FARM MANAGEMENT IN THE 21^{ST} CENTURY

Mullen, J.D.

NSW Agriculture, Head Office, 161 Kite Street, Orange, NSW 2800

Abstract

A key element of an agenda for farm management in the 21^{st} Century should be productivity on farms. The gains from productivity since 1953 have been enough to offset declines in the real price of farm outputs at least in the broadacre sector. Productivity gains will remain important to the sector in this century. For public institutions, the focus of research and extension activities will continue to switch to the management of natural resources. Farmers and policy makers will need to know the on-farm impacts of technologies and policies that will effect resource stocks over many years. A challenge to farm management professionals will be how to present this information, derived from sophisticated modelling, to farmers and policy makers. My guess is that Malcolm's 'few figurings' of a 'few futures' is the way to go.

Keywords: Productivity, Farm Management, Technical Change

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With the usual caveat, people who have contributed to the ideas in this paper include Phile Knopke, Gary Stoneham and Julian Alston. I also benefited from presenting an early version of this paper to a seminar in NSW Agriculture. When talking about farm management who knows the extent to which one is unconsciously influenced by Makeham and Malcolm. The views expressed here are those of the author and do not reflect the views of NSW Agriculture.

FARM MANAGEMENT IN THE 21ST CENTURY

Introduction

The Industry Commission in the Foreword to its recent report '*Assessing Australia's Productivity Performance',* said that 'productivity growth is the key ingredient in promoting sustainable economic growth and improving the material living standards of Australians'. It estimated that 'productivity growth has accounted for about two-thirds of the increase in Australians' average real incomes over the past three decades and about half the increase in Australia's output'. Nevertheless the Commission found that until recently Australia's rate of productivity growth of about 1.5 percent per year compared poorly with other OECD countries.

In thinking about an agenda for farm management in the 21st century, I have taken the unexceptional view that productivity will remain a key to the size and prosperity of the agricultural sector in Australia. In making this case I have started on familiar ground by reviewing past performance with respect to productivity, extending into more hypothetical scenarios about the contribution of R&D investments by public and private sectors in Australia to productivity growth in agriculture. Then I speculate that the focus of research and extension activities in public institutions is likely to remain related to the management of natural resources in ways that are profitable to farmers and meet community expectations about environmental outcomes. An important challenge for farm management professionals will be in presenting the results of the sophisticated modelling exercises necessary to address complex natural resource management issues in a way that is transparent to farmers, their advisers and policy makers. Finally I raise a concern that despite the longstanding misgivings of economists, there will continue to be a leakage of limited industry R&D resources to alternatives such as off-farm processing, promotion and business management skills which are unlikely to be as profitable as R&D directed to enhancing farm productivity.

Clearly these issues do not exhaust the agenda for farm management in the 21st century. There is a parallel session at this Conference on natural resource management with obvious implications for farm management. I have also ignored disciplinary issues like risk and dynamics and the increasingly sophisticated farm modelling being undertaken. I have only made passing reference to these issues. I have chosen to address areas where I have a little more experience if not expertise.

A Review of Estimates of Productivity Growth in Australian Agriculture

In the next section of this paper some simple arithmetic is used to estimate the value of gains in productivity since 1953. This analysis is based on assumptions about the rate of productivity growth. Hence the objective in the review of productivity studies in this section has been to settle on reasonable assumptions about trends in this parameter. Most of the studies relate to broadacre agriculture. Only the studies by Males et al. and by the Industry Commission relate to total Australian agriculture.

Measures of productivity relate outputs to inputs. Many are partial, relating one output to one input, yield per acre or milk production per labour unit, for example, and are limited in the extent to which they explain changes in output because generally the contribution of other inputs is not held constant. More useful are total- or multi-factor measures of productivity growth although these also are partial in the sense that all inputs (and outputs) are not included. Unpriced environmental inputs and outputs and changes in the quality of conventional inputs and outputs are often not explicitly measured and accounted for.

ABARE has had a longstanding, if somewhat intermittent, interest in measuring productivity in Australian agriculture. The earliest studies, reviewed by Lawrence and McKay (see also Paul and Jarrett and Lindner) were conducted in the early 1970s (going back several decades) but the first study using a 'modern' measure of total factor productivity was that by Lawrence and McKay[1]. They used a Tornqvist-Thiel total factor productivity (TFP) index. This remained the standard approach in Australia until Mullen and Cox, following Diewert's recommendation, used the Fisher index to measure productivity[2].

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[1] Modern in the sense of being based on a locally flexible functional form that can be interpreted as giving a second order approximation to an arbitrary production function.

[2] The Tornquist-Theil index fails the factor reversal test which states that the product of the price index and the quantity index equals the ratio of values over the period for which the indices are constructed (Diewert, p222).

Most studies of productivity in Australia have used ABARE farm survey data. ABARE has been collecting farm survey data since 1952-53. In that time the target population for the surveys has been broadened from the Australian sheep industry, defined to include all farms carrying at least 200 sheep, to those engaged in broadacre agriculture in Australia, as covered by the Australian Agricultural and Grazing Industries Survey. More information about the extent of the surveys, the methodology used and the definition of variables can be found in several papers by ABARE staff (Paul; Beck, Moir, Fraser and Paul; Knopke; Males et al.; Knopke, Strappazzon and Mullen). A crucial issue in assembling series on input use has been how to value the annual flow of services from capital in the form of land, machinery and livestock. In broad terms this flow of services has been estimated as the sum of an opportunity cost of capital, and allowances for depreciation and repairs and maintenance. Measures of inputs and outputs are on an average per farm basis. The dataset can be stratified in a number of ways including by region, state, size and enterprise specialisation. However survey data are subject to sampling error which increases with the degree of stratification.

The focus of the early studies was on the productivity in the Australian sheep industry. Given the pervasiveness of woolgrowing, this measure most likely provided a good measure of productivity growth in broadacre agriculture in Australia. As ABARE farm surveys broadened in focus to different industry classifications, so measures of productivity for specialist growers in the main broadacre enterprises became available. However apart from the dairy industry (Knopke), there are few estimates of productivity for farming systems outside broadacre agriculture or for agriculture in aggregate, as far as I am aware.

An alternative approach used by Males et al. and the Industry Commission for Australian agriculture and by Ball et al. and Acquaye, Alston and Pardey in studies of productivity in US agriculture is to use estimates of total outputs and inputs at State and Federal levels[3]. A variant of this gross output approach is a value added (by the agricultural sector) or gross product measure of productivity in which outputs less the value of intermediate inputs is related to inputs of labour and capital (see Males et al. for an application to Australian agriculture). This also seems to the approach of the Industry Commission although it was difficult to find a precise statement of how it measured multi-factor productivity.

