The Future Productivity and Competitiveness

Challenge for Australian Agriculture

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Abstract

The objective of this paper is to review likely trends in key drivers of productivity with a view to suggesting the rate of productivity growth that is likely to be required to maintain the competitiveness of Australian agriculture both within the Australian economy and relative to the agricultural sectors of other economies. The paper also canvasses prospect for achieving this level of productivity performance over the period to 2030.Growth in agricultural productivity has slowed over the last two decades and a significant proportion of this slowdown in growth can be attributed to the stagnation in public investment in agricultural R&D since the late 1970s. The prospect that rate of growth of TFP could stay at less than 1.0% rather than recover to a long term rate of 2.0% is obviously quite concerning for the future competitiveness of agriculture both domestically and internationally. It would seem that to maintain TFP growth in the 2.0 – 2.5% per year range, investment in agricultural R&D has to be returned to a level of 3.0% of agriculture's GVP (or 5% of GDP), a major challenge for government and industry.

Keywords: Productivity, R&D investment; Competitiveness

Introduction

The objective of this paper is to review likely trends in key drivers of productivity with a view to suggesting the rate of productivity growth that is likely to be required to maintain the competitiveness of Australian agriculture both within the Australian economy and relative to the agricultural sectors of other economies. The paper also canvasses how this level of productivity performance might be achieved over the period to 2030.

This paper is the lead paper in a set of six commissioned by the Australian Farm Institute 'to explore the scope of the productivity challenge facing Australian agriculture, and identify specific technologies and initiatives that could realistically assist the sector to attain the levels of productivity growth that are likely to be required in the future' (Mullen et al., 2012, p.iii). The other papers examined prospects for R&D and extension in plant, animal, and natural resource systems, and in key inputs such as energy, water, machinery and human capital to meet this productivity challenge.

A return to good seasons, strong commodity prices and rapid economic growth in developing countries where income per capita and population are rising are among factors suggesting a very positive outlook for Australian agriculture over the next twenty to thirty years. This could lead to some complacency amongst farm business managers and policymakers about the continuing importance of productivity growth to maintaining the competitiveness of the sector.

Such complacency is misplaced, as there is strong evidence globally that major developing nations are investing heavily in agriculture, and other sectors of the Australian economy are also experiencing strong growth and out-competing Australian agriculture for scarce resources. This confirms that while the outlook is positive, Australian agriculture faces increased competition in international markets and increased competition for essential resources within Australia. A resumption of strong productivity growth is the only realistic option available to the sector to respond to both these challenges.

Productivity growth has contributed strongly to growth in output in Australian agriculture, as is highlighted in Figure 1. It shows that in the absence of productivity growth over the past sixty years, the current gross value of production for the Australian agricultural sector would only be approximately A$12 billion per annum, rather than more than $40 billion. It also highlights that more than 70% of the value of agricultural production in 2010 could be attributed to past productivity growth, based on estimates that the average rate of productivity growth in Australian agriculture has been 2% per annum since 1953.

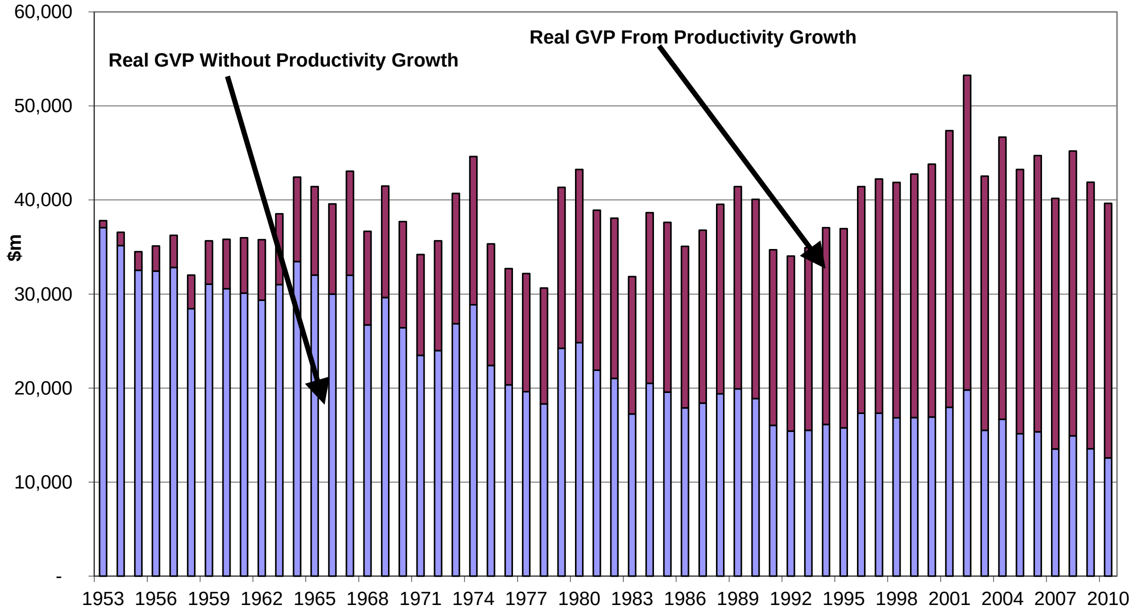

Figure -1: The value of productivity growth (2%) to Australian agriculture, 1953 – 2010 (A$2010).

Source: Derived by the author from ABARES data in *Australian Commodity Statistics*

Whilst this past performance by the sector is impressive, there is growing concern that the rising value of the Australian dollar and the strength of the mining sector threaten the future competitiveness of Australian agriculture. In addition there is evidence that productivity growth has slowed, not just as a result of poor seasons but also because of declining levels of public investment in agricultural R&D. There are also concerns that growth in agricultural productivity may be eroded by accelerating climate change, which some expect will impact on Australian agriculture to a greater degree than on other agricultural exporters.

While the focus of this discussion is on productivity, it should be borne in mind that farmers are more interested in profitability. Productivity is a key contributor to growth in profitability but its contribution is modified by trends in the terms of trade (the ratio of prices farmers receive for outputs to prices paid for inputs) experienced by farmers (O'Donnell 2010).

This paper first examines the concept of productivity and defines its components, before discussing issues surrounding the measurement of productivity. The paper then reviews historical trends in productivity, including work by ABARES to derive an estimate of productivity growth where the effects of climate variability have been removed. Then, follow sections reviewing prospects for potential major drivers of productivity growth in agriculture including climate change (section 4); trends in productivity and prices in other sectors of the economy particularly the resources sector (section 5), and the role of investment in agricultural research, development and extension (RD&E) in maintaining productivity growth (section 6). Concluding comments are made in Section 7.

Key Productivity Concepts

Calculation of rates of productivity growth.

Economists define productivity as the ratio of the volume of outputs to the volume of inputs for a particular production system or activity. Productivity growth is therefore the change in this ratio over time. In the case of a single output and a single input, these ratios are akin to a growth in crop yield per hectare or growth in animal product per hectare.

However in the normal multi-output, multi-input agricultural production environment, crop yield or livestock production per hectare are only partial measures of the productivity (often referred to as measures of partial factor productivity (PFP)) of the farm, and can be a poor indicator of changes in productivity when measured at a whole farm level. An improvement in wheat yield may not provide a sound indication of changes in whole farm productivity if the use of inputs has changed or if the change in wheat yields is associated with other changes the farming system (such as a the introduction of another crop in the rotation).

