services	4.7	4.7	2.2	2.7	3.6
Agriculture, forestry, & fishing	2.3	1.8	5.3	2.5	3.0
Finance & insurance	3.1	2.0	2.0	0.2	1.8
Medium					
Transport & storage	0.7	2.9	1.7	1.6	1.7
Wholesale trade	-1.8	3.9	2.9	1.3	1.5
Electricity, gas, & water	6.0	2.6	0.5	-3.2	1.4
Low					
Retail trade	-1.0	1.1	2.2	0.7	0.7
Manufacturing	0.9	0.5	1.1	0.4	0.7
Construction	-1.8	0.2	—	4.5	0.7
Mining	3.5	2.3	1.1	-5.9	0.2
Accommodation, cafes, & restaurants	-3.8	—	1.4	2.5	—
Cultural & recreational services	-0.9	-2.2	0.8	-0.2	-0.6
Market sector	**0.8**	**1.6**	**1.6**	**0.8**	**1.2**
Ratio of agriculture to market	**2.9**	**1.3**	**3.3**	**3.1**	**2.5**

Source: Adapted from ABS 2007, available at http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/ 5260.0.55.0022007-08?OpenDocument.

[2]The ABS also presents MFP estimates for the market economy for growth cycles in which growth peaks are estimated as local maximum divergences in the MFP from a trend MFP estimated used a smoothing process such as an 11-term Henderson moving average. However, productivity cycles at an industry level are unlikely to coincide.

[3]Most often the data in ABS 2007 refer to financial years, but the convention of referring to the 1985-86 year as 1986, for example, has been adopted.

over the entire period from 1986 to 2006. It surged strongly in the 1990s, growing by 1.6% per year, but slowed to 0.8% per year for the five years leading up to 2006.

Over the 1986-2006 period, productivity in the agriculture, fisheries, and forestry sector grew at an annual rate of 3.6%, 2.5 times that of the market economy. In three of the four subperiods, MFP in the agriculture sector grew at about 3 times the rate of the market economy.

Studies by Bernard and Jones (1996) and Martin and Mitra (2000) suggest that the agricultural sectors in few OECD (Organization for Economic Cooperation and Development) countries have performed as well relative to their economies as has the Australian agricultural sector. Hence, productivity growth in the Australian agricultural sector has likely been strong enough to enhance the sector's competitiveness relative to other sectors of the Australian economy and relative to the agricultural sectors in many other countries.[4]

Despite this apparently strong productivity performance of the agriculture, fisheries, and forestry sector relative to the market economy, the share of the sector in total Australian gross domestic product (GDP) has continued to decline (from 9.8% in 1964 to 2.5% in 2008) although the rate of decline has eased markedly since the late 1980s.

Over the longer period, 1978 to 2007, the average annual rate of growth in productivity in the agricultural sector at 2.4% was twice that of the market economy, at 1.2%.[5,6] Labor productivity in agriculture (value-added output per unit of labor [hours worked]) grew at a rate of 2.1% per year, faster than capital productivity (value-added output relative to a flow of services from a measure of the productive capacity of capital), and the capital-to-labor ratio (the ratio of these two partial productivity indexes) increased from less than 70 in 1978 to 100 in 2007, consistent with capital being substituted for labor.

To provide some perspective, real GDP (in 2008 Australian dollars) in the Australian economy in 2008 was $1,037 billion with the contribution of agricul-

[4]The qualification here is that the market economy estimates do not include property and business services, government administration and defense, education, health and community services, and personal and other services, sectors for which output is valued at cost. The relative performance of the agriculture sector may be overstated if productivity in these sectors not presently included has grown at a faster rate than the market economy.

[5]MFP growth rates were estimated as the coefficient on a time trend in a regression of the log of MFP against a constant and the time trend.

[6]ABS data are now available to 2008 (Figure 5.6) but ABARE data are only available to 2007. The extra year does not alter these estimated growth rates.

ture being $21.7 billion (2.1%) and that of fisheries and forestry being $2.3 billion (0.2%) (ABARE 2008).

There is an important distinction between value-added measures of MFP (reported in Table 5.1) and gross output measures of MFP (also reported by ABS for the period 1995-2004 and used exclusively by ABARE) (ABS 2007). The gross output measure is based on the total value of production of firms engaged in agriculture, fisheries, and forestry. The input measure used in estimating MFP is the total value of labor, capital, and all intermediate inputs. The value-added measures exclude the value of intermediate inputs both from the measure of outputs and the measure of inputs. The gross output measure has the attraction of attributing efficiency gains across all inputs and hence is more closely interpreted as Hicks-neutral technical change in an industry. The value-added measure is more partial in nature, attributing efficiency gains to labor and capital. However, the attractions of the value-added measure include ease of aggregation from industries to a market-economy measure of MFP and the timeliness by which the measure can be derived from national accounts data.

The growth in the gross output MFP measure can be derived as the growth in the value-added MFP measure times the ratio of nominal value-added to nominal gross output (ABS 2007). This relationship means that the growth in the gross output measure is flatter than the growth in the value-added measure. This will be an important consideration when comparing the ABS value-added and ABARE gross output measures of MFP in the following sections.

3. PRODUCTIVITY GROWTH IN NEW ZEALAND AGRICULTURE

There have been a number of studies of productivity growth for the New Zealand economy and its agriculture sector (including Philpott and Stewart 1958; Diewert and Lawrence 1999; Black, Guy, and McLellan 2003; Hall and Scobie 2006; Cao and Forbes 2007; and Mullen, Scobie, and Crean 2008). These studies are difficult to compare because of the different datasets and methodologies used to compute MFP. Statistics New Zealand did not start reporting productivity measures until 2006 and then only for the market economy (defined similarly to ABS). Attention here is confined to the Hall and Scobie research, because of its longer historical perspective, and the most recent analysis by Cao and Forbes from the Ministry of Agriculture and Fisheries (MAF), which is based on Statistics New Zealand data. All of the studies used value-added measures of MFP, and MFP growth was estimated as a compound annual growth rate.

Hall and Scobie (2006) constructed an MFP series for the years 1927-2001 using a value-added approach. They estimated that, over the entire period 1927–2001, their measure of MFP grew at a rate of 1.8% per year. The average annual growth rates by subperiod were 1.0% (1927-56), 2.2% (1957-83), and 2.6% (1984-2001).[7] The trend in productivity in New Zealand agriculture is graphed in Figure 5.2 for the period 1953 to 2001. It is noteworthy that this period of accelerating MFP from 1984 coincides with a period of major economic reform within the New Zealand economy.

The MAF publishes a value-added series (based on Statistics New Zealand data) for the years 1978 to 2007. Hall and Scobie have not updated their series, and the two series are unlikely to be perfectly consistent.