Before reviewing past studies, I raise two issues that make interpretation of trends in productivity difficult, especially over periods of less than a decade. Long periods of drought obviously have an impact on the outputs from and inputs used in agriculture. Second, the difficulty of estimating annual service flows allied with the cyclical nature of capital investment means that an apparent trend in productivity may be the result of the timing of investment rather than of technical progress (Knopke, Strappazzon and Mullen). Paul suggested that there was likely to be an inverse relationship between productivity growth and the terms of trade facing farmers – as farmers invested in response to rising prices, productivity declined at least temporarily.

Review of the Males and Industry Commission Studies

As already noted, few estimates have been made of productivity growth in Australian agriculture at an aggregate level. Males et al. estimated that for the period 1971/72 to 1988/89 productivity of Australian agriculture in aggregate had grown at the rate of 2.0 percent per year on a gross output basis (the estimation method comparable to that used in the studies based on ABARE survey data) or 2.7 percent per year on a gross product basis.

More recently the Industry Commission estimated that productivity in Australian agriculture grew at the rate of 1.4 percent between 1970 and 1994. Recall that this is a gross product based measure of the productivity gains to labour and capital in agriculture which Males et al. argued gives a higher estimate of productivity growth than the gross output measure. This estimate by the Industry Commission is unexpectedly low. The Commission found that productivity growth in agriculture was

[3] In Ball et al. multilateral measures of TFP were used to ensure consistency between productivity estimates at state and federal levels.

low relative to other sectors of the Australian economy and low relative to the agricultural sectors in other countries, findings at odds with both the Males et al. study based on aggregate data and with the studies based on ABARE farm level data. Presumably the Industry Commission was aware of the wide literature on productivity that used the ABARE survey data but it chose neither to refer to this literature nor to explain this wide divergence in estimated rates of productivity growth.

Review of Studies Using ABARE Farm Survey Data

There have been a series of studies based on ABARE's farm survey data using TFP methods, initially in the sheep industry and then, more generally, into broadacre agriculture. These studies are summarised in Table 1. The observation period in Table 1 is in calendar year form but refers to the last half of the financial year. In addition to the estimate of productivity growth for broadacre agriculture, productivity growth for crop and wool specialists has also been listed when available, to give an idea of the variance in productivity growth. Several of these studies also give estimates of productivity growth for the high-rainfall, wheat-sheep and pastoral zones.

Earlier studies of productivity growth are summarised in Jarrett and Linder. The most recent of these studies was that by Roy Powell of the 1921 – 70 period. Estimates from these studies of average rates of productivity growth in Australian agriculture ranged from 0.6 percent to 1.7 percent.

In contrast, estimates of broadacre productivity growth from the more recent studies summarised in Table 1 are in the 2.2 to 3.1 percent range with the exception of Paul. Although cross-country comparisons should be made cautiously, an average annual rate of productivity growth of say 2.5 percent is larger than those reported by Thirtle and Bottomley (1992) for UK agriculture from 1967-90 and those reported by Alston, Chalfant and Pardey (1993, p.9) from several studies of US agriculture. Perhaps one explanation for Australia's higher rate of productivity growth is that, as noted by Pardey et al. Australia has had a high research intensity (defined as the ratio of research expenditure to agricultural GDP) relative to other OECD countries.

This apparent difference in estimated productivity growth between the ABARE based studies and the earlier studies raises the issue of whether productivity has been growing at a faster rate in recent decades. Long periods of atypical seasonal conditions and long investment cycles should make us wary about interpreting trends in productivity growth. Nevertheless there is some evidence that the rate of productivity growth has increased. Stoeckel and Miller suggested that 1968/69 was a 'watershed' year for agriculture noting that while output continued to grow, this year marked the time from which inputs actually declined. Their study only extended as far as 1980 and inputs have grown since but it is true that since then the rate of growth in inputs has rarely exceeded one percent.

Unaware of Stoeckel and Miller's declaration of 1968/69 as a 'watershed' year, Mullen and Cox divided their observation period data into three sub-periods -- 1953-68, 1969-84 and 1985-94. Growth rates for inputs, outputs and productivity for these three sub-periods are detailed in Table 2. Growth in output and productivity were low in the middle period but no doubt the severe drought in the early 80s contributed to this. During the most recent period, growth in inputs remained low and most gains in output came from productivity growth. Later studies reported in Table 1 tell a similar story.

Outside broadacre agriculture, the dairy industry is the only industry for which productivity studies have been conducted that I am aware of. The original study was by Knopke and this was updated by Males et al. Knopke estimated that productivity in the dairy industry grew at the rate of 1.5 percent per year between 1967/68 and 1982/83. Males estimated a rate of growth of 1.7 percent for the longer period to 1988/89 and speculated that the faster growth came from a return to good seasons and a continuing decline in measured inputs. Both studies found faster productivity growth in Victoria than NSW and argued that this reflected deregulation in Victoria that allowed farmers to save costs through seasonal milk production.

Scenarios about Productivity Growth in Australian Agriculture

I have accepted Stoeckel and Miller's view that productivity growth prior to 1968/69 was lower than has been achieved since. In the baseline scenario below I have assumed that productivity growth in Australian agriculture has been 2.5 percent per year since Stoeckel and Miller's watershed year of 1968/69 and from 1952/53 until that year, productivity growth was slower at a rate of 2.0 per cent per year (twenty percent lower). The evidence from the ABARE studies going back to the 1950s is mixed and differences may reflect different ways of assembling the capital input series. However, in very few of the earlier studies reviewed by Jarrett and Lindner did productivity growth exceed 2.0 percent.

These assumed growth rates are perhaps a little lower than those for broadacre agriculture. From the review above it is clear that the grounds to defend such an assumption are not strong. Males et al. found that productivity growth in agriculture was 0.2 percent slower than productivity growth in broadacre agriculture. Several studies by Knopke suggested that productivity in the dairy industry was lower than in broadacre agriculture and several studies have found that productivity growth achieved by extensive livestock specialists has been lower than for wheat/sheep producers but we know little about productivity in industries such as horticulture and intensive livestock industries.

An alternative scenario was to assume that productivity has grown at only half the rate assumed in the baseline scenario, as suggested by the very low rates of productivity growth in agriculture from the Industry Commission study. In this scenario I assumed a growth rate of 1.0 percent prior to 1968/69 and 1.25 percent since then.

Productivity growth also varies between States. Knopke, Strappazzon and Mullen reported broadacre productivity growth at a State level for the period 1977/78 to 1993/94 and Knopke has provided unpublished estimates of the same series extended to 1998/99. These estimates are presented in Table 3. With the exception of Queensland and South Australia there has been little change.