Total factor productivity (TFP), which attempts to measure gains in the efficiency with which all inputs are combined to produce all outputs[1] can be represented as:

$$TFP_{ms,nt} = \frac{q_{nt}/q_{ms}}{x_{nt}/x_{ms}} = Q_{ms,nt} / X_{ms,nt}$$

where TFP is an index of the *change* in productivity which can be either for different time periods for a collection of farms or different farms in the same time period but here it is defined as between firm n in period t and firm m in period s, *q* is output *quantity*, *x* is input *quantity* and Q and X, like TFP are *indices of change* (using notation from O'Donnell, 2010).

There is a large literature (O'Donnell 2010) about the various functions which may be used to construct these measures of aggregate outputs, inputs and TFP and their index number properties, which will not be reviewed here. However in approximate terms inputs and outputs are aggregated using prices to derive measures of total cost and total revenue. Prices are held constant between farms or time periods to so that the aggregates reflect changes in quantities.

Clearly the accuracy of any measure of TFP depends on the accuracy of the data for inputs and outputs. One source of bias arises when the changes in the quality on inputs and outputs go unmeasured. The quality of land may decline because more marginal land is being used or because its nutrient status is being degraded. Farm labour may be improving because of higher educational attainments. Farm products may be increasingly differentiated on quality grounds to meet users' needs more closely. The extent of the bias arising from these problems is unknown. The fact that prices averaged over grades in inputs and outputs also reflect quality change is a 'self correction' mechanism of unknown value.

Conceptually the solution is to compute quantity and price indices over an exhaustive classification of inputs and outputs. This is expensive. Statistical agencies often make some attempt to adjust for quality change in key inputs and outputs using hedonic price modeling.

TFP is almost always estimated at a farm or sector level rather than at the level of a farm enterprise such as the wheat enterprise. In other words Q and X relate to aggregates of all farm inputs and outputs not just those related to a particular enterprise on a farm. The reason

[1] Some prefer the term multifactor productivity (MFP) to TFP in more explicit recognition that in practice not all outputs and inputs are accounted for.

for this is that for most farms, the various crop and livestock enterprises are linked by biological relationships including carryover impacts related to soil fertility, and weed and disease control, and economic relationships which mean that changes in relative profitability alter input and output mixes. Restricting attention to inputs and outputs associated with the wheat enterprise provides only a partial measure of whole farm productivity change because it ignores associated changes in other farm enterprises that are included in TFP estimates.

ABARES has published measures of TFP based on their annual farm surveys of a large sample of farms across Australia. ABARES conducts these analyses for broadacre and dairy farms [2](farms which earn most of the income from dairying). Recently the Australian Bureau of Statistics (ABS) has also published estimates of TFP growth by sector, from National Accounts data (and using a value added rather than gross value measure) (ABS 2011).

The relationship between productivity and profitability.

As noted earlier, productivity growth provides no advantage to a farm business unless it also provides an opportunity to increase profitability (ceteris paribus). It is therefore important to understand the relationship between farm productivity change and productivity.

Consider the relationship between productivity growth, profitability and the terms of trade (the ratio of prices received by farmers for outputs to prices paid by farmers for inputs). Profitability, the ratio of growth in income to growth in costs, can be represented as (O'Donnell 2010):

$$PROF_{ms,nt} = \frac{P_{ms,nt}}{W_{ms,nt}}\frac{Q_{ms,nt}}{X_{ms,nt}} = TT_{ms,nt} \times TFP_{ms,nt}$$

where $PROF_{ms,nt}$ is the profitability of firm *m* in period *s* relative to the profitability of firm *n* in period *t* and TT is the ratio of P prices received for outputs to W prices paid for inputs for firm *m* in period *s* relative to TT of firm *n* in period *t*[3].

Intuitively this equation equates an index of value, PROF, with a quantity index, TFP, times a price index, TT. Growth in productivity only translates directly into growth in profitability if the terms of trade are constant. Further, changes in the terms of trade induce changes in some of the sources of productivity growth, described below.

Components of TFP

While calculated TFP provides information about overall changes in the ratio of inputs to outputs for a business or industry, it does not provide information about why the ratio has changed. Intuitively, there are a range of different factors that could result in a change in TFP, and understanding these factors provides an opportunity to better target how TFP might be influenced by management or policy measures.

O'Donnell (2010) has detailed how TFP can be decomposed into productivity growth from technical change and productivity growth from a group of efficiency measures, some of which respond to changes in the terms of trade. In understanding productivity an important concept is the concept of a *production frontier* for a particular production system which relates output on the y axis to inputs on the x axis for the most efficient farms.

The factors influencing TFP growth are as follows;

[2] Since 2004-05 ABARES farm surveys included establishments classified as having an EVAO of A$40 000 or more.

[3] P and W are aggregate prices defined such that PQ is total revenue and WX is total costs.

- *Technical change (TC)*: shifts the production frontier outwards so that more output is achieved from the same inputs. An important source of technical change is new technologies arising from investment in RD&E. Other sources of technical change may include education and infrastructure.
- *Technical efficiency(TE)*: the difference between the performance of average farms and the best farms, , a movement towards the production frontier in other words.
- *Scale efficiency (SE)*: the extent to which a farm business is at its most efficient scale, given available technologies and management systems.
- *Mix Efficiency(ME)*: the extent to which a farm business manager has selected the best mix of inputs and enterprises in order to maximise the aggregate output of the business.

O'Donnell pointed at while TFP is directly related to technical change and technical efficiency, an increase in terms of trade (TT) might encourage firms to sacrifice scale and mix efficiency, and hence TFP, in the pursuit of profit and vice versa.

In general terms the growth in TFP comes from technical change, and a number of sources of efficiency - technical, scale and mix efficiency. The relationship can be written (loosely) as:

$$TFP_{ms,nt} = TC_{ts} \quad x \quad \left(TE_{nt,ms} \quad x \quad SE_{nt,ms} \quad x \quad ME_{nt,ms}\right)$$

where all terms are indices of change. Starting with the three efficiency terms - TE, SE and ME - of the equation, these can be explained with reference to the following figure (O'Donnell 2010) which represents a production function relating aggregate input to aggregate output. The ratio of output to input, productivity, is given by the slope of the rays from the origin.

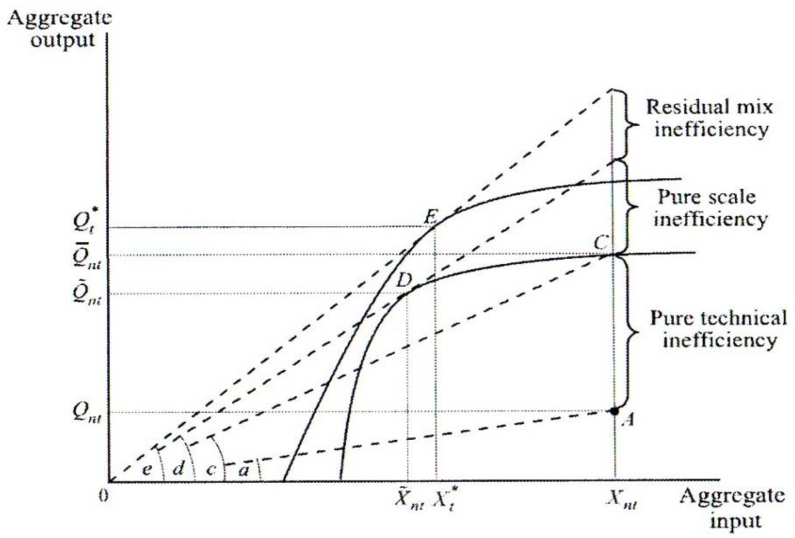

Figure 2: Measures of Efficiency

Source: O'Donnell, 2010

At point A the firm is technically inefficient because it can expand output to the point C without increasing inputs. Technical efficiency at an industry level is driven in part by investment in agricultural extension services. The production function through the points D and C is restricted in the sense that further efficiency gains can be made if the farmer is allowed to change input and output mixes and the scale of his operation. From C, productivity can be improved by reducing scale to the point D where the slope of the ray from the origin through D is greater than the slope of the ray through C. Scale efficiency is a measure of the extent to which farms are close to most efficient size. Adjustment policies can either speed up or retard the movement of farms towards an efficient size. Allowing changes in output and input mixes expands the production frontier to that passing through E and so there is a further gain in efficiency from mix economies in moving from D to E.