Using this MAF series, Cao and Forbes estimated that for the period 1988-2006, MFP in agriculture (not including forestry and fisheries) grew at a rate of 2.7% per year, which was 1.8 times faster than MFP growth of 1.5% per year for the market economy as estimated by Statistics New Zealand (Figure 5.3).[8] As for Australia, labor productivity in New Zealand agriculture grew more quickly than capital productivity, and input use declined. There is little evidence that growth in productivity in New Zealand agriculture has slowed.

Given that the Cao and Forbes measure of MFP is a value-added measure (expected to be steeper than a gross output measure) and that MFP growth in New Zealand agriculture has not been as fast relative to the New Zealand market economy as has been the case in Australia, it seems most probable that productivity growth has been faster in Australian agriculture than in New Zealand agriculture. The most recent multilateral study by Rao, Coelli, and Alauddin (2004) found that MFP growth rates in Australia and New Zealand over the period 1970-2001 were 2.0% and 0.8% per year, respectively.

In each of the figures for the Hall and Scobie and MAF series on MFP in agriculture, a terms-of-trade index has been graphed (Figures 5.2 and 5.3). For Hall and Scobie this index was estimated as the ratio of an index of output prices to an index of input prices from their productivity database. The Hall and Scobie (2006) series declined from around 176 in 1953 to 100 in 2004. This is a much slower rate of decline than that faced by Australian farmers as will be

[7]Mullen, Scobie, and Crean (2008) reported lower growth rates because they re-estimated them from a regression of the log of MFP against a constant and time trend.

[8]The MAF series now extends back to 1978, but when Cao and Forbes did their analysis only data from 1988 were available.

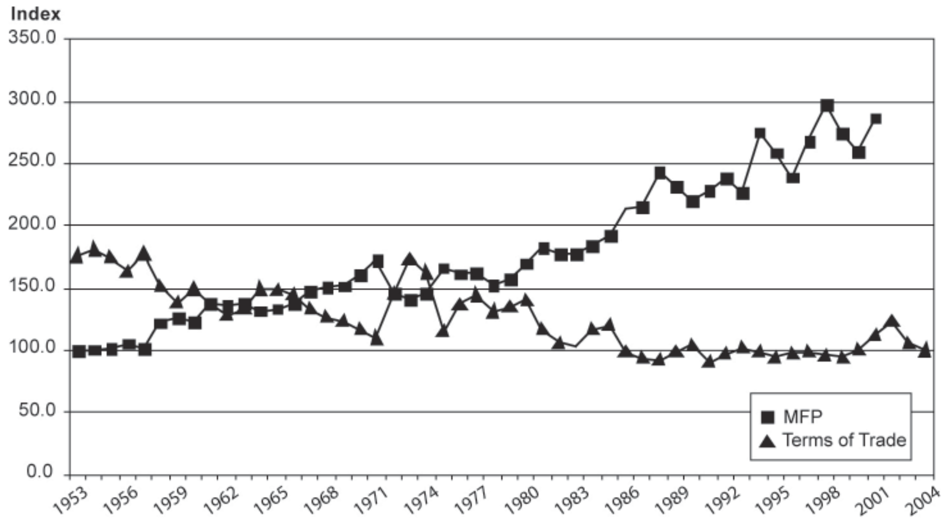

Figure 5.2. Productivity growth and terms of trade in New Zealand agriculture from Hall and Scobie: 1953 to 2001

Source: Hall and Scobie 2006: terms of trade is estimated as the ratio of an index of output prices to an index of input prices, and MFP is a value-added measure.

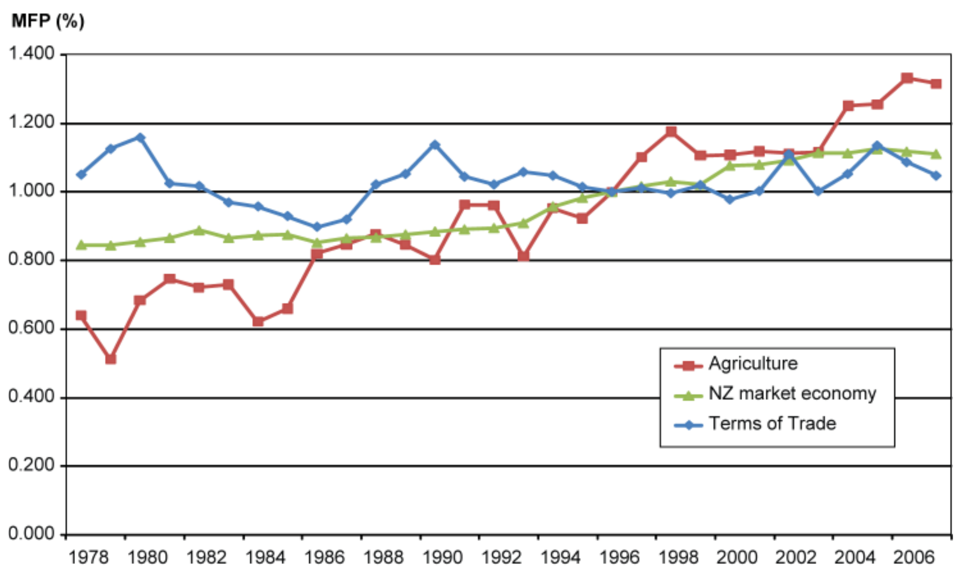

Figure 5.3. MFP for New Zealand agriculture and the New Zealand market economy from MAF: 1978 to 2007

Source: MAF, available at http://www.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/sonzaf/2008/tables/A-4.xls. Terms of trade is estimated as the ratio of an index of prices received for exports to an index of prices paid for imports, and MFP is a value-added measure.

seen in what follows. Cao and Forbes estimated the terms of trade as the ratio of an index of prices received for exports to an index of prices paid for imports. The two series are different, but both suggest that there has been no trend in the terms of trade for the New Zealand farm sector since the late 1980s, similar to the experience of Australian farmers. As a consequence, the gains to New Zealand (and Australian) farmers from productivity growth were not offset by unfavorable price changes during this recent period.

Mullen, Scobie, and Crean (2008) suggested that while public research intensity in Australia has been about twice that in New Zealand, returns to agricultural research in the two countries seemed similar, and hence relative levels of research investment seemed appropriate. The speculation that Australia has a larger agricultural sector and larger share of broadacre cropping (where MFP growth was most rapid, at least until 2000) may partly explain Australia's better performance.

4. PRODUCTIVITY GROWTH IN AUSTRALIAN BROADACRE AGRICULTURE

ABARE has conducted farm surveys over many years for broadacre agriculture, the extensive grazing and cropping industries, and for dairying. Data from these surveys are used to follow trends in productivity using gross output measures. Most farms in Australia jointly produce several crop and livestock commodities. ABARE monitors the productivity of segments within broadacre agriculture—such as specialist sheep (meat and wool) producers or specialist crop producers—but does so using stratified samples from their overall farm survey.

In 2008 the total value of crop production (Australian dollars) was $21.4 billion, of which grains and oilseeds comprised $9 billion. The total value of livestock production was $19.8 billion, of which dairying contributed $4.6 billion, wool, $2.6 billion, and livestock slaughtering (including extensive and intensive stock), $12.1 billion (ABARE 2008).

