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Public investment in agricultural research and development in Australia remains a sensible policy option

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Abstract. There is evidence that productivity in Australia's broadacre agriculture (extensive cropping and livestock industries) has been slowing in the past decade. A series of poor seasons has been partly responsible, but an econometric analysis of structural changes in the trend of total factor productivity (TFP) indicates that stagnant public investment in agricultural R&D has also made a significant contribution to this slowdown in TFP. Related econometric analysis of the returns to public investment in agricultural R&D in the broadacre sector confirms that the rate of return to investment remains high. Despite these findings, a recent enquiry by Australia's Productivity Commission into the financing of rural research suggests that the public sector may be 'crowding out' private sector investment in agricultural R&D and recommends a reduction in public support. In this paper I briefly review the econometric analyses to date and the trends in TFP and public R&D investment. While I have not been able to conclusively test the 'crowding out' hypothesis, there seems to be little empirical evidence to prefer this hypothesis to a more traditional 'market failure' hypothesis. Clearly, stakeholders in agricultural R&D in Australia have to do a better job in communicating the case for public investment in agricultural R&D. Other developed countries are experiencing the same phenomenon and it may become an issue in the future for developing countries in Asia.

Keywords: total factor productivity, returns to research, crowding out.

Introduction

Agricultural R&D can be thought of as adding to a knowledge stock that has an impact on productivity for 35 or more years. This is an important source of wealth in countries making these investments. Moreover, new technologies developed in rich countries able to make the largest investments have 'spilled over' to poor countries and hence public R&D has been an important source of wealth and poverty alleviation across the world. The need for continued productivity growth is evident with world population still to grow by another 2-3 billion and the challenges for productivity from climate change to be met in coming decades.

Despite these challenges, public investment in agricultural R&D is under threat in many developed countries (Pardey et al. 2006). Moreover, evidence is also emerging of a slowdown in productivity growth in agriculture in at least some rich countries, likely in part as a consequence of a slowdown in R&D investment.

The continuing unresolved controversy about the role of government in funding agricultural research in Australia is evidenced by the four enquiries held by the Productivity Commission (PC) (or its forebears) since 1976. The Productivity Commission has usually recommended that the maximum government grant matching the levies collected by the Research and Development Corporations (RDCs) be reduced from its present level of 0.5% of the gross value of the relevant industries. One reason for this recommendation is that the PC argues that public support to agricultural R&D far exceeds that to other industries. The extent of this 'excess' support is disputed in submissions to

the 2011 PC enquiry by the Australian Farm Institute and ABARES, for example, but this argument is not pursued here. The PC also argued that were the grant to be reduced, the RDCs would make up any shortfall by increasing their levy rates. This is a variant of the hypothesis that government investment is 'crowding out' industry investment.

The 2011 Inquiry followed past inquiries in recommending a halving of the cap for a matching grant to 0.25% of industry Gross Value of Production (GVP) over ten years. A notable departure from previous inquiries was the recommendation for an uncapped contribution of 20 cents for every \$1 raised from industry beyond the cap for the matching grant, thus providing industry with an ongoing incentive to increase investment in R&D.

The alternative view presented to the PC enquiries is that the public good characteristics of R&D give rise to socially suboptimal levels of investment by industry and this market failure requires some continuing public investment, even in R&D, delivering benefits largely to industry¹. The development of the RDC model has

* I have benefited from insights (and data) from colleagues at ABARES and from those who attended seminars at the SA Branch of AARES and James Cook University, Townsville.

¹ There seems little argument that there is likely to be market failure in the provision of research service related to environmental and social outcomes although there is a naive argument held by some that where community benefits are jointly provided by, say, RDC supported research, no further investment is required by the public sector. to capture these outcomes for the community.

ameliorated but not solved the market failure problem.