Technical progress can be represented in Figure 2 as a further shift over time in the production function north west of the frontier through E. Production possibilities are expanded.

Profit is maximised where a (iso-profit) line with a slope equal to W/P is just tangent to the production frontier. When the slope of this line equals the slope of the ray from the origin through E then E is the point of maximum profit and maximum productivity but if P increases relative to W, a favourable change in the terms of trade, then the point of tangency between the isoprofit line and the production function slides towards the north east away from E and farmers are induced to accept some scale and mix inefficiencies in pursuit of higher profits. Hence TFP is not independent of TT.

TFP and unmeasured changes in natural resource flows

The availability and quality of data on inputs and outputs is a key problem for the measurement and analysis of productivity. A common drawback is that the use of natural resources in agricultural production, such as soil fertility and water which sometimes imposes costs on other farmers and the community (externalities in other words) is not fully accounted for. To some extent, this criticism is overstated. Yield losses as soil fertility is used up, and increased inputs such as fertilisers are reflected in measures of outputs and inputs both for the farms causing the degradation and for neighbouring farms suffering externalities. For example, in an analysis of rice farms in NSW, Chapman et al. (1999) found that farms in areas with high water tables, poor water quality and difficult soils for irrigation often had lower productivity.

Nevertheless, farming activities can result in negative and positive externalities whereby the full costs or benefits from farming are not reflected in the prices of inputs and outputs, hence creating a divergence in the interests of individual famers and society. For example farming activities may lead to a change in the quantity and quality of water leaving farms that have an impact on other farmers and communities downstream. While traditional measures of TFP adequately represent the incentives facing farmers, some of the efficiency gains may come from exploiting un-priced natural resources and hence, from society's viewpoint, the gains in efficiency are much smaller than from the farmers' viewpoint and vice versa for when farming activities enhance environmental factors.

In recent decades as an appreciation has grown of the economic significance of these environmental service flows from natural resources, governments have sought to introduce pricing (either incentives or penalties) for some uses of natural resources so that there is less divergence in interests between users and the broader community. It is likely that because of these changes, a decreasing proportion of productivity growth in agriculture can be attributed to the unpriced degradation of natural resources.

In addition a significant proportion of publicly funded R&D seeks not only to enhance productivity but also to deliver better environmental outcomes. In assessing the returns from public investment in R&D the benefits of improved environmental outcomes should be valued together with the gains from improved productivity, but estimating the value of these unpriced environmental outcomes is rarely attempted.

Having defined and explained how productivity is measured, trends in some of the key drivers of productivity –climate change, the productivity performance of agriculture relative to other sectors, and investment in RD&E; – are analysed as a starting point for assessing future prospects.

Past Trends in Key Parameters in Agriculture and Other Sectors

Trends in TFP in broadacre agriculture

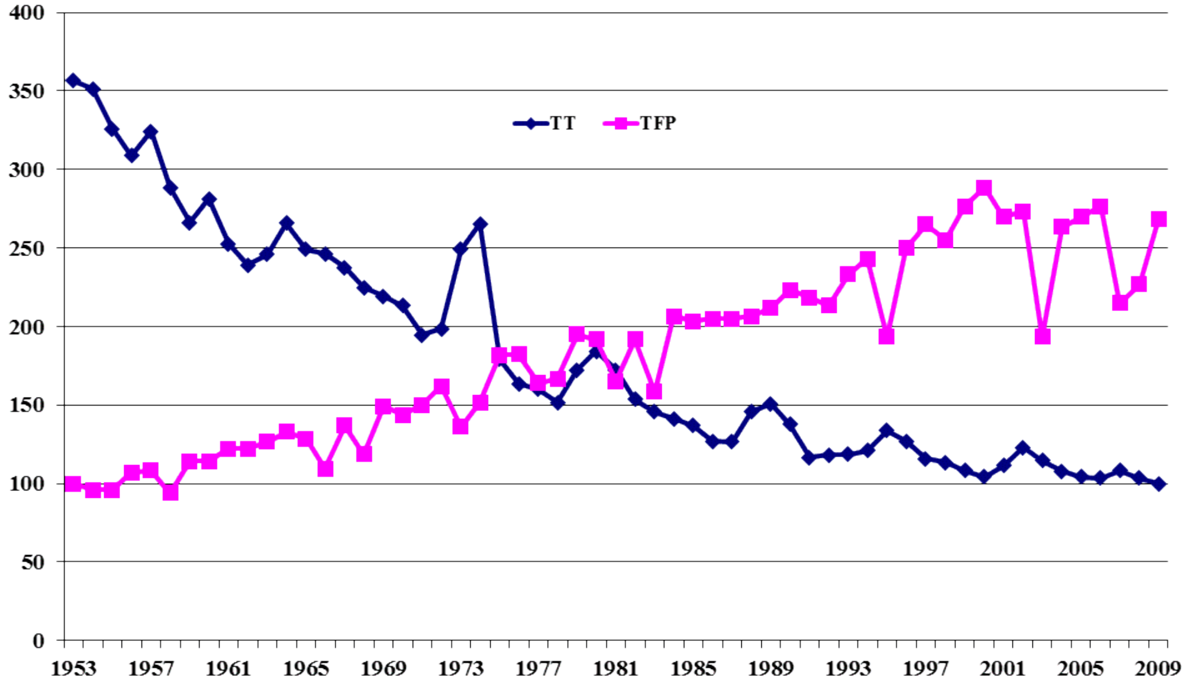

Figure 3: TFP and TT in broadacre agriculture, 1953 - 2009

Source: Derived by the author from ABARES data

ABARES has conducted farm surveys over many years for broadacre agriculture, encompassing the extensive grazing and cropping industries (but not horticulture, intensive livestock or irrigated agriculture) , and for dairying. Data from these surveys are used to follow trends in productivity using gross output measures. Most broadacre farms in Australia jointly produce several crop and livestock commodities and hence TFP must be measured at a whole farm level[4].

TFP for Australian broadacre agriculture increased almost threefold, from an index of 100 in year 1953 to 288 in 2000. It then declined to 193 in 2003 and 215 in 2007 reflecting particularly poor seasons in a run of poor years before increasing to 268 in 2009 (Figure 3).

[4] ABARES monitors the productivity of segments within broadacre agriculture—such as specialist sheep producers or specialist crop producers—but does so using stratified samples from their overall farm survey still at a whole farm level.

The series is highly variable, falling in 21 of the 57 years, reflecting seasonal conditions. Such variability makes it difficult to discern trends in the underlying, more stable rate of technical change. The average annual rate of TFP growth over the entire period was 1.9% per year, about 0.5% per year lower than the long-term rate previously reported (in Mullen 2007, for example).

TFP grew at the rate of 2.2% per annum from 1953 to 1994 but since 1994 there has been no significant growth in TFP and since 2000 when drought condition became particularly severe, the rate of growth of TFP was -1.2% per annum (Sheng et al. 2010) In examining possible reasons for these changes, it was found that while poor climatic conditions over the 2000s decade were an important contributor, the slowdown in public investment in R&D since the 1970s (discussed further below) had also made a significant contribution.