I assembled an MFP series for the years 1953 to 1994 using ABARE farm survey data, which I extended subsequently in a piecemeal fashion, again using ABARE data, as reported in several papers, most recently a 2007 article in the *Australian Journal of Agricultural and Resource Economics*. Recently, the dataset was updated by integrating it with ABARE's complete MFP data for the period 1978 onward to yield a consistent productivity dataset for 1953 to 2007.

Alongside yearly additions to ABARE's dataset (as each survey is completed), ongoing revisions to previous years are made in "cleaning" the data. The accumulated effect of these small changes over a number of years means that re-estimating earlier estimates can yield substantially different results. For example, using the new dataset, average MFP growth between 1978 and 2004 is estimated at 1.7% a year, compared to 2.7% using the dataset from Mullen 2007. As new estimates reflect the latest data revisions, it appears that my earlier estimates and those of ABARE most likely overstated broadacre productivity growth.

There have also been changes in ABARE's survey and survey methodology over time, which can influence MFP estimates. For example, the sampling frame adjusts from year to year based on a population drawn from the ABS Australian Business Register, and hence individual farms are not consistently surveyed. Also, the target population is revised over time to reflect changes in the value of farm production. Since 2004-05, the ABARE survey has included farm establishments with an estimated value of agricultural operations of $40,000 or more. In earlier years, excluding the smallest farms required a smaller cut-off. Finally, in 2002, the survey definitions of farm capital inputs were changed.[9] These changes mean that in evaluating differences in the rate of agricultural productivity growth across time periods it is important to use a consistent dataset, and comparing reported estimates across a range of literature can be misleading.

The index of MFP for Australian broadacre agriculture increased almost threefold, from 100 in year 1953 to 288 in 2000. It then declined to 193 in 2003, reflecting the drought in that year, before reaching 277 in 2006 and then falling to 215 in the drought year of 2007 (Figure 5.4). The index is highly variable, falling in 20 of the 55 years, reflecting seasonal conditions (Figure 5.5). Such variability makes it difficult to discern trends in the underlying, more stable rate of technological change. The average annual rate of MFP growth over the entire period was 2.0% per year, 0.5% per year lower than the long-term rate I previously reported (in Mullen 2007, for example).

Changes in productivity can be compared with changes in the terms of trade faced by farmers[10] as a partial indicator of whether Australian agriculture is becoming more or less competitive. The conventional wisdom is that the terms of trade facing Australian agriculture have been declining inexorably. However,

[9]Further details of ABARE survey methods can be found in ABARE 2009.

[10]Reported in ABARE 2008 and estimated as the ratio of an index of prices received by farmers to an index of prices paid by farmers.

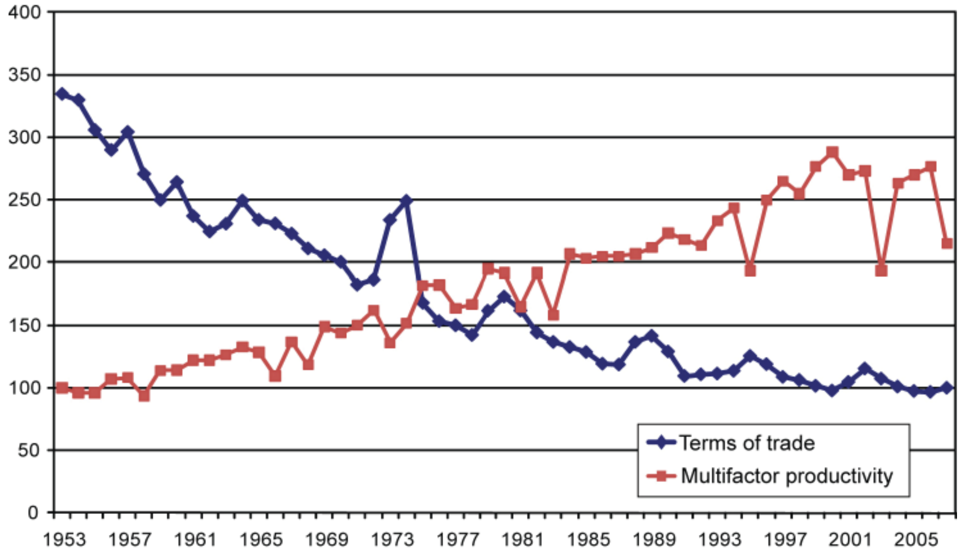

Figure 5.4. Broadacre MFP and terms of trade in Australian agriculture: 1953 to 2007

Source: Terms of trade is estimated as the ratio of an index of prices received by farmers to an index of prices paid by farmers (ABARE, Australian Commodity Statistics, 2008) and MFP is a gross output measure.

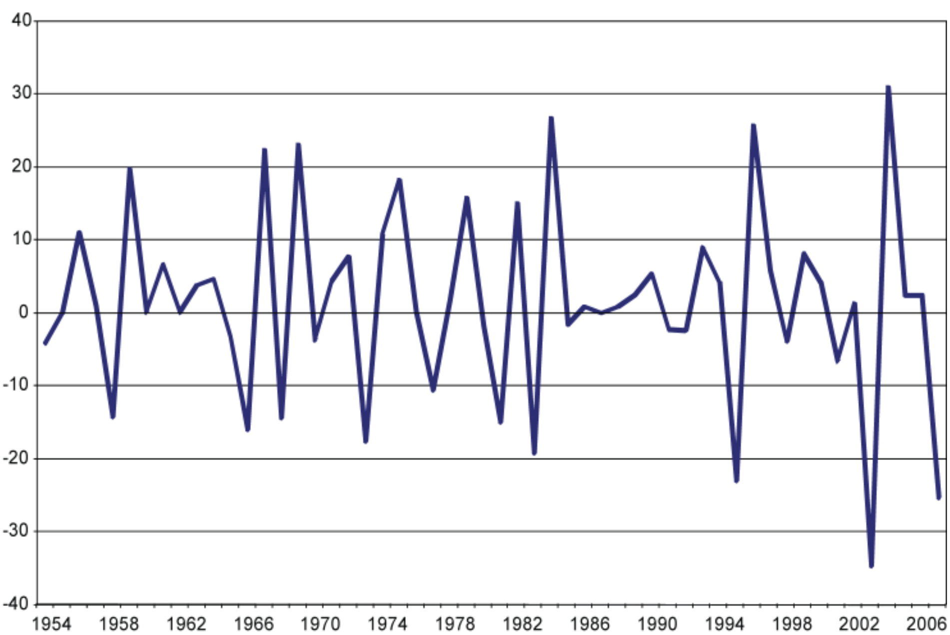

Figure 5.5. Annual growth rates for MFP in Australian broadacre agriculture

Source: Adapted from Mullen and Crean 2007.

while the terms of trade declined for about 40 years from 1953 (Figure 5.4), since the early 1990s, the rate of decline has been much slower, at least for the sector as a whole. While the MFP index grew from 100 in 1953 to 215 in 2007, the terms of trade declined from about 335 to 100, at a rate of 2.3% per year over the period 1953 to 2007, faster than the rate of productivity growth in broadacre agriculture. However, the rate of decline was 2.6% per annum from 1953 to 1990, and from 1991 to 2007, it was less than 1.0% per annum.