My purpose here is to assess the extent to which the limited empirical evidence about the relationship between investment in R&D and productivity growth supports (or not) these competing hypotheses about the role of government in funding agricultural R&D. First there are brief reviews of trends in public investment in agricultural research in Australia and in productivity in Australian broadacre agriculture. Then follows reviews of econometric work first, linking the slowdown in productivity growth with the slowdown in public investment and climate and second, estimating the rate of return to public investment in R&D in broadacre agriculture in Australia. Finally, I discuss how consistent this empirical evidence is with the 'crowding out' and 'market failure' hypotheses.

Trends in public investment in agriculture in Australia

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 is 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 is focussed on farm production research and investment. R&D in fisheries and forestry, in environment and social outcomes and in the processing of farm products is not included. The GDP deflator was used to express investment in R&D in 2008 dollars.

Total public expenditure on agricultural R&D in Australia has grown from A\$140 million in 1952-53 to almost A\$830 million in 2006-07 (in 2008 dollars) (Figure 1) (Mullen 2010a). Expenditure growth was strong to the mid-1970s, but has essentially been static since that time although there was a spike in investment (nearly A\$950 million) in 2001. Likewise, agricultural research intensity, which measures the investment in agricultural R&D as a percentage of GDP, grew strongly in the 1950s and 1960s, but has been drifting down from about 4.0-5.0% annually of agriculture GDP in the period between 1978 and 1986 to about 3.0% per annum in recent years (as compared to 2.4% per annum in developed countries).

A feature of the agricultural research sector in Australia has been the prominent role played by the RDCs. In approximate terms, RDCs commission agricultural research on a competitive basis among public and private research providers using funds from levies on

production and matching Commonwealth grants (up to 0.5% of the value of production). The attraction of the RDC system is that it ameliorates the non-excludability characteristic of information generated by research, while preserving the benefits from its non-rival nature. In 2007, total expenditure by the RDCs on production agricultural research (excluding the fisheries, forestry and energy RDCs and Land and Water Australia (LWA) was A\$478 million (\$2008), which is almost 60% of total public expenditure on agricultural R&D. Some of this investment by the RDCs is directed towards the processing sectors rather than production agriculture and some is directed to environmental outcomes. If these investments outside production agriculture amount to a third of the total then it seems likely that the RDCs are funding 40 – 50% of research into production agriculture in Australia. Recall also that over half of these RDC funds are raised from farmers. In the 1980s, RDC funding amounted to less than 15% of total public expenditure on agricultural R&D.

Productivity growth in Australian broadacre agriculture

The estimates of productivity growth in Australian broadacre agriculture used here were based on farm survey data from the Australian Bureau of Agricultural and Resource Economics (ABARE). A more thorough review of the trend in agricultural productivity in Australia and its estimation can be found in Nossal et al. (2010). Productivity growth is measured as the growth in outputs less the growth in inputs².

Starting from 100 back to 1952-53, the estimated multifactor (MFP) index increased to 218.3 in 2006-07 with the annual growth rate of 2.0% a year (Figure 2). The index is highly variable, falling in 20 of the 55 years, reflecting seasonal conditions. Such variability makes it difficult to discern trends in the underlying, more stable rate of technological change.

Changes in productivity can be compared with changes in the terms of trade faced by farmers³ 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.

² The terms multifactor productivity (MFP) and total factor productivity (TFP) are used equivalently. The former term recognises that in practice not all factors can be measured and included in the index.

³ Reported in ABARE (2008) and estimated as the ratio of an index of prices received by farmers to an index of prices paid by farmers.

The real situation was a decline of 2.6% per annum from 1953 to 1990, and less than 1% per annum from 1991 to 2007.

A better indication of 'competitiveness' is the growth in productivity in agriculture relative to that in the rest of the economy. Mullen (2010b) reported ABS data suggesting that in recent decades productivity in the agriculture, fisheries and forestry sector often grew at three times the rate of that in the rest of the economy⁴. The agricultural sectors in few other OECD countries have performed as well. Hence, productivity growth in the Australian agricultural sector has likely been strong enough to enhance the sector's competitiveness relative to other sectors of the economy and relative to the agricultural sectors in many other countries.