TFP and terms of trade

Changes in TFP can be compared with changes in the terms of trade faced by farmers 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, while the terms of trade declined for about 40 years from 1953 (Figure 3), since the early 1990s the rate of decline has been much slower. While the TFP index grew from 100 in 1953 to 268 in 2009, the terms of trade index declined from about 355 to 100, at a rate of 2.2% per year over the period 1953 to 2009. This decline was faster than the rate of productivity growth in broadacre agriculture. The rate of decline in terms of trade was 2.6% per annum from 1953 to 1990, but over the period from 1990 to 2009, it slowed to 1.1% per annum. Rates of productivity growth for the corresponding periods were 2.5 % and 0.1%.

Without the benefit of a decomposition of TFP back to 1953 (as outlined by O'Donnell and Hughes et al., 2011) it seems likely that because growth in TFP has largely been offset by the decline in the terms of trade, there has been little change in the profitability of the sector as a whole (from the equation above) and this may explain in part why the real value of agricultural production has hovered around the A$40 billion mark consistently for only the last decade. It may also be that the profitability of broadacre agriculture has declined, but is being offset in gross agricultural output data by stronger productivity growth rates in the non-broadacre sectors.

Correcting TFP measures for climate variability

Properly accounting for climate variability is critical to correctly assessing the relative importance of technical change and technical efficiency in Australian farm productivity data. Hughes et al. (2011) pointed out that unless climate variability (estimated using soil moisture data) was properly accounted for, the extent of technical inefficiency was likely to be overstated. Once adjusted for climate, the TFP growth series is less variable. It seems likely that were the series in Figure 3 adjusted for climate, it would have fluctuated more narrowly around the 250 level since about 1993 showing little growth since then.

Upon decomposing their adjusted TFP series, Hughes et al. (2011, pp. 35) found that for the period 1978 to 2008, climate adjusted TFP and TC (Technical change) for broadacre agriculture in Australia both grew at an annual rate of 1.53% with a decrease in technical efficiency of 0.31% exactly offset by a gain in scale and mix efficiency. However since 2000 climate adjusted TFP has only grown at a rate of 0.24%. Technical change has grown a little more strongly at the rate of 0.4% per year. This slowdown is consistent with Sheng et al. findings.

It is quite concerning, because it suggests that if climate variability has been fully accounted for, it is difficult to see how productivity growth will return to a rate anywhere close to 2% (as experienced from 1978 to 2000), especially given the continuing decline in public investment in agricultural R&D. The slowdown is more pronounced in western and northern regions as compared to the southern region (GRDC regions).

Moreover they found that since 2000 gains from technical change were offset to a considerable degree by a decline in technical efficiency. Together trends in these two measures mean that: 'while farms overall are improving, the average farms have not been able to improve at the same rate as the best farms' (Hughes et al. 2011, pp.34). Despite this declining trend, the level of technical efficiency across regions and farming types averaged 0.8 suggesting that Australian broadacre cropping farmers have been reasonably close to the production frontier.

The relative contribution of technical change and technical efficiency to productivity growth has potentially important policy implications with respect to the proportion of funds devoted to R&D (with the aim of shifting the production frontier) compared to extension (aiming to move more farmers towards the frontier). Hughes et al. found that while technical change made the largest contribution to TFP growth since 1978 (1.53%), the level of technical efficiency has been drifting down at the rate of -0.31% per year and this rate of fall becomes significant relative to the much smaller rate of technical change since 2000 (0.4%).

Having assessed past trends in broadacre TFP and its components, the focus turns to key issues that are likely to affect TFP in the future and the competitiveness of agriculture within the Australian economy and relative to the agricultural sectors in other economies. The set of issues reviewed here include the implications climate change might have for productivity growth, the importance of investment in R&D for productivity growth and external factors - such as trends in the terms of trade, the growth of the mining sector and the exchange rate - which are likely to influence the prosperity of agriculture in the period to 2030.

Implications of Climate Change for Agricultural TFP

Climate variability is a longstanding feature of Australian agriculture. As Crean et al. (accepted) pointed out 'farmers facing climate risk have to plan for a range of possible seasonal conditions other than the ones that ultimately occur. This means that farmers do not use resources as they would if climate conditions in the approaching season were known'. Lower productivity is one of the costs of uncertainty.

Climate variability and some underlying rate of climate change are already reflected in observed rates of TFP growth (Hughes et al. 2011). The observed rate of growth is lower than what might be expected if farmers were certain about coming seasons.

There remains a great deal of uncertainty not only about the extent of climate change at a regional level but about how climate change will translate into changes in the pattern and level of agricultural output. Kingwell (2006) found general agreement in the climate change science literature that temperatures were likely to rise across Australia – indicating a southward shift in temperate agriculture - but implications for rainfall were more uncertain with at least some regions likely to experience an increase. However in areas where rainfall increased, soil moisture availability was still likely to fall because of higher evaporation rates associated with higher temperatures. Kingwell (2006) pointed out that the impact of climate change will be revealed not just in altered production possibilities but also through changes in the demand for and supply of agricultural inputs and outputs.

It is not yet possible to determine the likelihood that these projections of rainfall and temperature change across various geographic locations will be realised. However a few climate change scenarios can be developed and their potential implications for farm productivity growth assessed. A first step is to think heuristically about the relationship between productivity growth and technical change. Figure 4 provides an illustration, abstracting from other sources of productivity growth. The dark blue line represents the unobserved rate of technical change made possible by investment in research. Simplistically, the other coloured lines represents a series of discrete climate change events, each one of which causes an immediate reduction in the absolute *level* of productivity before growth resumes at the same rate as the underlying rate of technical change. So starting at the origin TFP grows along the dark blue line until the first climate change event drops the level of productivity to the black line and then TFP growth resumes along the pink line until the next discrete climate event takes the level again back to the black line. The envelope of these discrete steps, the black line, is the observed rate of productivity growth.

Obviously the observed rate of productivity growth reflects not only technical change, climate change and farmers' adaptation to climate change but other sources of productivity growth. The rate of productivity growth at least to 2000 was relatively strong, indicating that the rate of technical was outpacing the rate of climate change. However the rate of productivity growth adjusted for climate variability has only been 0.24% since 2000 (technical change, 0.4%) (Hughes et al. 2011). Hence acceleration in climate change in coming decades may pose a real threat to productivity growth unless the rate of technical change also accelerates.

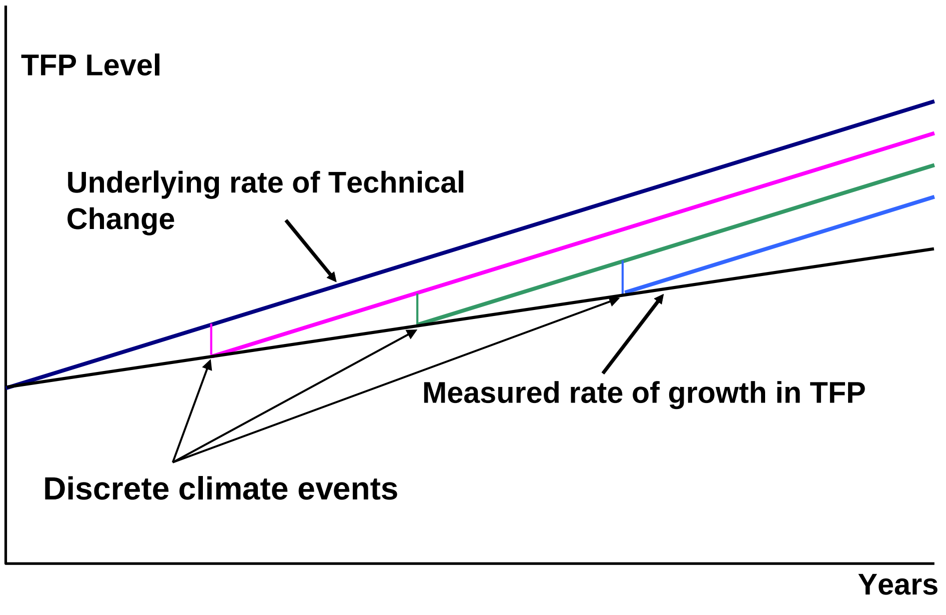

Figure 4: A conceptual model of how Climate Change impacts on TFP.