The ABARE estimates of productivity growth in broadacre agriculture can also be compared with the ABS estimates for agriculture, fisheries, and forestry (Figure 5.6). For the period 1978 to 2007, the ABARE and ABS estimates of average annual productivity growth rates were 1.5% and 2.4%, respectively. The ABARE and ABS series tracked each other closely except from 2001 when the ABARE series dipped while the ABS series continued to rise.

The most important reason for the much faster growth rate of the ABS measure is that it is a value-added measure. The ABS also report a gross output measure for the years 1995 to 2004, which is noticeably flatter than the ABS value-added series over the same period and similar to the ABARE series (Figure 5.6). In fact, the annual growth rates over this 10-year period were 2.1%, 2.2%, and 4.4% for the ABARE, ABS gross output, and ABS value-added measures, respectively.

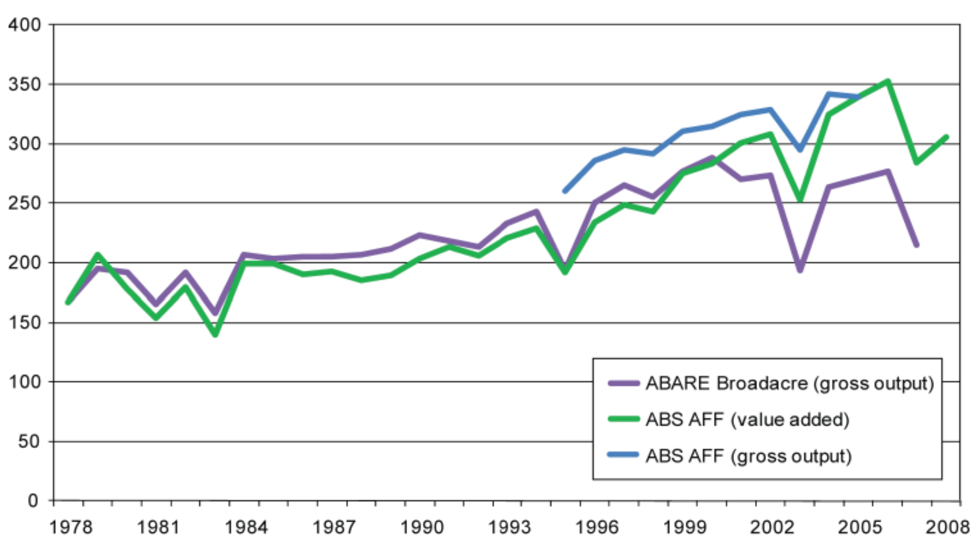

Figure 5.6. MFP trends as estimated by ABARE for broadacre agriculture and by the ABS for agriculture, fisheries, and forestry using value-added and gross-output measures

In addition, the industry coverage of the ABS and ABARE series is different. The ABS measure includes all agriculture, forestry, and fisheries, whereas the ABARE measure covers broadacre including extensive livestock and cropping industries but not including important industries like dairying, intensive livestock, horticulture, and viticulture. The share of broadacre agriculture in total value of output from agriculture (not including forestry and fisheries) has fallen to about 60%. Because of the run of poor seasons over the past decade, which has had more severe impacts on broadacre agriculture than other components of the sector, there has been a divergence in the growth of MFP for broadacre agriculture and that for the agriculture, fisheries, and forestry sector.

Productivity growth in broadacre agriculture since 1978 reflects output growing by 0.8% per year combined with input use declining by 0.6% per year (Nossal et al. 2009). Labor use declined (1.7%) faster than the use of capital (1.2%) and land (0.7%) while the use of purchased inputs increased (2.4%), resulting in higher rates of growth in partial factor productivity (PFP) of labor (2.5%) and capital (2.1%).

As noted earlier, the ABARE broadacre dataset was stratified based on the Australian and New Zealand Standard Industrial Classification (ANZSIC) system to provide estimates of productivity growth by the enterprise or industry.[11]

Here I have adopted the same stratification: cropping, mixed crop–livestock, beef, and sheep. Alternative definitions have been used for specific industry analyses (as in Nossal, Sheng, and Zhao 2008), but the findings were not dissimilar.

Since 1978, cropping specialists have achieved much higher rates of MFP growth (2.2% per year) than have beef specialists (1.5% per year) and sheep specialists (0.3% per year) (Table 5.2). Generally output grew while input use stayed static or declined. In particular, cropping specialists greatly increased their use of purchased inputs (4% per year) and reduced their use of labor (-0.2% per year) and capital (-0.4% per year), resulting in strong growth in partial productivity of labor and capital (Nossal et al. 2009). A switch toward reduced-tillage cropping—which is also associated with more diverse cropping rotations and more opportunistic cropping to exploit available soil moisture (as opposed to fixed rotations and fallows)—partly explains the changes in input use and the strong rate of productivity growth.

[11]ANZSIC is consistent with international standards and permits comparisons between industries, both within Australia and internationally. Farms assigned to a particular ANZSIC class have a high proportion of their total output characterised by that class (ABS 2006, cat. no. 1292.0).

Table 5.2. Average annual growth in broadacre MFP, by industry and by state, 1978 to 2007

	Percentage Growth		
	MFP	Output	Input
Total broadacre	1.5	0.8	-0.6
Cropping	2.1	3.1	1.0
Mixed crop/livestock	1.5	0.1	-1.5
Beef	1.5	1.7	0.1
Sheep	0.3	-1.4	-1.8
New South Wales	1.2	0.3	-0.9
Victoria	1.4	0.6	-0.8
Queensland	0.8	0.6	-0.2
South Australia	2.0	1.5	-0.5
Western Australia	2.4	1.8	-0.6
Tasmania	0.8	-2.1	-2.9
Northern Territory (Beef)	1.7	1.6	-0.1

Sources: Nossal et al. 2009 for the industry data. The state data come from the same database but were not published in Nossal et al. 2009.

Wheat yield, about 2 tons per hectare in good years, grew by 0.9% per year on average since 1972, or by 1.5% per year if the drought years of 2007 and 2008 are omitted (Figure 5.7). Wool cut per head, which in good years approaches 6 kilograms per head, grew by 0.2% per year.[12] Perhaps growth in these yields has slowed since the mid-1990s, but a run of poor seasons confounds any firm conclusions.