Table 3: Broadacre Productivity Growth Rates by State (%)			
	1977/78 – 1993/94	1977/78 – 1998/1999	Research Intensity %
New South Wales	2.8	2.7	2.3
Victoria	2.3	2.1	0.9
Western Australia	3.3	3.4	1.8
South Australia	4.1	3.3	1.4
Queensland	2.1	2.4	n.a.
Australia	2.7	2.6	n.a.

One reason for interest in productivity growth at a State level is that Mullen, Lee and Wrigley found significant differences in expenditure on research and extension activities at a State level which may explain differences in productivity growth. The ratio of expenditure on research and extension to the value of agricultural production in a state is referred to as research intensity and is a measure of the relative support given to research across States. Average research intensity since 1953 to 1998 is presented in Table 3 and shows marked differences among States[4]. The correlation between productivity growth and research intensity does not appear to be strong.

In the baseline scenario below I have assumed, again with little strong justification, that since 1968/69 productivity growth rates by State were as estimated by Knopke for the 1977/78 – 1998/99 period and that prior to 1968/69 they were twenty percent lower.

Valuing Gains from Productivity Growth in Australian Agriculture since 1953

Details of the gross value of agricultural production in Australia and by State (approximately a farmgate measure) can be found in Table 4. The nominal value of production has been deflated by the GDP deflator so that values are expressed in Year 2000 dollars. For Australia the real gross value of production has grown from $26b in 1953 to $30b in 2000. There has been little change in the value of output in NSW,

[4] These are averages and actual research intensities had converged considerably by 1998.

Victoria and South Australia while strong growth has been recorded in WA and Queensland.

Recall that the baseline assumptions about productivity growth are an annual rate of 2.0 percent up to 1969 and a rate of 2.5 percent from then until 2000. Output has grown at the rate of 3.5 percent per year on average over the entire period. Inputs have grown at the rate of 1.0 per cent to contribute to this growth in output but most of the growth in output, 2.5 percent per year, is accounted for by productivity growth. However the real prices of broadacre outputs (estimated from the data used by Mullen and Cox) have been falling at a rate of 2.7 percent per year (Figure 1) and hence the there has been little change in the real value of farm GVP in Australia (Figure 2).

The real value of productivity growth for Australia is detailed in Table 5 and graphed in Figure 2. It was estimated by applying the assumed rates of productivity growth to the real value of farm GVP and compounding these benefits forward. The heavily shaded sections of the bars in this graph represent the contribution of productivity to real output. Holding technology at its 1953 state, only thirty percent of the value of output in 2000 can be accounted for by conventional inputs. Seventy percent of the value of farm output arises from the various sources of productivity growth such as improvements in infrastructure, higher quality inputs, and new technologies from research and extension activities.

Compounding this stream of benefits forward to 2000 at a real interest rate of four percent gives an aggregate value of benefits to Australia of $1,097 billion. Similar calculations have been made for the States using the assumptions about productivity growth described above. If assumed productivity growth rates are halved, in line with Industry Commission estimates, the compound value of these benefits from 1953 to 2000 falls to $637 b. Halving the interest rate under the baseline growth rate assumptions reduces the compound value of benefits to $737 b.

The benefits of these farm level gains in productivity accrue to farmers, processors and consumers. How they are shared depends largely on the relative elasticities of demand and supply, providing the marketing chain is competitive. Alston and Mullen estimated that woolgrowers received about sixty percent of benefits from new farm technologies and this was based on their assumption that the elasticity of demand and supply of wool at the farm gate were both about 1.0. It is generally believed that, with the exception of wool, the demand for the major rural commodities in Australia is highly if not perfectly elastic. Most econometric studies find that supply is inelastic although this finding is a little difficult to explain. It seems likely then that Australian producers have captured about seventy percent of these gains in productivity – gains of about $700 b since 1953. The rest of the benefits go to processors and consumers, many of whom are non-residents of Australia. If two thirds of the value of farm production is exported then the gains to Australian processors and consumers may have been of the order of $100 b since 1953. Total benefits to Australia may have been in the order of $800 b.

Sources of Productivity Growth

Productivity growth is a residual, being that part of the growth in outputs not explained by the growth in inputs. Griliches referred to measures of productivity as measures of our ignorance. In general terms this residual arises because inputs and outputs have been mismeasured or omitted. One of the inputs not measured is the flow of services in the form of new technologies from the stock of knowledge built from public and private investments in research. However there are other sources of productivity growth including:

- Scale economies;
- Unmeasured changes in the quality of outputs of inputs;
- Changes in the use of unmeasured natural resources;
- Improvements in infrastructure such as roads and telecommunications.

These are briefly discussed before returning to technical change.

Knopke, Strappazzon and Mullen and Knopke, O'Donnell and Shepherd observed that productivity growth was faster on larger farms suggesting that some part of observed productivity growth may be coming from the trend towards larger farm size. Knopke, O'Donnell and Shepherd estimated that productivity growth on the larger grain farms had been about one percent higher than the smaller farms. The benefits of size may arise from greater efficiencies in the use of capital and of new technologies. On the other hand, Mullen and Cox found conflicting evidence about the nature and extent of returns to scale on broadacre farms which they were not able to resolve econometrically. They concluded that the impact of returns to scale on productivity growth was likely to have been small.

Productivity growth can be mismeasured if changes in the quality of inputs and outputs are not fully accounted for. A better educated workforce, for example, may not be reflected as an increase in labour input and the consequent increase in outputs is attributed to the residual, productivity growth. Conversely not accounting for higher quality outputs, in wheat for example, may mean that productivity growth is understated.

Changes in quality can be better accounted for as the degree of disaggregation of outputs and inputs increases. Acquaye, Alston and Pardey using a more disaggregated dataset than Ball et al. found that while productivity estimates for the U.S. as a whole were similar, significant differences were apparent at a State level. ABARE's farm survey data does not provide the level of detail to allow the degree of disaggregation evident in the US studies. There is no apparent way to judge the importance of this issue but it is likely that a significant proportion of changes in input and output quality are associated with technical change and hence with research activities. Extension activities may make an important contribution to the skills of the labour force.

Another sources of productivity growth is likely to have been from the depletion of natural resources. ABARE (Chapman, Rodriguez and Harrison; and Chapman, Samaranayaka and Harrison) has found some limited evidence that productivity growth is related to changes in the natural resource base. A longstanding but sometimes overstated criticism of TFP measures is that they ignore the depletion of natural resources used in the production of agricultural products. However yield losses, increased inputs such as fertilizers, and declining land values, associated with land degradation are reflected in measures of outputs and inputs. Against this, TFP measures do not capture the externalities imposed on the rest of the community by agriculture (although the externalities imposed on agriculture are captured).