Heyhoe et al. (2007) assessed the potential impacts of climate change in productivity terms for major broadacre enterprises in a number of Australian regions using models partly based on ABARES' farm survey data. The scenarios examined included wheat, beef, sheep meat and wool in NSW and WA under low and high rainfall conditions. If climate change leads to higher rainfall then productivity is projected to increase in all cases. Low rainfall is projected to lead to decreases in the level of TFP especially for wheat which in 2030 is projected to be lower by 4.2% in NSW and by 7.3% in WA. Allowing farmers some ability to adapt to climate change reduces these losses by about half to 2.1% in NSW and 3.6% in WA.

It is instructive to focus on the low rainfall wheat scenario for NSW and to assess implications for the growth rate of productivity of this scenario. Setting the level of productivity at an index of 100 in 2007 and allowing it to grow at 2.0% per year means that by 2030 the index will be 158. If TFP is climate adjusted and so growing by only 0.4% per year[5] then the productivity index will be 110 in 2030. If the level of productivity in NSW wheat growing falls by 4.2 % by 2030 then the new levels will be 151 for unadjusted TFP growth and 105 for climate adjusted TFP growth. The rates of TFP growth leading to these new lower levels of productivity are 1.8% and 0.003%. If farmers adapt such that the decrease in the level of productivity is only 2.1% then by similar reasoning, TFP growth rates fall by a smaller amount to 1.9% and 0.003%. In a more recent paper Gunasekera et al. (2007) assumed a 17% decline in productivity in 2050 based on work by Cline (1992)[6]. Following Heyhoe, the decline in productivity in 2050 may be about 9% with adaption. Using the same procedure as above this translates into a decline in the rate of TFP growth from 2.0% (an index value of 234) to 1.8% (an index value of 213), a similar result to Heyhoe et al.

John et al. (2005) were more pessimistic estimating that profitability for WA farmers may fall by 50% (equivalent to a 50% fall in the level of TFP if the terms of trade are unchanged) under a climate change scenario they considered. The impact of climate change is expected to be larger in WA but John et al. pointed out that they did not allow for CO_2 fertilisation and only a limited degree of adaptation, both of which would reduce the projected climate impact.

In summary it seems that were TFP to continue to grow at the rate of 2% per year then the impact of climate change is projected to be relatively small, but if the rate of technical change is as low as 0.4% per annum then climate change is likely to largely offset any growth that occurs in TFP.

TFP and Competitiveness

Concepts of competitiveness

Part of the rationale for the strong interest in international comparisons of agricultural productivity growth relates to competitiveness. All other factors unchanging, increased productivity within a sector lowers real output prices and improves international competitiveness. As has been noted, 'Productivity growth is central to the performance and international competitiveness of Australia's agriculture sector' (Productivity Commission 2005).

Gopinath et al. (1997) pointed out that 'While productivity growth of a sector or an economy is vital to a country's standard of living, absolute productivity comparisons between countries, by themselves, provide no insights into competitive advantage' (pp.101). The authors suggested that what determines international agricultural competitiveness is the productivity of a country's agricultural sector relative to non-agricultural sectors compared with relative agricultural productivity in its major competitors.

[5] This is equal to the rate of technical change estimated by Hughes et al. since 2000 and so here the assumption is that in future, changes in technical efficiency and scale and mix efficiency cancel out as they did over the whole 1978 – 2008 period.

[6] It is not clear whether Cline uses a measure of TFP or partial productivity measures.

Defined in this manner competitiveness is closely aligned with the concept of *comparative advantage*. The theory of comparative advantage suggests that a country should export goods and services that it is relatively more productive in creating, and import those goods and services that it is relatively less productive in creating.

The principal notion behind comparative advantage is the concept of 'opportunity cost'. In an economy-wide context, the opportunity cost of producing agricultural products is the value obtained from the employment of those same factors of production (land, labour, capital) in producing goods in another area of the economy. The challenge then is for the agricultural sector to use available factors of production more profitably than other sectors of the economy can.

Previously, Mullen and Crean (2007) reported that productivity growth in Australian agriculture, over the period 1975-99, had been up to 4 times higher than that in the rest of the economy, whereas in a selection of Organization for Economic Cooperation and Development (OECD) countries, it averaged about twice that in other sectors (Bernard & Jones 1996). Australian agriculture, while ranking 14th in the rate of agricultural productivity growth over the period from1970 to1987, had the third best ratio of agriculture TFP to non-agriculture TFP, suggesting the sector retained competitiveness over the period (Bernard & Jones 1996).

It is beyond the scope of this paper to comprehensively review prospects for the international competitiveness of Australian agriculture in the future, but assessing its performance relative to other sectors of the Australian economy is manageable. This can be done using data on productivity by sector for the Australian economy assembled by the ABS. The data are for a group of 12 sectors (referred to here as the *market group)* from 1986 to 2011.

	1986-1991	**1991-1996**	**1996 2001**	**2001-2006**	**2006-2011**	1986 -2011
			Growth rate in MFP (%):			
Agriculture, Fisheries Forestry	3.08	2.00	5.27	3.22	1.60	**3.0**
Mining	3.84	2.46	1.08	-4.14	-6.22	**-0.7**
Manufacturing	0.66	0.28	1.23	-0.32	-0.46	**0.3**
Communication	4.27	4.30	0.22	0.41	0.86	**2.0**
Market Sector	0.72	1.76	1.61	1.02	-0.59	0.9
			Ratio to Market Sector			
Agriculture, Fisheries Forestry	4.3	1.1	3.3	3.2	-2.7	**3.4**
Mining	5.3	1.4	0.7	-4.1	10.6	**-0.7**
Manufacturing	0.9	0.2	0.8	-0.3	0.8	**0.3**
Communication	6.0	2.4	0.1	0.4	-1.5	**2.2**

Table 1: ABS Estimates of TFP growth by selected sectors since 1986.

Source: Derived by the author from ABS (ABS 2011)

Productivity growth for the market group averaged 0.9% per year from 1986 to 2011 (Table 1). Productivity growth in the agriculture, fisheries and forestry (AFF) sector averaged 3.0% per year (3 times that for the market group) followed by the communications sector which averaged 2.0% per year (2 times the market group). It is noticeable from Figure 3 that whereas TFP growth in agriculture rebounded from about 2006, TFP growth in other sectors has declined. Up to 2006 the market group had been growing at an average rate of 1.3% per year.

This suggests that if productivity in the AFF sector continued to grow at 3 times the average of the market group it would likely remain competitive domestically. Such a rate of growth would also be likely to maintain competitiveness against the agriculture sectors of most OECD countries if the findings of Bernard and Jones (1996) still hold.

The marked difference between the ABS and ABARES measures of productivity warrant further comment. The ABS measure is for the Agriculture, Fisheries and Forestry (AFF) sector as a whole (as compared to broadacre agriculture for ABARES) and is a value added (rather than a gross value) measure of productivity. 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.