It is not clear why MFP has grown more quickly in cropping than in livestock, particularly in sheep production (Mullen 2007). The production cycle is much longer in livestock than in cropping, which may mean it is more difficult to demonstrate to farmers the benefits from new technologies. Perhaps genetic gains have been more rapid in crops than in livestock over this period. Perhaps specialist crop farmers have a greater range of input substitution and output transformation opportunities than specialist wool growers, for example. However my analysis with Crean (Mullen and Crean 2007) pointed out that the productivity gains of mixed farmers (who presumably have the greatest opportunities for economies of scope), while greater than those of specialist livestock farms, were less than those of specialist crop farmers. The Productivity Commission (2005) pointed to a rapid advance in cropping technologies as an explanation for this

[12]How wool cut per head translates into wool cut per hectare depends on stocking rate. Stocking rates typically decline during drought years but often not at a rate to maintain wool cut per head.

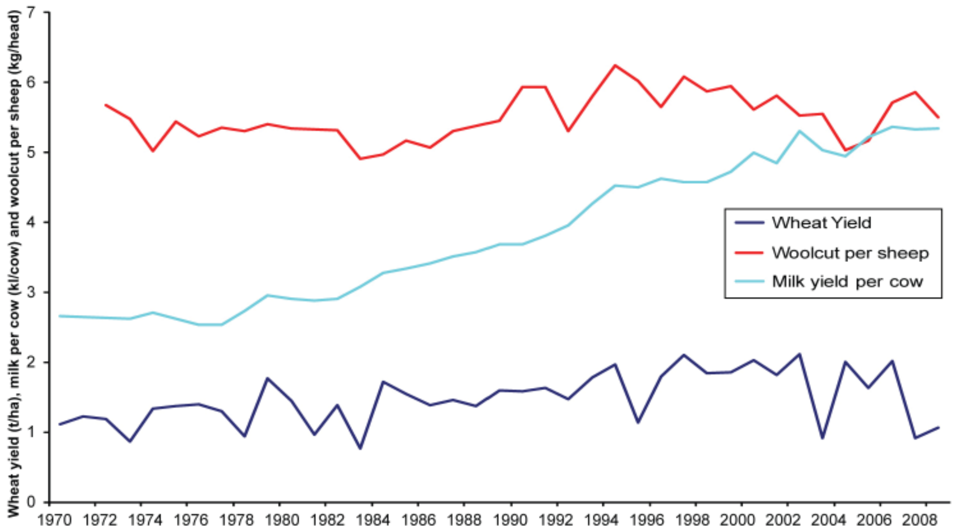

Figure 5.7. Yields of milk, wheat, and wool in Australia: 1970-2008
Source: Derived from data in ABARE 2008.

divergence in MFP growth. These technologies included higher-yielding, disease-resistant varieties; improved fertilizers and pesticides; and reduced tillage.

Productivity growth has also varied by state, with productivity growth much faster in Western Australia and South Australia than in New South Wales and Victoria. Hailu and Islam (2004), using a multilateral approach to compare broadacre MFP (based on ABARE data) across states from 1977 to 1999, found that faster growth in Western Australia and South Australia meant that MFP indexes were converging across states.

In several papers, Knopke and colleagues (1995, 2000) enquired into sources of Australian agricultural productivity growth. The most robust of their findings was that scale matters. Large farms have higher rates of productivity growth than small farms. Dividing the farms into three groups by size (measured in terms of livestock carrying capacity), Knopke et al. (1995) found that productivity grew by 3.1% per year for the group of largest farms, 1.9% per year for the group of medium-sized farms, and 0.9% per year for the group of smallest farms. In the 2000 study, Knopke et al. found that productivity grew by 3.5%, 2.7%, and 2.4 % per year respectively for the three groups of farms.[13]

[13]Note that the study by Knopke et al. (1995) analyzed the performance of broadacre farms generally, not just grain farms, as in later studies. The 2000 study did not include specialist livestock producers.

The most thorough attempt to quantitatively examine the sources of agricultural productivity in Australia was the study of the Australian grains industry by Alexander and Kokic (2005). Theirs was a cross-sectional study using individual farm data for Victorian grain farms from the ABARE broadacre survey for the years 1999 and 2002, as well as for 2001. Using an adjustment to the Fisher total factor productivity (TFP) formula to ensure transitivity,[14] they were able to compare the absolute *level* of productivity between farms. Their measure of TFP represents the extra output some farms gain holding constant the quantity of inputs.

Given the earlier findings that the key factor associated with higher levels of productivity was farm scale, with larger farms being more productive, Alexander and Kokic (2005) undertook regression analysis (M-quartile regression) to estimate unit production costs and their relationship with size. Their findings confirmed that costs per hectare were negatively related to farm size and productivity, meaning that smaller farms had higher costs per hectare and lower productivity.

Soil moisture generally had a statistically significant, positive effect on productivity in all regions and years. While farmers may be able to manage available soil moisture to some degree, rainfall is outside their control.

Other factors that generally had a positive and significant influence on productivity for grain farms in all regions included the use of reduced-tillage technologies, the extent of specialization in cropping, farmer education, and farmer participation in training. Off-farm income had a negative effect on productivity, but perhaps farm size is confounding this relationship, as small farms rely much more heavily on off-farm income.

While some other factors were significant in one or more regions in one or more years, their impact on productivity (either positive or negative) was not consistent. For example, soil acidity was negatively related to productivity in the northern and western regions in some years and positively related in the southern region in 2001-02.

In these studies, potential economies of scale were identified as a source of productivity growth. The Productivity Commission (2005) noted that average farm size in Australian agriculture (not just broadacre farming) has been increasing. In 1983 there were 178,000 farms and the average size was 2,720

[14]See Coelli et al. 2005, for example.

hectares. The ABS (2009) reported 141,000 farms in 2008 and an average size of 2,959 hectares.[15] The rate of increase in farm size was initially about 1% per year, but it has slowed in recent years. Hence, some share of estimated growth in Australian agricultural MFP may be attributable to increasing farm size. The policy implications of productivity growth relating to farm adjustment should be considered. That noted, changes in farm size occur quite slowly and, hence, may not have been a major contributor to recent productivity growth in Australian agriculture.

A major source of productivity growth has been from technical change arising from investment in research and development (R&D). The public sector, financed to a significant degree in recent decades by levies on production, has been the major provider of R&D services in Australia. In a series of analyses (most recently Mullen 2007) I found that the returns to this investment in broadacre agriculture have remained high (an internal rate of return of 15%-40% per year). However the downward revision of the ABARE productivity series for broadacre agriculture, previously noted, is likely to mean that my estimates are likely to be biased upward.

5. PRODUCTIVITY GROWTH IN AUSTRALIAN DAIRYING

Aside from the broadacre agricultural sector, ABARE data also enable productivity analysis of the dairy industry. The most recent study based on the revised ABARE dataset was reported in Nossal et al. (2009). MFP in dairying grew by 1.2% per year over the period 1989–2007, with output growing at a rate of 5.9% per year and inputs growing at a rate of 3.9% per year, a different experience from that of broadacre agriculture.[16] The dairy industry has responded to significant deregulation of marketing (particularly since July 2000), with small farms leaving the industry and the remaining farms growing in size and intensity.[17] Milk yields per cow grew at an average rate of 2.4% per year since 1972 and are approaching 5.5 kiloliters per cow per year. Total production of milk fell from 11.3 billion liters in 2002 to 9.1 billion liters in 2008.