There is much interest in developing measures of productivity (Repetto, 1996) and GDP (Solow, 1993) adjusted for resource use. In this spirit of accounting for degradation, Chisholm (1992) pointed out that one widely used estimate of the cost of degradation in the form of lost agricultural production was $600m per year in 1988/89 dollars which he translated into a farm level cost of around $4,800 per farm per year. Adjusting TFP by this estimate of the cost of degradation only reduced the growth in TFP by 0.1 percent although this does not account for the environmental costs to the broader community.

There are a number of other sources of productivity growth in Australian agriculture. Improvements in infrastructure, roads and telecommunications for example, are an important source of productivity growth but empirical estimates of this contribution are not available.

The Contribution of Technical Change to Productivity Growth

An important source of productivity and the subject of a large empirical literature, is technical change arising from research activities financed by public and private institutions in Australia and elsewhere.

Mullen and Cox, using conventional econometric methods, estimated that the rate of return from public sector investments in research in broadacre agriculture in Australia was in the range 15 to 40 percent per year. This estimate was supported by Cox, Mullen and Hu using nonparametric techniques. A note of caution came from Mullen and Strappazzon in the form of a finding that a cointegrating relationship did not exist between productivity growth, their estimate of service flow from investments in research, and other variables that might explain productivity. An attempt to synthesize the findings about returns to research from many studies in many countries using a meta-analysis approach can be found in Alston, Chan-Kang, Marra, Pardey, and Wyatt.

No attempt is made here to econometrically estimate the returns to research in Australian agriculture. However some assumptions have been made about sources of productivity in an attempt to provide some perspective about the size of the estimate of $1,100 b as the value of productivity gains since 1953.

Extending the dataset assembled by Mullen, Lee and Wrigley, the value of real investments in farm level agricultural research by public institutions in Australia (including much of that funded by RDCs) from 1932 to 1999 compounded forward to 2000 at a rate of four percent is estimated to be $55 b. By ABS estimates, the share of agricultural research by the private sector in Australia has always been less than 10 percent – say $5 b. CSIRO and the universities do very little extension and account for less than half of total agricultural research - $25 b. Extension is a major activity for State Departments and the ratio of extension to research spending has been about 40:60. Hence expenditure on extension is likely to have been in the order of $17 b. Hence total expenditure on research and extension may have been about $77 b in real terms between 1932 and 1999.

The most speculative issue remains the share of total productivity gains of $800 b to Australia that can be attributed to public and private research and extension in Australian agriculture ($77 b). If all is attributed to Australian research and extension then the benefit-cost ratio is a little over 10:1.

A significant source of technical change is that embodied in purchased inputs such as machinery, chemicals and fertilisers. While the inputs themselves may not be imported a large share of the embodied technologies were probably developed by U.S. or European firms. No doubt the innovating firms have been able to capture some of the benefits from the technologies they develop through the prices charged for inputs, particularly where there are few close substitutes. Nevertheless some of the measured growth in productivity arises from embodied technologies developed outside Australia.

It is likely also that some disembodied technologies developed in other countries have been adapted in Australia by public and private research institutions and by farmers themselves. The potential contribution to productivity growth of improvements in infrastructure, economies of scale and resource depletion have already been noted.

There is little empirical evidence to guide us in what share of productivity gains would be attributed to Australian public and private research and extension efforts. Brennan (Brennan; Brennan and Bantilan) has attempted to estimate the contribution of international centres to yield gains in the rice and wheat industries. He estimated that about two thirds of the gains in both industries could be attributed to the efforts of the international centres. In his Presidential Address at this Conference, Alston (see also Alston and Pardey, 2001) noted the incomplete nature of the empirical evidence but concluded that the evidence that is available indicates that more than half the productivity gains in many countries are attributable from technology 'spillins' from other countries. Note that other countries may gain from technologies developed in Australia but Australia doesn't capture these gains. In fact Australia's gains may be reduced lose if this leakage of technology causes world prices to fall.

A reasonable scenario may be that a third of productivity gains can be attributed to better infrastructure, higher quality inputs, resource depletion and economies of scale, one third comes from imported technologies and one third comes from local public and private research activities.

If the share of gains from Australian public and private research and extension activities is one third, then the value of these gains to Australians is about $267 b giving a benefit-cost ratio of 3.3:1. Recall that while expenditure from 1933 to 1998 is recognised, benefits from research activities only accrue from 1953 and are not recognised past 2000 – a conservative approach[5].

If productivity has only grown at rates suggested by the Industry Commission, then total benefits of $640 b translate to benefits to Australians of $510 b. The benefit-cost ratio is 6.4:1 if all gains are attributable to Australian research and extension and 2.1:1 if only a third are attributable to Australian research and extension.

[5] I have assumed that there is a 20 year lag before significant productivity gains emerge from research investments.

Implications for the Farm Management Agenda in 21st Century

So far I have concentrated on making the case that productivity gains since 1953 have provided significant benefits to Australia. In recent decades it has allowed output to grow at a rate approximating the decline in product prices without requiring an increased use of inputs. The relationship between the terms of trade for agricultural products and the rate of productivity growth will continue to be important for the size of the agriculture sector in Australia in the future. It seems most likely that despite some recent concerns about food security (Tweeten), the terms of trade for Australian farmers will continue to fall (Duncan). This seems particularly true for the second half of the century when world population is expected to decline (Tweeten)[6].

In view of the continuing importance of productivity growth, in the rest of the paper I would like to speculate about sources of technical change in the future and implications for collectively, that is RDC or publicly, funded research and extension activities in agriculture. In the interests of clarity and brevity I have omitted the obvious qualifications to some of the broad generalisations that follow. My view is that these qualifications will not alter the implications I draw but only if I have not misjudged their significance.

One of the issues that arises is the importance of 'knowing' the on-farm impacts of complex resource management technologies which have impacts over many years. This is important both to the adoption of new technologies and to the development of policy tools efficient in delivering environmental outcomes to the community. Closer to the topic of this session, it raises the question of type of farm management information and skills farmers require to make choices between complex resource management strategies and relates to Bill Malcolm's discussion of a 'few figurings' as the basis of decision making in his address to this session of our Conference in Sydney, 2000.

[6] The implications for Australian agriculture of a declining world population within 50 years should be high on a farm management agenda. I understand the RIRDC is supporting some research in this area.

The nature of technical change

Technical change comes in a variety of forms including higher yielding varieties of plants and animals, machines that allow more timely planting and harvesting, chemicals to enhance yields directly or indirectly through their control of pests and diseases, and scientific knowledge that allows improved management of farming systems to take advantage of interactions between components. Australian agriculture has benefited from technologies across this spectrum but it is surprising, at least to me, that we know little about the relative contributions of say, plant breeding as compared to the 'sub and super' technology. It is part of the attribution problem.