Were the ABS and ABARES measures covering the same set of industry sectors, the growth in the gross output TFP measure could be derived as the growth in the value-added TFP 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 partly explains the apparent stark differences between the ABS and ABARES measures however the strong performance of the AFF sector according to ABS data contrasts strongly with the negative growth of broadacre agriculture since 2000 revealed by the ABARES data. Even though the broadacre sector probably now only accounts for about 50% of agriculture as a whole, this divergence is unexpected (to the author at least) and hard to explain, requiring very high rates of growth in the other AFF sectors.

Mining and agriculture

Taking account of developments in the mining sector, however, it becomes apparent that while relative rates of productivity growth are important, they are not the complete story. From Table 1 the productivity performance of the mining sector has been poor, declining markedly since 2001. The ABS (2010) suggested some reasons for this poor performance including: (1) deteriorating quality of natural resource inputs, (2) lengthy time lags between the commencement of mining capital projects and formation of productive capacity; and (3) the entrance of less experienced workers into the mining industry. Perhaps with the industry in an expansionary phase there is also a risk that capital services flows may be overstated in a period of high capital investment (TFP understated) followed by a period of understatement once capital stocks are stable or declining (TFP growth overstated).

Yet despite this poor productivity performance, the mining sector has grown by a factor of 3.7 in GDP terms since 1975 (GDP increasing from A$23b to A$84b) whereas the AFF sector has only increased by a factor of 2.4 (GDP increasing from A$13b to A$31b) (ABARES 2010, Table 1). This suggests that in recent decades, AFF has become less competitive for resources with mining although not necessarily with other sectors. This accords with a steady stream of media stories about the difficulty agriculture has in competing for resources such as land, labour and water and about a ‘two speed’ economy, reflecting concern across other sectors.

The puzzle with respect to the relative performance of productivity in the agriculture and mining sectors can perhaps be resolved by reference to the relationship between profitability, productivity and the terms of trade that is discussed above. Profitability (and hence GDP) is also driven by the terms of trade. ABARES do not publish a terms of trade index for the resources sector as it does for the farm sector. However since 2000 the price of iron ore has risen by a factor of 3, the price of coal by a factor of almost 2 and metal prices have risen even more strongly (see also World Bank data in Table 2). In contrast the ABARES index of agricultural prices received has only grown by about 20% from 2000 to 2010.

The relationship developed by O'Donnell presented above can be adapted in the following way:

$$\frac{PROF_A}{PROF_M} = \frac{TFP_A}{TFP_M} \cdot \frac{TT_A}{TT_M}$$

where A is agriculture and M is mining.

The profitability of agriculture relative to mining improves if TFP grows more rapidly in agriculture, as has been the recent history and declines if the TT in agriculture declines relative to that in mining, as has likely been the recent history.

The difficulties posed for other sectors of an economy when one sector, such as the mining sector, grows quickly are well known. Gregory (1976) pointed out that rapid growth in the mining sector leads to an appreciation of the Australian dollar (and/or domestic inflation) and a decline in the price of internationally traded goods relative to non-traded goods. (Since Australia is a price taker in most markets, an appreciation of the Australian dollar likely results in a fall in the Australia dollar price of, say, wheat.) This change in relative prices of traded and non-traded goods is reflected in a decline in the relative terms of trade between agriculture and mining and hence in the relative profitability of agriculture.

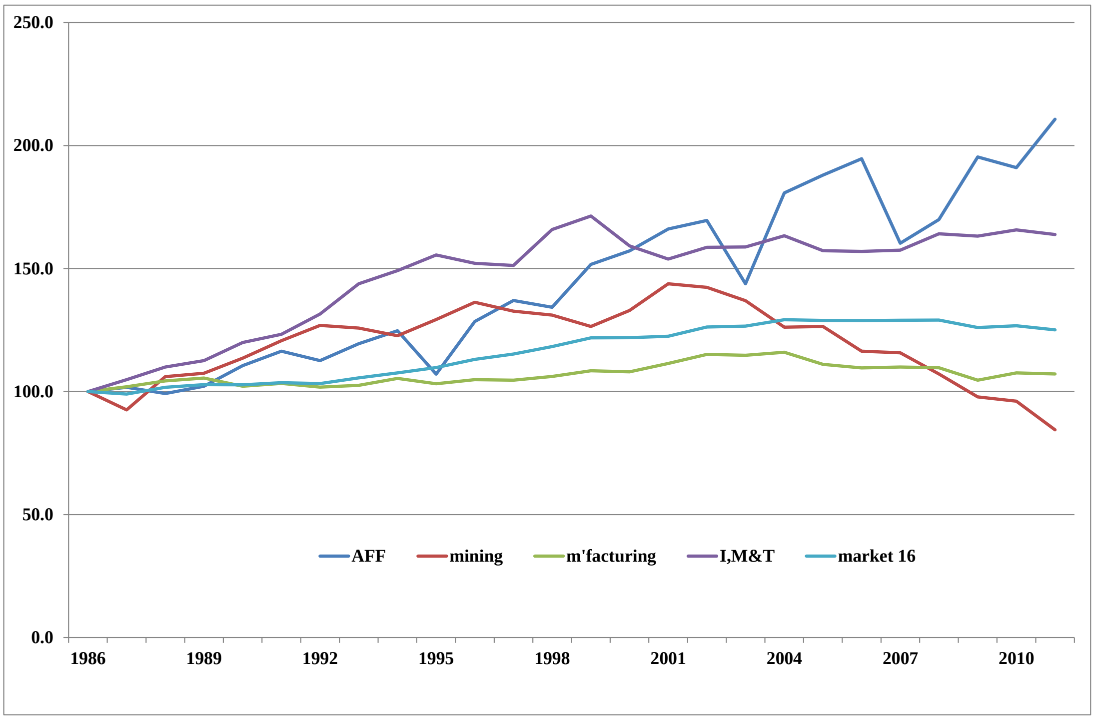

Figure 5: Trends in TFP by selected sectors since 1986.

Source: Derived by the author from ABS (ABS 2011)

Agriculture is also in competition for resources with the environment 'sector'. The fact that environmental service flows are not traded in traditional markets means that conventional measures of GDP, productivity and terms of trade are unavailable for the sector. Perhaps it can be inferred from the growing concern over recent decades about environmental flows that the TT in the environment sector is rising more quickly than agriculture. For the environment sector to be making efficient use of resources, decisions to protect or enhance environmental assets (by various means) ought to be based on some understanding of the opportunity costs from society's viewpoint of diverting resources to the environment.

Future prospects for commodity prices

The trend in the relative prices of agricultural and resource commodities will have important implications for the competitiveness or profitability of agriculture in 2030 through their impact on TT (with further implications for scale and mix efficiencies as seen above).

Professor Pinstrup–Andersen (2012) reviewed the current debate about global food security including projections of rising food prices by the FAO and IFPRI. He concluded that while price volatility is likely to continue, real food prices need not rise providing governments refrain from altering price signals for short term political gain and invest in infrastructure past the farm gate to encourage farmers to exercise a latent capacity to increase production.

As already noted the prices of resources such as iron ore and coal have been rising steeply driven by the fast growing economies of China and India. However it seems likely that commodity prices may decline from their high levels in 2012 as demand slows and supply improves with new capacity coming on line (World Bank 2012b). The World Bank's (2012a) longer term projections have both agricultural and resources prices (in real terms) falling out to 2025. Coal and iron ore prices are projected to decline by 20% and 27% respectively which should temper Australia's rising exchange rate. Wheat and meat prices are expected to decline more slowly by 16% and 14%. These price data are not terms of trade data but in terms of the equation above, a likely prospect seems to be that the trend in the relative terms of trade facing agriculture and resource commodities may have little impact on their relative profitability and may even slightly favour agriculture.

		actual real prices		projected real prices	
		1980	2011	2012	2025
Coal	$/mt	52.7	98.4	102.2	51.4
Crude oil	$/bbl	48.4	84.6	83.7	65.1
iron ore	$/dmt		136.5	127.8	93.6
copper	$/mt	2,863	7,181	7,241	5,288

Table 2: World Bank price projections for selected commodities (2005 A$US).