[15]The ABS and Productivity Commission estimates may not be consistent but there is no doubting the trend.

[16]Note the shorter observation period—from 1989 for dairying as compared to 1978 for broadacre.

[17]Dairy farms now rely more heavily on purchased feed and irrigated pastures and are more likely to specialize in dairying.

Productivity grew the fastest in New South Wales, arguably where the gains from deregulation have been greatest (Zhao et al. 2008). In their data envelopment analysis of a cross-section of dairy farms, Fraser and Graham (2005) noted that dairy farms in New South Wales and Queensland in 2000 were farther from the efficiency frontier than those in Victoria, implying greater scope for productivity growth in those states as dairy farmers adjusted to deregulation.

6. HAS PRODUCTIVITY GROWTH IN AGRICULTURE SLOWED?

In Australia, a decade of poor seasonal conditions has made it difficult to discern whether and why agricultural productivity growth has slowed. According to the ABS valued-added measure, productivity growth in the agriculture, fisheries, and forestry sector has remained strong despite a weakening in the rest of the economy (Table 5.1), growing at a rate of 2.5% per year in the 10 years leading up to 2007.

However, ABARE estimates for broadacre agriculture suggest that productivity growth slowed in the 10 years leading up to 2007.[18] In this period, MFP peaked at 288 in 2000 and the next peak was 276 in 2006 (Figure 5.6). The annual growth rate from 1998 to 2007 was -1.4% (Table 5.3).

Recall that, were a gross output measure for the agriculture, fisheries, and forestry sector available for this period, its growth rate would be much flatter and more similar to the ABARE measure. Nevertheless, it seems highly likely that because of the different industry composition of the two measures and the greater susceptibility of broadacre industries to the impact of drought, MFP

Table 5.3. Trends in MFP for broadacre industries, 1978 to 2007

	All Broadacre	Cropping	Mixed Crop-Livestock	Beef	Sheep
			percent		
1979-80 to 1988-89	2.2	4.8	2.9	-0.9	0.4
1984-85 to 1993-94	1.8	4.7	3.2	3.1	-1.7
1988-89 to 1997-98	2.0	1.9	1.4	1.6	-1.2
1993-94 to 2002-03	0.7	-1.2	0.0	1.0	3.4
1997-98 to 2006-07	-1.4	-2.1	-1.9	2.8	0.5
1977-78 to 2006-07	1.5	2.1	1.5	1.5	0.3

Source: Nossal et al. 2009.

[18]Trends within enterprises that make up broadacre agriculture are reviewed in the next section.

growth in the agriculture, fisheries, and forestry sector has been faster than that in broadacre industries over the past decade.

Trends in productivity have not been even across industries within broadacre agriculture (Table 5.3). For cropping specialists, MFP grew by 4.8% per year from 1980 to 1994 but declined by 2.1% per year from 1998 to 2007. There seems much less evidence of a slowing in MFP growth for beef and sheep specialists. Nossal et al. (2009) speculated that productivity growth of sheep specialists, usually ranking the lowest among the industry groups, might finally be catching up.

Why might broadacre productivity be slowing? Some argue that it is not surprising that productivity growth in agriculture is drifting down because "all the big gains have been made." However, Australian research agronomists seem confident that there are still practical research opportunities to develop new technologies that would allow farmers to grow crops more efficiently. For example, Angus (2001) argued that trends in Australian wheat yields showed little signs of slowing down (Figure 5.8). Anderson and Angus (*World Wheat Book,* in press) said:

> "Despite the new technology, the mean yield is only 2.0 tons per ha, about half of the water-limited potential…. Further research will be needed to increase yield closer to the water-limited potential. The gains are most likely to come from tactics that enable crops to take advantage of the more favorable seasons in the variable climate, and concentration of inputs on the parts of farms with the highest yield potential."

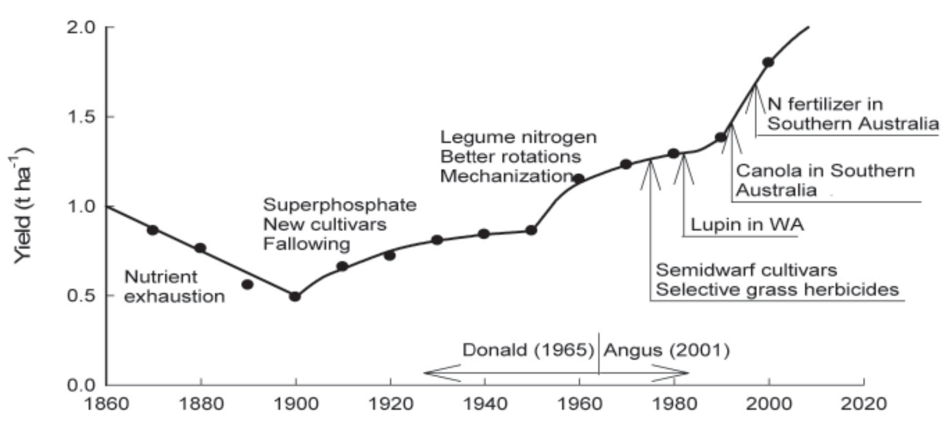

Figure 5.8. Trends in average wheat yield in Australia: 1860 to 2000
Source: Donald 1965, modified by Angus in 2001.

Two other factors likely to explain a significant portion of productivity growth in broadacre agriculture (at least at the aggregate level) are climate or seasonal conditions and public investment in agricultural research.

The annual rainfall anomaly for the Murray Darling Basin (Figure 5.9) published by the Bureau of Meteorology for the period 1900-2008 shows the annual deviation in rainfall from average annual rainfall between 1961 and 1990. There have now been eight consecutive years of below-average rainfall. No judgment is made here about the extent to which long-term climate change has contributed to this run of poor seasons. If farmers are using inputs in expectation of a normal season but a dry season eventuates, then MFP falls. In addition, perhaps farmers' expectations about seasons are now more conservative such that they are operating on a less efficient part of the production function.