Looking to the future, the development of higher yielding plants and animals and technologies to protect them from pests and diseases will remain important. Biotechnology seems to offer great promise.

We often distinguish between embodied and disembodied technical change. This distinction is useful because it differentiates at least approximately, those forms of technical change for which it may be possible to protect intellectual property and hence reduce 'free-riding', from those forms of technical change that are likely to require collective provision by RDCs or public research institutions.

In the past in Australia much of the development of higher yielding varieties and of pest management technologies has been publicly funded and much has been imported either directly or indirectly through public research institutions (as already discussed). The growing ability to protect these technologies suggests that the role of Australian public research institutions in their development is likely to decline. Given the small size of the Australian agricultural sector it seems likely that a large proportion of these technologies will be imported with perhaps RDCs making investments to adapt them to Australian conditions.

However there will also be increasing requirements to understand the natural resource system of which agriculture is a part, both to allow farmers to profitably manage the flow of services from these resources and to meet the increasing expectations of the community with respect to environmental outcomes[7]. Perhaps we could argue that until recently much technical change involved input substitution where the impact on capital stocks of natural resources such as land and water quality were either small or not appreciated.

It seems to me that these management- or knowledge- based disembodied technologies will have to be provided collectively because it is difficult to exclude free riders and knowledge is non-rival in consumption. To the extent that these technologies have environmental consequences for the rest of the community, the public sector will have an incentive to invest and we are already observing quite a marked shift in research and extension resources to these areas. To the extent that these technologies allow farmers to more profitably manage resource flows through time, there will be an incentive for RDCs to invest in these areas and again, we are observe RDCs making such investments.

A theme of the paper, explored next, is that knowing farm level impacts is important both to promoting complex technologies and to developing environmental management strategies that recognise the incentives facing farmers.

Farmers follow self-interest

Despite the respectable rate of productivity growth historically, there seems to be a certain amount of angst that there are technologies on scientists' shelves that farmers are not adopting. Most recently, as discussed in Marsh and Pannell, there is concern at the low rate of adoption of landcare technologies.

With Jack Lang and Paul Keating, I remain faithful to the school that believes that people, including farmers, pursue self-interest and that there is nothing inherently reprehensible about this. There are many reasons why farmers do not adopt technologies but their expectations about profitability must rank highly. There is little need to repeat at length the case made by Marsh and Pannell and others that the community cannot rely on 'suasive arguments' to encourage farmers to adopt

[7] Randall Jones pointed to the growing importance of these dynamic issues.

resource management technologies that are not in their interest.

However the profitability of resource management technologies that have impacts across several enterprises and over many years because of their impacts on service flows from natural resources such as land, is often not obvious. Hence there is a need for increasingly sophisticated modelling of the impacts of complex technologies at the farm level. Where the focus of the technology is on farm level efficiency, those promoting the adoption of such technologies need to be able to demonstrate their impact on the welfare of farmers. Where the focus is on environmental outcomes, it is difficult to see how effective mechanisms of either a regulatory or market nature can be devised without some understanding of farm level impacts, or in other words, without an understanding of the incentives facing farmers.

A quick glance at the list of contributed papers at this Conference demonstrates the high level of investment by public sector agencies in modelling dynamic natural resource systems although the complementarities between farm and catchment scale modelling to establishing the value of externalities (as demonstrated by Quiggin) is perhaps not fully appreciated.

Farm management extension and training

How information from this sophisticated modelling is made available to farmers and policy makers is another issue that is perhaps important enough to make the agenda for the 21st century. It is not clear to me how results from complex models are best explained to farmers and policy makers. It seems to me that farmers are unlikely to take on faith answers from black boxes nor will it be in their interests to fully understand a dynamic programming model of soil acidity, for example. Bill Malcolm at this Conference two years seemed to be arguing for a 'few figurings' of some sensible scenarios in a whole farm context. My guess is that farmers, well aware of their uncertain environment, are happy to make choices between technologies if the science sounds logical and if a 'few figurings' presented in transparent whole farm budgets but based on more complex models which suggest that a profit can be turned. The skills farmers and extensions officers need, in my view, are to be able to identify the benefits and costs at least qualitative terms of the changes they are considering based on some understanding of the biology and to be able to use a 'few figurings' to get the relative magnitude of the key benefits and costs right.

No doubt there would be some benefits from farmers, their advisers and policy makers having better skills in identifying and assessing the benefits and costs of different resource management strategies but it seems to me that the present level of investment by state and federal departments and RDCs in areas such as business skills, benchmarking and decision support systems is disproportionate and could perhaps be better spent actually demonstrating to farmers to profitability of some of important technologies directly.

The concern by economists about investments in these areas is not new. Hardaker and Anderson queried the conventional wisdom that farms should develop their record keeping skills and Mauldon and Schapper criticised comparative analysis uncritically applied. Malcolm and Ferris asked for benchmarking to benchmarked. Marsh and Pannell provide a more recent critique of group methods and benchmarking. The slow rate of uptake of computer based decision support systems is discussed in McCown.

I have a number of concerns. Developing business skills of farmers and extension officers may have a pretty high opportunity cost particularly if the skills being developed are not relevant to the 'few figurings' required. In a past life I plead guilty to being bedazzled by 'many figurings'. As someone who works in a public institution, the other concern I have is that I am not sure that a strong case of market failure can be made in this area of business skills. Consultants and accountants seem to be in a position to provide both the skill and even the training.

Other Diversions from the Main Game

Having taken a fairly subjective swipe at the business management industry, it would be remiss of me not to give similar treatment to other types of investments that divert attention from what I view as the main game – enhancing productivity growth at the farm level. While agricultural research and extension organisations in Australia have used most of their resources to develop new, more-productive technologies for Australian farmers there always seems to be competition for limited R&D resources from alternative investments off-farm. Over the past three decades these alternatives have included (in addition to the farm business management/benchmarking area):

- Off-farm processing / value adding / niche marketing;

- Generic promotion;

I am not going to review each of these categories in any detail here but instead point to some of the research that cautions against accepting uncritically the view that investments in these areas are likely to provide greater returns than enhancing productivity in the farming sector. At the end of the day judgements remain subjective because the marginal rates of return from investments in these areas and in on-farm production research are not well known.

Mullen, Alston and Wohlgenant demonstrated that off-farm research and promotion investments in the wool industry had to return far more per dollar invested than farm level research because off-farm gains are shared to a greater degree with processors, wool growers and consumers many of whom were non-residents of Australia. Watson pointed out that ‘value adding’ generally also involves ‘cost adding’ (see also Cashin). Piggott queried the returns to growers from generic promotion. For many years woolgrowers were being levied 3.5 percent to fund promotion compared to 0.5 percent to fund research and as much as forty percent of the funds for research were used for research into post-farm activities.