Source: Derived by the author from World Bank (2012a)

The Relationship between Research and Development and Productivity in Agriculture

The Productivity Commission (2011) now accepts that investment in agricultural R&D in Australia has made a significant contribution to agricultural productivity growth. The original econometric analysis for broadacre agriculture by Mullen and Cox (1995) estimated that from 1953 to 1988 the *rate of returns* from public investment in R&D had been in the order of 15 – 40%. The most recent updating of that analysis by Sheng et al. (2011), using a longer dataset, accounting for foreign 'spill-ins' of technology and a research strategy adapted from Alston et al. (2010), estimated a rate of return of nearly 30% from their preferred model. The analysis also confirmed that there are long lags of the order of 35 years from the commencement of research and when its impact becomes small

These aggregate econometric studies are also consistent with the many reputable benefit cost analyses at a project level conducted in Australia by state departments of agriculture and by private consultants for the Research and Development Corporations (RDCs). Much of this material is referenced in the recent report from the Productivity Commission (2011) and Mullen (2011). Prevailing high rates of return to research provide strong support for the long standing hypothesis that there remains some degree of underinvestment in agricultural research in Australia.

Despite this strong evidence of the contribution of public R&D to agricultural productivity growth, public support for R&D has been declining since the 1970s. The way in which the data on R&D investment have been assembled from ABS sources and from a previous dataset developed by Mullen et al. (1996) is described in Mullen (2007). Expenditure was attributed to research providers, rather than funders. As a result, expenditure by state departments of agriculture or universities, for example, includes funds obtained from rural RDCs. Attention was focused on the expenditures for *socio-economic outcomes*[7] related to farm production but investment in R&D for the fisheries, forestry, environment and processing of farm products socio economic objectives was not included. The GDP deflator was used to express investment in R&D in 2010 dollars.

Total public expenditure on agricultural R&D in Australia grew from A$146 million in 1952-53 to almost A$1,000 million in 2000-01 before declining markedly to A$716 million in 2008-09 (in 2010 dollars) (Figure 6). Expenditure growth was strong to the mid-1970s but has essentially been static since that time although there was a spike in investment in 2001. Likewise, agricultural research intensity, which measures the investment in agricultural R&D as a percentage of GDP, grew strongly in the 1950s and 1960s, but has been drifting down from about 4.0 -5.0 % of agricultural GDP in the period between 1978 and 1986 to about 3.5 % in recent years (as compared to 2.4 % per annum in developed countries). Private sector investment in R&D has been rising but Keogh et al. (2011) finds that private sector R&D investment is complementary to public sector R&D investment in Australia, rather than a substitute.

As already noted Sheng et al. (2010) found that this slowdown in R&D investment (along with poor seasonal conditions) contributed to the slowdown in broadacre TFP growth. This slowdown is a response to recent decades of stagnant public sector R&D investment, and the long time-lags associated with returns to such investment noted above.

Despite this finding and the consistent findings of high returns to agricultural research investment in Australia, public investment in agriculture remains under threat with the recent PC (2011) report recommending a halving of the RDC levy because it doubts that the matching grant has called forth much additional research from industry[8]. It expects that were the government to reduce the Gross Value of Agricultural Production (GVAP) cap for a matching grant to 0.25%, the RDCs would increase their levies to offset this reduction. In other words the PC holds the view that public sector is ‘crowding out’ industry investment.

[7] As defined by the ABS classification of R&D activities

[8] The PC argument is also based partly on a contested assessment, not pursued here, that public support for agricultural research is much higher than for research in other sectors.

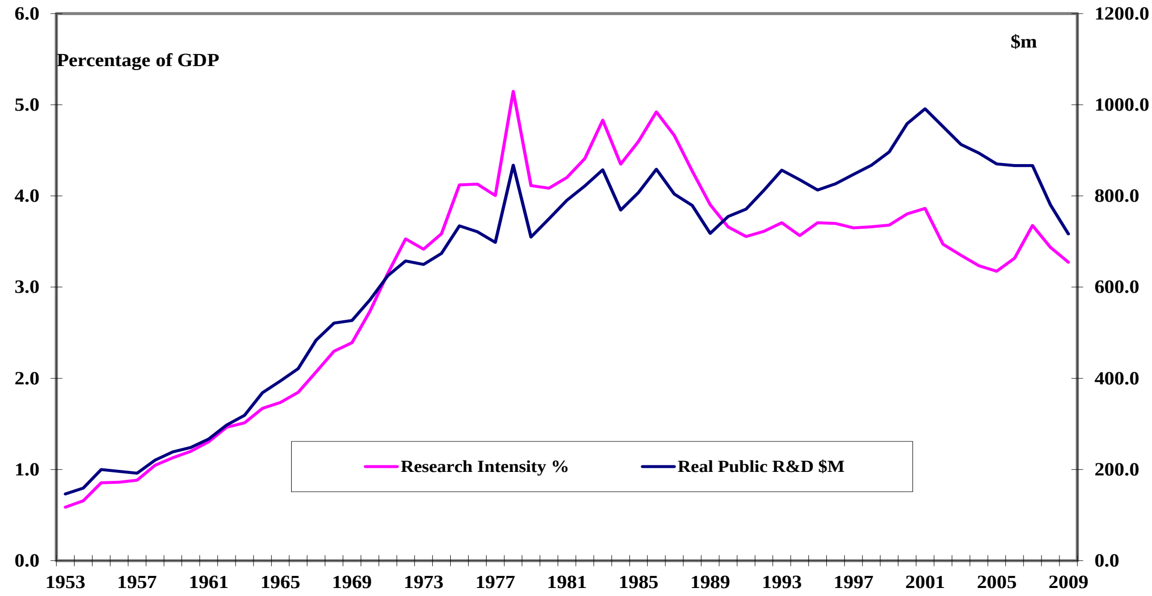

Figure 6: Real public investment and research intensity in Australian agricultural R&D

Source: Derived by the author from various public sources including ABS R&D data

Mullen (2011) reviewed the ‘crowding out’ hypothesis and suggested that such a scenario would most likely be typified by low rates of return to research and pressure to reduce levy rates. Observed high rates of return are only consistent with crowding out in the unlikely scenarios of either sharply diminishing returns to future research and/or constraints on the supply of research services. The PC provides little empirical evidence to support their recommendations.

Moreover there seem to be good reasons why RDCs will face resistance to increases in R&D levies. It should not be surprising that farmers understate their true willingness to pay for research under the common uniform levy of the RDC model (see Alston and Fulton, 2012). Remaining incentives to ‘free ride’ are complemented by heterogeneity in the resource endowment of farms and in the applicability of particular technologies. In addition the long lags in the development of new technologies may be a disincentive to increasing levies. This disincentive arises not only because farmers may not receive any benefits in their working life but more likely because they do not appreciate the contribution to their present farming system of past research efforts nor foresee how present research efforts may change farming systems decades hence. Some of these arguments are noted in the PC report. The PC also argued for a stronger culture of impact assessment within research institutions so that stakeholders could be persuaded of the benefits from their investments and research funds be allocated to higher returning activities.