Total public expenditure on agricultural R&D (not including fisheries and forestry) in Australia has grown from $140 million in 1953 to almost $830 million in 2007 (in 2008 Australian dollars) (Mullen 2010). Figure 5.10 shows that expenditure growth was strong to the mid-1970s. The trend in expenditure has essentially been static since that time, although there was a spike in investment (nearly $950 million) in 2001. Likewise, agricultural research intensity, which measures the investment in agricultural R&D as a percentage of GDP, grew strongly in the

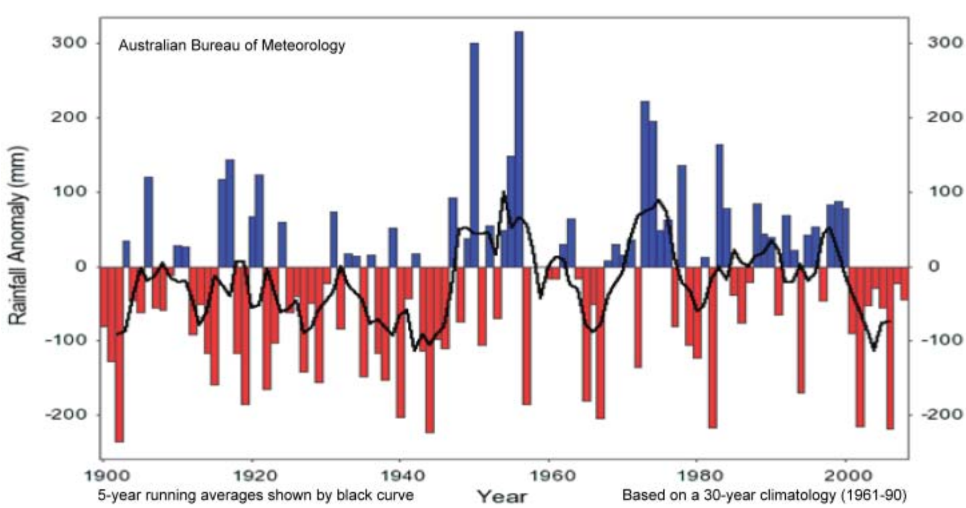

Figure 5.9. Annual rainfall anomaly, Murray Darling Basin, 1900 to 2008
Source: The Bureau of Meteorology, available at http://reg.bom.gov.au/cgi-bin/climate/change/timeseries.cgi?graph=rranom&area=mdb&season=0112&ave_yr=0.

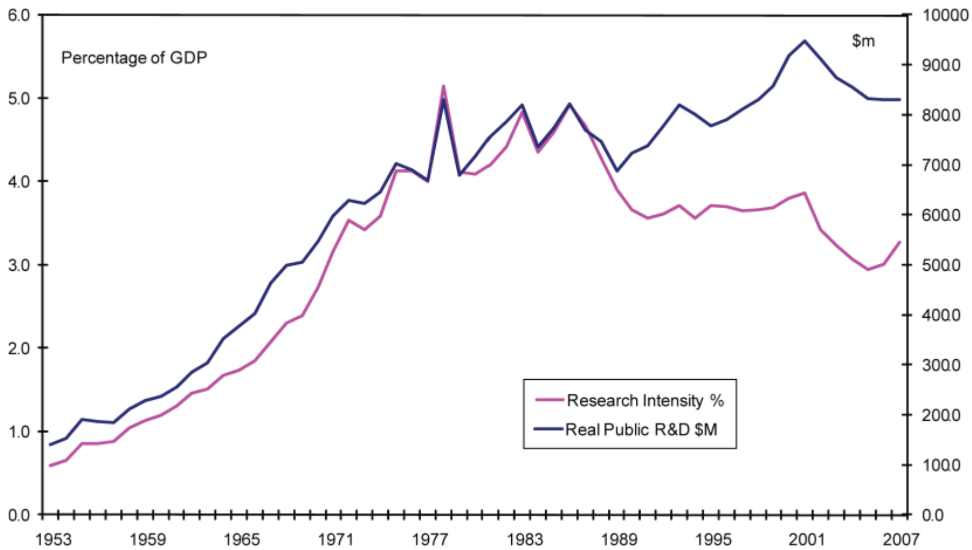

Figure 5.10. Real public investment and research intensity in Australian Broadacre Agriculture: 1953 to 2007 (2008 dollars)
Source: Mullen 2010, derived from public financial statements of public research institutions and the ABS.

1950s and 1960s but has been drifting down from about 4.0%-5.0% annually of agriculture GDP in the period between 1978 and 1986 to about 3.0% per annum in recent years (as compared to 2.6% per annum in developed countries).

Sheng, Mullen, and Zhao (2009) found that based on an analysis of the stability of the MFP index for broadacre agriculture from 1953 to 2007 using the adjusted cumulative sum square index, climate alone did not explain the slowdown in broadacre productivity growth. Rather, the slowdown can be attributed to both poor seasons and the lagged impact of the stagnation in public investment in agricultural R&D since the 1970s.

7. CONCLUSION

MFP in agriculture in New Zealand had been growing slowly relative to the New Zealand economy, but recent estimates from the MAF suggest that this is no longer true. MFP in agriculture since 1988 grew by 2.7% per year and shows no sign of slowing, whereas the MFP growth rate for the economy as a whole was 1.5%.

In Australia, productivity growth in the agriculture, fisheries, and forestry sector has remained strong and shows little indication of slowing. Since 1978 it has grown at a rate of 2.4% per year (using a value-added measure) and has often exceeded growth in the market economy by a factor of 3. Nevertheless agriculture's share in the economy's GDP has continued to fall, though at a slower rate in recent decades. It seems likely that productivity growth in agriculture has been faster in Australia than in New Zealand.

Productivity growth in broadacre industries, on the other hand, while strong to 1998, has been negative in the 10 years leading up to 2007 (-1.4%). Reconciling the ABS and ABARE measures is difficult because the industry coverage is different and the ABS reports a value-added measure for the sector as a whole whereas ABARE reports a gross output–based measure for broadacre industries. Value-added measures exceed gross output measures to the extent that, for the period 1995 to 2004, the growth rate for the ABS series, when converted to an equivalent output-based measure, was similar to the ABARE measure.

Prior to the poor seasonal conditions since 1998, MFP in the broadacre industries was growing at a rate of about 2% per year. Hence, it seems likely that MFP growth in the agriculture, fisheries, and forestry sector also grew at about this rate in terms of an output-based measure and that it continued to grow at about this rate through to 2007.

The performance of industries within the broadacre grouping is diverse. Since 1978, MFP for cropping specialists grew at a rate of 2.1% per year on average but in some subperiods it grew at a rate approaching 5%, and after 1998 it decreased at 2.1% per year. Long-term average MFP growth for livestock specialists was much lower than for crop specialists; however, this trend appears to have reversed for the past 10-15 years. Generally within these industries, output has grown while labor and capital use has been static or declining, with partial productivity measures for these inputs rising. However, for cropping there was a large increase in the use of purchased inputs (4%).

The better performance of cropping specialists and their increased use of purchased inputs is likely explained by a switch toward reduced-tillage cropping also associated with more diverse cropping rotations and greater opportunities to exploit available soil moisture (as opposed to fixed rotations and fallows). Scale economies have likely been an important source of productivity growth in broadacre industries, particularly among crop specialists. Livestock specialists seem to have less scope to switch between enterprises in response to changing economic and climate conditions.