A general if not universal criticism of the cases put for investments in these alternatives is that they fail to establish convincingly that there has been a failure by the market to deliver the outcomes desired by the industry. The criticism can be cast in a benefit-cost context as a failure to identify the most appropriate ‘without investment’ scenario (Marshall and Brennan). The correct without investment scenario is not that these investments would not be made but for the intervention of the public institution or the RDC. Rather, careful thought needs to be given to whether these investments would be made by others perhaps in a different form, at a different time and to a different degree. The net benefits of these investments are the benefits from the ‘with’ scenario of public or industry intervention less the benefits that would have flowed from investments made by individuals in the normal course of their business. As investments have more of the characteristics of public goods so the benefits from this ‘without’ scenario go to zero.

The view that traditional on-farm research activities are public or industry goods is widely accepted. Unless this research is undertaken collectively it is most probable that the level of investment will be too low from the perspective of the industry. In Australia the levy paying mechanism provides a means for the industry rather than the public purse, to fund research and extension activities that largely deliver industry benefits. Some argue that industry should be funding a larger share of on-farm production research.

In my view the case for market failure for the three broad categories of investment identified above is more difficult to make than for traditional on-farm research. Specific investments need to be scrutinised for market failure on a case-by-case basis.

Conclusion

In good company, I have made the unexceptional argument that on-farm productivity will remain an important item on the agenda for farm management in the 21st century. Productivity growth is an important source of income growth, allowing community and environmental goals to be met less onerously and allowing a still growing world population to be fed at similar real costs.

Assuming that productivity in Australian agriculture has grown at the rate of 2 to 2.5 percent per annum since 1953, I have estimated that the compound value of these gains in 2000 were about $1,100 b to Australians and others and about $800 b to Australia. This estimate does not include the cost of externalities imposed on the community by agriculture nor the external benefits from productivity gains in agriculture.

Some perspective on agriculture’s productivity performance can be gained by examining trends in the value of outputs and relating the value of productivity gains to investments in research and extension. I was surprised that in real terms there has been very little growth in the value of output since 1953. The value of agricultural production for Australia had grown by less than twenty percent and has actually declined in some States. This small growth in the real value of output reflects the quantity of output growing by about 3.5 percent over the period being almost completely offset by real output price falling by 2.7 percent (based on ABARE broadacre survey data).

Given the high proportion of output exported, growth in output is dependent on growth in exports. Exchange rates, influenced by productivity in other sectors such as the mining sector, and market access may be even more important determinants of export performance than domestic productivity. However Australia's export performance in agriculture would have been weaker had not agricultural productivity grown at this rate.

The sources of productivity growth include improvements in infrastructure, scale economies and any failure to properly account for improvements in the quality of inputs such as the skills of the labour force, and resource depletion, as well as new technologies. There is very little empirical evidence to assist in attributing productivity growth between these sources, Although it seems likely that at least half the gains from technical change are the result of research activities in other countries, including the international research centres.

I have examined a scenario in which productivity gains are attributed at the rate of a third to domestic, private and public research activities; international research activities; and residual gains from infrastructure, scale economies and resource depletion. In this scenario the benefits of productivity gains to Australians of about $267 b, when related to estimated expenditure on public and private research and extension in Australia since 1933, give a benefit-cost ratio of 3.3:1. If all the benefits to Australians are attributed to local research and extension, the benefit-cost ratio is 10:1. While these hypothetical scenarios support other empirical work suggesting that agricultural research and extension have been good if not exceptional investments for Australians, there seems little room for complacency about the rate of productivity growth in agriculture.

In the future it seems likely that the focus of public and RDC funded research and extension activities will be on the management of natural resource systems both to enhance the efficiency with which these resources are used by farmers and to better meet community expectations with respect to environmental outcomes. From both perspectives it will be important to be able to measure and demonstrate the impact of alternative resource management technologies and policies on the income of farmers. However, how the results of this modelling is communicated to farmers and policy makers seems to be another important item for the farm management agenda for the 21st Century. I have not pursued this issue fully here but my guess is that the answer lies not so much with developing the business skills of farmers but in presenting the results of good modelling in ways intuitively appealing to farmers using 'a few figurings' of a 'few futures' in Malcolm's terms.

Table 1: Estimates of Productivity Growth in Australian Broadacre Agriculture				
Authors	**Observation Period**	**Input Growth %**	**Output Growth %**	**Productivity Growth %**
Lawrence and McKay	1953 - 1977	1.5	4.4	2.9
Lawrence	1960 - 1977			3.1
Paul	1968 - 1982	1.5	2.7	1.1
Beck et al.	1953 - 1983	1.3	4.0	2.7
Males et al.	1978 – 1989			
• All agriculture				2.0
• All Broadacre		1.4	3.6	2.2
• Crops		-1.8	3.7	5.5
• Sheep		1.3	1.5	0.2
Zeitsch and Lawrence	1983 – 1994			
• Sheep				≈ 1.0
Mullen and Cox	1953 - 1994	0.1	2.6	2.5
Knopke, Strappazzon &Mullen	1978 - 1994			
• All Broadacre		0.2	2.9	2.7
• Crops		0.4	5.0	4.6
• Sheep		0.5	1.5	1.0
Knopke, O'Donnell and Shepherd	1978 – 1999			
• All Broadacre		0.7	3.3	2.6
• Crops		1.3	4.8	3.6
• Sheep		0.6	1.2	0.6

Table 2: Average Growth in Outputs, Inputs and Productivity (Fisher Index)

	1953-1994	1953-1968	1969-1984	1985-1994
Outputs (%)	3.5	4.5	2.4	2.6
Inputs (%)	1.0	2.5	0.6	0.1
Productivity (%)	2.5	2.0	1.8	2.5