Sheng et al. (2011, Table 7, pp.34)) examined the consequence for productivity growth under various scenarios about the future funding of R&D. Their scenarios were based on real public investment in agricultural R&D in 2007[9] and the elasticity of TFP with respect to research knowledge stocks. One scenario involved increasing research investment permanently by

[9] note the heading in their Table 7 is somewhat misleading

10% (A$170m) from 2008 and assuming that the growth rate for TFP started at its long term average of 1.96%. Given the long lags, it is not surprising that the growth rate in agricultural TFP only increased to 2.02% for the period to 2020. Only when lag effects to 2050 were accounted for did the long term growth rate average 2.09%, which remains a small response.

Since 2007 public investment has fallen by about A$150m in real terms which is close to a decrease of 10%. Were this to be a permanent decrease then it might be expected the rate of growth in TFP to be less than 1.9% per annum.

Sheng et al. also examined scenarios where R&D was maintained at 3.1% of the Gross Value of Agricultural Production (GVAP) (the level of research intensity[10] attained in 1978). Under this scenario (based on ABARES projection of GVAP to 2015), TFP growth might be expected to increase to an average rate of about 2.4% per year once the long lag effects began to be of influence (after 2020). However, such a R&D intensity would have implied an important increase of the level of R&D investment (from A$866 million to A$1.245 million in 2007 and from A$717 million to A$1,299 million in 2009). Hence it would seem that to achieve a growth in TFP approaching 2.5% per annum, domestic investment in research has to be increased to over 3.0% of GVAP, quite a reversal to the trend over the last 3 decades.

The other issue to be resolved is how this level of investment is to be shared between the public purse and the industry through the RDCs.

Data on public and private expenditure on extension services are scarce. Mullen et al. (1996) derived a series by applying budget shares derived from management information systems used by the State Departments back in the 1990s to total expenditure by the Departments. These budget shares have never been updated and so the confidence bounds around the updated series on extension used by Sheng et al. (2011) are larger. Nevertheless it is highly likely that public expenditure on extension has fallen at least as much as expenditure on R&D. The nature of public extension services has also changed markedly to the extent that advice tailored to particular farms is now rarely available. There has been a marked increase in the private extension services through consultants and agribusiness firms but the level of expenditure associated with this is unknown.

Hughes et al. (2011) noted a decline in technical efficiency (although the level of technical efficiency remained high) and the estimates by Sheng et al. (2011) suggested that the returns from investment in extension were higher than those from R&D. Hence some may argue that a larger proportion of public funds be diverted to extension at the expense of R&D. I don't share these views. Arguments about market failure in the provision of extension are harder to make than in the provision of R&D. Perhaps RDCs should continue to closely monitor how private extension services interact with public (and private) research services and encourage farmers to see extension services as another farm input to be acquired where expected benefits exceed costs.

Conclusions

The intention in this paper has been to assess what rate of productivity growth will be required in the period to 2030 for Australian agriculture to remain competitive both within the Australian economy and relative to the agricultural sectors of other countries.

The competitive position of Australian agriculture is influenced by a range of factors including its own growth in productivity and the terms of trade it faces. External factors such

[10] Not research intensity here is defined in terms of the gross value of agricultural production rather than in terms of agricultural gross domestic product. The GDP measure in 1978 was 5.1%, also a maximum.

as productivity growth and the terms of trade in other sectors of the Australian economy and in other economies are at least as important. The uncertainty about future trends in these various factors influencing agriculture's competitiveness makes it impossible to judge with any degree of confidence the rate of productivity growth that agriculture should be aiming for.

Mullen and Crean (2007) have previously observed that productivity growth at a rate of 2.0% since the 1950s until about 2000 was strong relative to other sectors of the Australian economy and the agricultural sectors of OECD countries, and this has been confirmed above at least for the Australian sectors. Much of this growth in TFP has come from technical change which, driven by R&D, shifts the production frontier outwards. It has been highly variable because of climate variability

Few other Australian sectors and few other agricultural sectors have maintained a rate of growth in this 2.0 – 2.5% range over long periods. Hence, a conservative approach might be to accept that this range is as much as could be realistically expected and to consider threats to Australian agriculture continuing to perform at this level. A growth rate of 2.0% (2.5%) would mean that output would double between 2012 and 2047 (2040).

It is most concerning that growth in agricultural productivity has certainly slowed since 2000 but perhaps from as far back as 1994 (Sheng et al.). Since 2000 productivity growth has actually been negative. Simultaneously productivity growth in the Australian economy also slipped to very low levels and was negative between 2006 and 2011.

Hughes et al. developed a measure of broadacre cropping TFP adjusted for climate variability. By this measure, growth in TFP between 2000 and 2008 was 0.24% per year with the rate of technical change faring a little better at 0.4% per year. It is tempting to think that now that a more normal run of seasons has returned, TFP growth will again resume this long term 2.0% rate. However evidence (Sheng et al. and Hughes et al.) that the decline in growth is not due to climate alone is strong.

It seems most probable that a significant proportion of this slowdown in growth can be attributed to the stagnation in public investment in agricultural R&D since the late 1970s and the more marked decline in recent years. This decline in investment has occurred despite strong evidence that the returns to research have been high and that the lag between investment and impact on productivity is high. Moreover high rates of return seem more consistent with a hypothesis that there is market failure in the provision of research services to agriculture than with the alternative view that public investment is 'crowding out' investment by industry.

This suggestion that the rate of growth of TFP could stay at less than 1.0% rather than recover to a long term rate of 2.0% is obviously quite concerning for the future competitiveness of agriculture both domestically and internationally. It would seem that to maintain TFP growth in the 2.0 – 2.5% per year range, investment in agricultural R&D has to be returned to a level of 3.0% of agriculture's GVP (or 5% of GDP), a major challenge for government and industry. It seems likely that this rate of growth is required to maintain agriculture's competitiveness with other sectors in the Australian economy and with the agricultural sectors of other countries.

Other sources of productivity growth such as technical efficiency seem unimportant relative to research driven technical change. Most empirical work suggests that Australian farmers are operating close to the production frontier although Hughes et al. suggest a drift away from the frontier in recent years. While climate change offsets productivity growth, its impact would be reduced if TFP growth were to resume a 2% per year trajectory.

Perhaps a recovery in productivity growth in the rest of the economy will also boost agricultural productivity. Measures of technical change (and TFP) in agriculture also pick up sources of productivity growth in the economy at large such as gains in infrastructure, telecommunications, microeconomic reform and education. These links have not been explored empirically.

Whether growth in productivity in the 2.0 – 2.5% range is sufficient to maintain agriculture's competitiveness depends on trends in productivity and prices in other sectors of the Australian economy and in other countries.

The mining sector is of particular interest because the surge in demand for resources has seen the sector expand rapidly and the exchange rate has appreciated markedly. While productivity growth in agriculture has to date been much stronger than that in the minerals sector, the relative terms of trade between the sectors has almost certainly favoured the minerals and energy sectors.

Looking to the future, productivity in the mining sector may well grow strongly once this current period of rapid investment slows down. However the World Bank forecasts that prices of agricultural, mineral and energy commodities are all most likely to decline out to 2025 from their present high levels and perhaps agricultural commodity prices may decline a little less than the prices of other commodities.

The relative profitability of the agricultural sector vis a vis the minerals sector, its competitiveness in other words, depends on relative changes in the terms of trade and in the rate of productivity growth. If there is little change in the relative terms of trade in coming decades then the key driver of productivity growth in agriculture is likely to be R&D induced technical change. While not ignoring other sources of productivity growth, a return to past rates of investment in research, whether funded from public or industry sources seems crucial to maintaining the high rate of productivity in agriculture relative to other sectors of the economy.

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