MFP growth in dairying was 1.2% per year over the 1989-2007 period with output growing at a rate of 5.9% per year and inputs growing at a rate of 3.9%

per year, a different experience from broadacre agriculture. The dairy industry has responded to significant deregulation of marketing (particularly since July 2000), with small farms leaving the industry and the remaining farms growing in size and intensity.

An obvious reason for the slowdown in MFP growth for cropping specialists, and broadacre industries more generally, has been the run of poor seasons. Rainfall in the Murray Darling Basin has been below the average for the 1960-1990 period for the eight years starting in 2001.

Public investment in agricultural research has also stagnated since the 1970s. There is a long lag between investment in research and increased productivity on farms. There is concern that this stagnation in investment is now being reflected in the downturn in MFP.

Recent econometric research to disentangle climate and investment factors confirms that there has been a slowdown in broadacre MFP growth and that slowdown can only be explained by the effects of both poor seasons and declining public investment in R&D, not by either of these singly. Australian agronomists are confident that good research opportunities remain to develop technologies that will advance the growth of MFP in Australian broadacre agriculture.

REFERENCES

ABARE (Australian Bureau of Agricultural and Resource Economics). 2008. *Australian Commodity Statistics 2008*. Canberra: Author.

———. 2009. *Survey Methods and Definitions*. Canberra: Author. http://www.abare.gov.au/publications_html/economy/economy_09/survey_methods.pdf.

ABS (Australian Bureau of Statistics). 2007. "Experimental Estimates of Industry Multifactor Productivity: Australia." Information paper 5260.0.55.001. Canberra: Author. http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5260.0.55.0012007?OpenDocument.

———. 2009. "Agricultural Commodities." Catalogue No. 7121.0. Canberra: Author.

———. Various. "Research and Experimental Development, All-Sector Summary, Australia." Catalogue No. 8112.0. Canberra: Author.

Alexander, F., and P. Kokic. 2005. *Productivity in the Australian Grains Industry.* Canberra: Report prepared for the Grains Research and Development Corporation.

Anderson, W.K., and J.F. Angus. In press. "Agronomy and Cropping Practices in Semi-Arid Conditions in Australia." In *World Wheat Book 2,* A. Bonjean, W. Angus, and M. van Ginkel, eds. Chappes, France: Limagrain.

Angus, J.F. 2001. "Nitrogen Supply and Demand in Australian Agriculture." *Australian Journal of Experimental Agriculture* 41: 277-288.

Bernard, A.B., and C.I. Jones. 1996. "Productivity Across Industries and Countries: Time." *Review of Economics and Statistics* 78: 135.

Black, M., M. Guy. and N. McLellan. 2003. "Productivity in New Zealand 1988 to 2002." New Zealand Treasury Working Paper, 03/06, Wellington.

Cao, K., and R. Forbes. 2007. "Productivity in the New Zealand Primary and Downstream Sectors." *Australasian Agribusiness Review* 15(Paper 9).

Coelli, T.J., D.S.P. Rao, C.J. O'Donnell, and G. Battese. 2005. *An Introduction to Efficiency and Productivity Analysis,* 2nd ed. New York: Springer.

Diewert, E., and D. Lawrence. 1999. "Measuring New Zealand's Productivity." New Zealand Treasury Working Paper 99/05, Wellington. http://www.treasury.govt.nz/workingpapers/1999/99-5.asp.

Donald, C.M. 1965. "The Progress of Australian Agriculture and the Role of Pastures in Environmental Change." *Australian Journal of Science* 27: 187-198.

Fraser, I., and M. Graham. 2005. "Efficiency Measurement of Australian Dairy Farms: National and Regional Performance." *Australasian Agribusiness Review* 13(7): 1–18.

Hailu, A., and N. Islam. 2004. "Multilateral Productivity Levels and Growth Rates for Australian Broadacre Agriculture." 48th Annual Conference of the Australian Agricultural and Resource Economics Society, Melbourne, February 11–13.

Hall, J., and G. Scobie. 2006. "The Role of R&D in Productivity Growth: The Case of Agriculture in New Zealand: 1926–27 to 2000–01." New Zealand Treasury Working Paper 06/01, Wellington.

Knopke, P., V. O'Donnell, and A. Shepherd. 2000. *Productivity Gains in the Australian Grains Industry.* ABARE Research Report 2000.1, Canberra: ABARE.

Knopke, P., L. Strappazzon, and J.D. Mullen. 1995. "Productivity Growth: Total Factor Productivity on Australian Broadacre Farms." *Australian Commodities* 2: 486-497.

Martin, W., and D. Mitra. 2000. "Productivity Growth and Convergence in Agriculture and Manufacturing." *Economic Development and Cultural Change* 49(2): 403-422.

Mullen, J.D. 2007. "Productivity Growth and the Returns from Public Investment in R&D in Australian Broadacre Agriculture." *Australian Journal of Agricultural and Resource Economics* 51(4): 359-384.

Mullen, J.D. 2010. 'Trends in Investment in Agricultural R&D in Australia and Its Potential Contribution to Productivity." *Australasian Agribusiness Review* 18(Paper 2): 260. http://www.agrifood.info/review.

Mullen, J.D., and J. Crean. 2007. *Productivity Growth in Australian Agriculture: Trends, Sources, Performance.* Surry Hills, NSW: Australian Farm Institute.

Mullen, J.D., G.M. Scobie, and J. Crean. 2008. "Agricultural Research: Implications for Productivity in New Zealand and Australia." *New Zealand Economic Papers* 42(2): 191-211.

Nossal, K., Y. Sheng, and S. Zhao. 2008. *Productivity in the Beef Cattle and Slaughter Lamb Industries.* Research Report 08.13. Canberra: ABARE.

Nossal, K., S. Zhao, Y. Sheng, and D. Gunasekera. 2009. "Productivity Movements in Australian Agriculture." *Australian Commodities* 16(1): 206-216.

Philpott, B.P., and J.D. Stewart. 1958. "Capital, Income and Output in New Zealand Agriculture 1922-1956." *Economic Record* 44(August): 223-237.

Productivity Commission. 2005. *Trends in Australian Agriculture*. Canberra: Commonwealth of Australia.

Rao, P, T. Coelli, and M. Alauddin. 2004. "Agricultural Productivity Growth, Employment and

Poverty in Developing Countries: 1970–2000.” Employment Strategy Papers, Centre for Efficiency and Productivity Analysis (CEPA), School of Economics, University of Queensland, Brisbane.

Sheng, Y., J.D. Mullen, and S. Zhao. 2009. “Has Growth in Productivity in Australian Broadacre Agriculture Slowed?” Paper presented at the workshop “Measuring Agricultural Productivity,” Centre for Efficiency and Productivity Analysis, School of Economics, University of Queensland, 2 October 2009.

Zhao, S., K. Nossal, P. Kokic, and E. Elliston. 2008. “Productivity Growth: Australian Broadacre and Dairy Industries.” *Australian Commodities* 1(March): 236-242.