Table 4: Real Gross Value of Agric. Production for Australia and States ($m in 2000)						
	Australia	NSW	Victoria	W.A.	S.A.	QLD
1953	25,897	8,769	6,481	2,212	3,111	4,574
1954	25,056	8,546	6,319	2,273	2,750	4,456
1955	23,640	7,424	6,363	1,995	2,566	4,458
1956	24,058	7,463	6,336	2,307	2,610	4,400
1957	24,827	7,924	6,296	2,103	2,969	4,736
1958	21,934	6,521	6,076	1,992	2,318	4,182
1959	24,426	7,682	6,290	2,244	2,722	4,652
1960	24,535	8,056	6,461	2,370	2,163	4,618
1961	24,778	7,659	6,713	2,404	2,645	4,543
1962	24,419	7,785	6,377	2,503	2,442	4,450
1963	26,634	8,635	6,839	2,590	2,611	5,084
1964	29,219	9,502	7,468	2,570	3,069	5,638
1965	28,665	9,507	7,508	2,470	2,998	5,230
1966	27,024	7,566	7,408	3,281	2,790	4,987
1967	29,639	9,545	7,413	3,195	3,138	5,344
1968	25,157	7,467	6,091	3,223	2,302	5,107
1969	28,667	8,845	6,715	3,393	2,963	5,738
1970	25,905	8,133	6,707	2,553	2,661	4,887
1971	23,550	7,021	5,957	2,928	2,263	4,491
1972	24,453	6,940	6,213	2,826	2,642	4,955
1973	28,000	8,683	6,769	3,228	2,875	5,391
1974	31,111	9,342	6,869	4,985	3,749	5,199
1975	24,449	6,886	5,342	3,519	2,948	5,105
1976	22,486	6,610	4,576	3,621	2,467	4,640
1977	22,056	6,831	4,494	3,122	2,318	4,619
1978	21,018	6,295	4,663	3,014	2,104	4,239
1979	28,744	8,635	6,035	3,764	3,045	6,201
1980	29,718	8,848	6,533	3,995	3,388	5,941
1981	26,691	7,067	6,370	3,877	3,038	5,544
1982	26,311	7,455	5,834	3,881	2,958	5,409
1983	21,885	5,523	4,823	4,105	2,232	4,424
1984	26,778	8,033	6,008	3,393	3,122	5,440
1985	25,911	7,296	5,420	4,434	2,749	5,228
1986	24,097	7,084	5,332	3,458	2,501	4,907
1987	25,252	6,989	5,873	3,766	2,710	5,086
1988	27,195	7,965	6,219	4,037	2,769	5,310
1989	28,649	8,458	6,242	4,548	2,707	5,571
1990	27,715	8,084	6,086	3,959	3,005	5,651
1991	24,055	7,302	5,322	3,085	2,158	5,386
1992	23,590	6,469	5,384	3,177	2,429	5,025
1993	24,245	6,414	5,741	3,434	2,539	5,248
1994	25,711	6,922	6,044	3,674	2,485	5,684
1995	25,598	6,427	5,547	4,161	2,656	5,895
1996	28,676	7,440	6,725	4,725	3,371	5,600
1997	29,078	8,553	6,276	4,344	3,061	5,877
1998	28,864	7,912	6,278	4,465	3,259	6,036
1999	29,484	7,885	6,440	4,376	3,310	6,515
2000	30,212	7,936	6,813	4,741	2,991	6,771

Table 5: Real Value of Productivity Growth for Australia and States ($m in 2000)						
	Australia	**NSW**	**Victoria**	**W.A.**	**S.A.**	**QLD**
1953	508	185	107	59	80	86
1954	973	358	207	119	140	166
1955	1,364	461	310	154	193	247
1956	1,832	611	409	235	258	322
1957	2,340	803	503	264	363	430
1958	2,457	785	578	296	336	451
1959	3,162	1,067	692	384	454	580
1960	3,595	1,266	806	458	407	652
1961	4,045	1,340	935	516	553	715
1962	4,387	1,498	979	589	560	771
1963	5,213	1,809	1,145	662	651	960
1964	6,180	2,149	1,353	708	824	1,151
1965	6,506	2,306	1,462	728	861	1,146
1966	6,543	1,956	1,541	1,028	853	1,166
1967	7,617	2,618	1,639	1,059	1,015	1,326
1968	6,831	2,162	1,425	1,125	785	1,340
1969	9,827	2,694	1,656	1,243	1,060	1,585
1970	9,296	3,098	2,093	1,155	1,178	1,698
1971	8,819	2,789	1,943	1,377	1,042	1,629
1972	9,530	2,867	2,113	1,378	1,262	1,872
1973	11,329	3,720	2,394	1,629	1,421	2,115
1974	13,040	4,144	2,521	2,596	1,914	2,113
1975	10,594	3,155	2,030	1,888	1,551	2,146
1976	10,054	3,123	1,797	1,998	1,335	2,014
1977	10,159	3,322	1,821	1,769	1,289	2,066
1978	9,958	3,146	1,946	1,750	1,200	1,951
1979	13,987	4,429	2,592	2,238	1,778	2,932
1980	14,833	4,652	2,882	2,428	2,023	2,883
1981	13,648	3,803	2,884	2,407	1,853	2,757
1982	13,767	4,103	2,707	2,458	1,841	2,754
1983	11,706	3,105	2,291	2,649	1,416	2,303
1984	14,627	4,608	2,918	2,229	2,017	2,893
1985	14,440	4,267	2,690	2,963	1,807	2,838
1986	13,689	4,220	2,702	2,348	1,672	2,716
1987	14,612	4,238	3,035	2,597	1,840	2,869
1988	16,016	4,912	3,276	2,825	1,909	3,049
1989	17,159	5,302	3,349	3,228	1,893	3,255
1990	16,870	5,147	3,323	2,848	2,130	3,356
1991	14,872	4,719	2,956	2,247	1,549	3,250
1992	14,804	4,241	3,039	2,343	1,766	3,079
1993	15,436	4,262	3,293	2,562	1,868	3,264
1994	16,597	4,661	3,519	2,772	1,850	3,585
1995	16,745	4,383	3,277	3,173	1,998	3,769
1996	19,000	5,136	4,030	3,640	2,563	3,627
1997	19,507	5,974	3,813	3,379	2,351	3,856
1998	19,595	5,589	3,864	3,506	2,527	4,009
1999	20,246	5,631	4,015	3,467	2,590	4,378
2000	20,977	5,727	4,301	3,789	2,362	4,602

Figure 1: Indices of Productivity and Prices

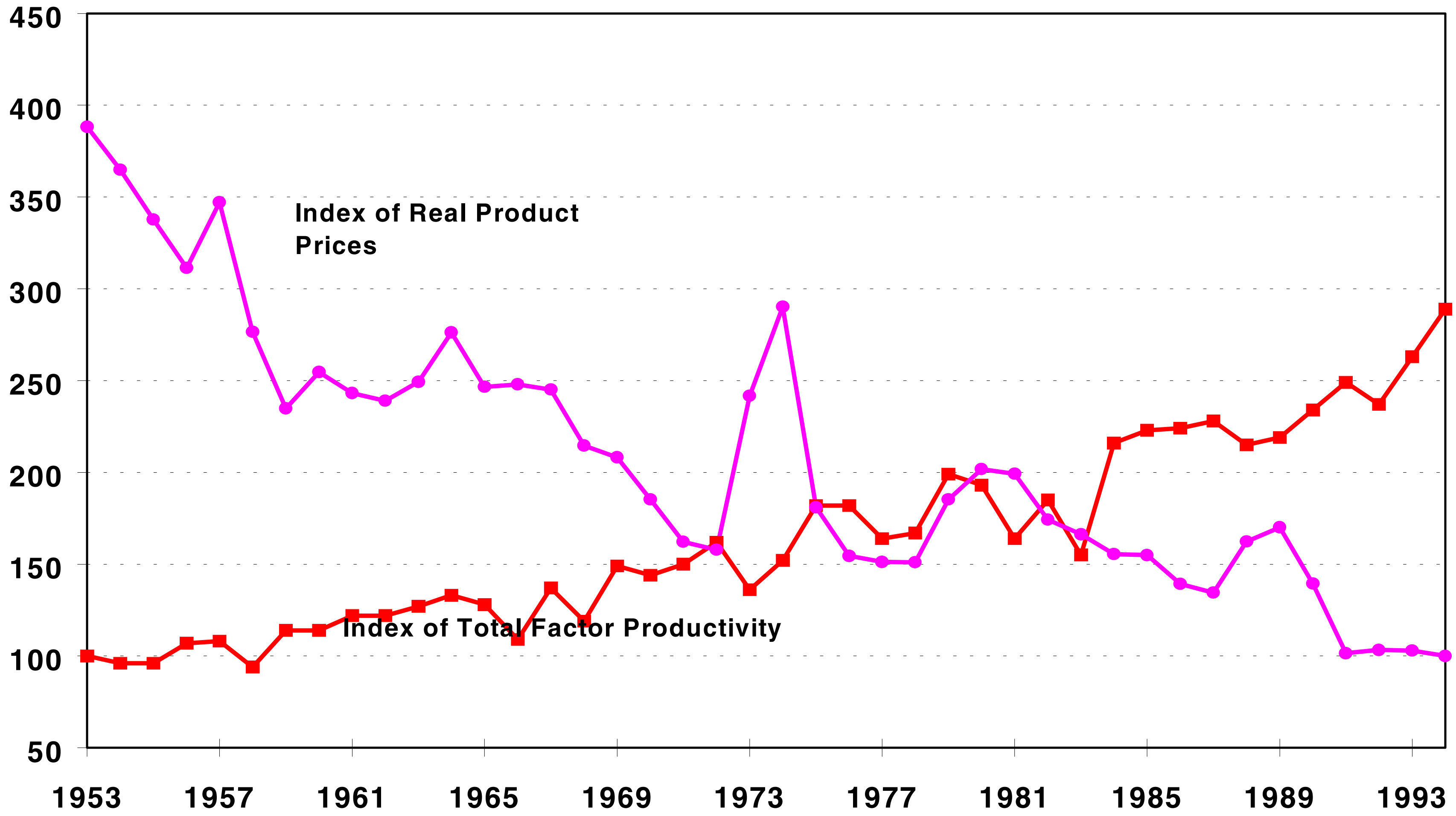
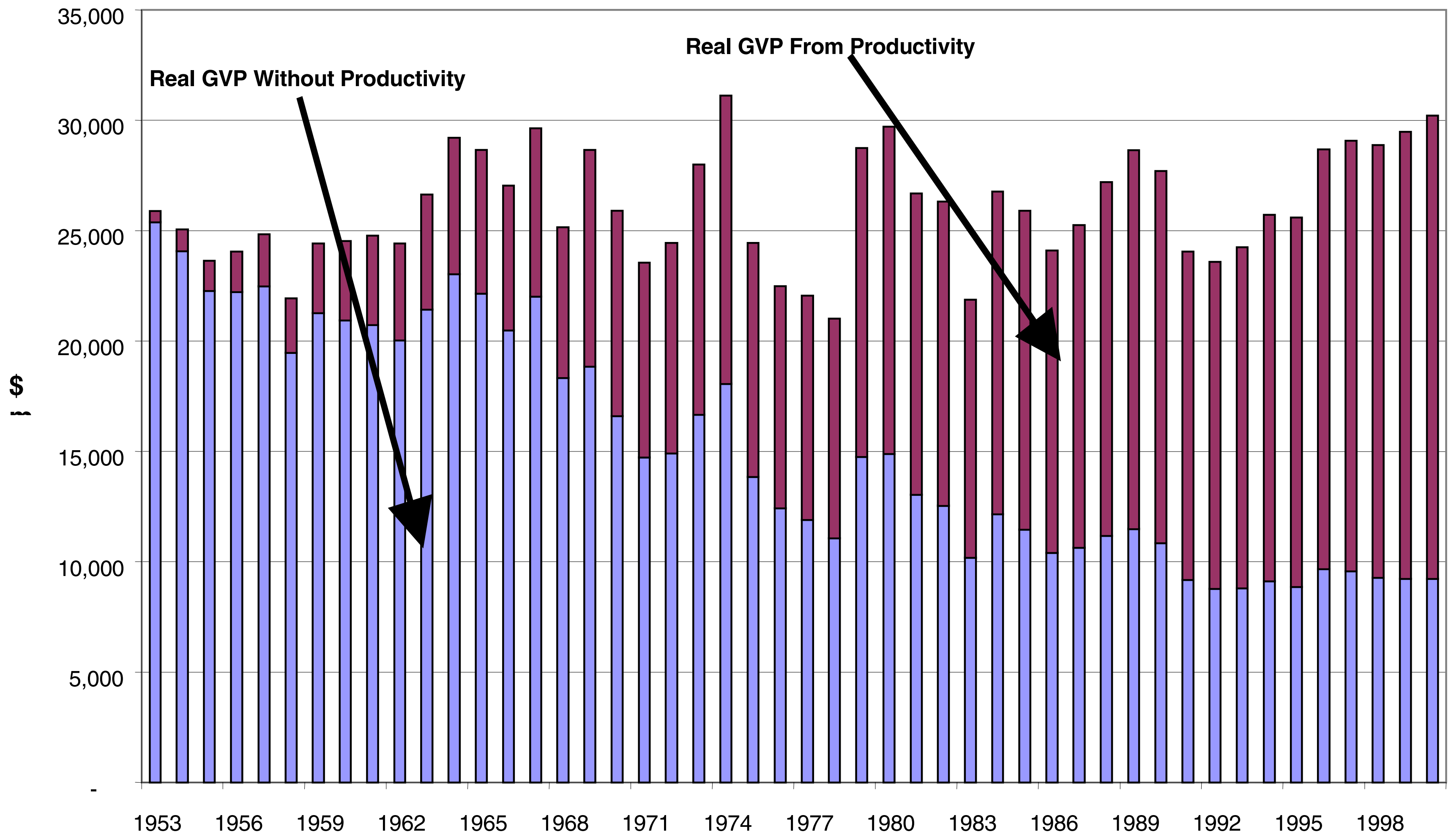


Figure 2: Value of Productivity Growth in Australian



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