The ABARE broadacre dataset can be stratified to provide estimates of productivity growth by the enterprise or industry: cropping, mixed crop–livestock, beef, and sheep. Since 1978, cropping specialists have achieved much higher rates of MFP growth (2.1% per year) than have beef specialists (1.5% per year) and sheep specialists (0.3% per year) (Table 1) (Nossal et al. 2010). Generally output grew while input use stayed static or declined. In particular, cropping specialists greatly increased their use of purchased inputs (4% per year) and reduced their use of labour (-0.2% per year) and capital (-0.4% per year). A switch toward reduced-tillage cropping—which is also associated with more diverse cropping rotations and more opportunistic cropping to exploit available soil moisture (as opposed to fixed rotations and fallows)—partly explains the changes in input use and the strong rate of productivity growth.

However, recent data suggest that productivity growth in Australian agriculture – and that of other developed countries (Pardey et al. 2006) – has slowed in the 10 years leading up to 2007. From 1998 to 2007 productivity fell at the rate of 1.4% per annum (Table 1). Trends in productivity have not been even across industries within broadacre agriculture (Table 1). For cropping specialists, MFP grew by 4.8% per year from 1980 to 1994 but declined by 2.1% per year from 1998 to 2007. There seems much less evidence of a slowing in MFP growth for beef and sheep specialists. Nossal et al. (2010) speculated that productivity growth of sheep specialists, usually ranking the lowest among the industry groups, might finally be catching up.

⁴ Mullen (2010a, b) explained difference in the ABARE and ABS MFP series for Australia.

Why might broadacre productivity be slowing?

Some argue that it is not surprising that productivity growth in agriculture is drifting down because "all the big gains have been made." However, Australian research agronomists seem confident that there are still practical research opportunities to develop new technologies that would allow farmers to grow crops more efficiently. Anderson and Angus (*World Wheat Book*, in press) said: "Despite the new technology, the mean yield is only 2.0 tons per ha, about half of the water-limited potential... Further research will be needed to increase yield closer to the water-limited potential. The gains are most likely to come from tactics that enable crops to take advantage of the more favorable seasons in the variable climate, and concentration of inputs on the parts of farms with the highest yield potential."

Another factor likely to explain a significant portion of productivity growth in broadacre agriculture (at least at the aggregate level) is climate or seasonal conditions. No doubt some of the recent productivity decline is due to the run of poor seasons shown by the rainfall anomaly⁵ for the Murray Darling Basin from 2000-2008 (Figure 3), but recent research by Sheng et al. (2010) has demonstrated that the stagnation in public investment in R&D from the late 70s is now also contributing to the slowdown in MFP.

Econometric analyses of the relationship between public investment in Australian broadacre agriculture and productivity growth in broadacre agriculture

Two approaches have recently been applied to examine the relationship between productivity growth and public investment in research in broadacre agriculture in Australia. One approach used time series techniques to assess whether there have been changes in the trend in broadacre productivity and, if so, what factors might explain any trend changes. The second approach updates traditional regression analyses of the factors including public investment in R&D and productivity growth and goes on to estimate a return to investment.

Analysis of the Trend in Broadacre Productivity

Sheng et al. (2010) tested whether Australian broadacre productivity growth had slowed and, if so, when and why. TFP is highly variable due, in part, to unstable

⁵ The anomaly is the annual deviation in rainfall from average annual rainfall between 1961 and 1990.

seasonal effects. Therefore, detecting fundamental shifts in the long-term trend required suitable statistical methods. An analysis of recursive residuals from regression models (the CUSQ method) was used to examine the systematic deviation from trend in current total factor productivity (TFP) in Australian broadacre agriculture between 1952-53 and 2006-07. They found that a significant structural change or 'turning point' occurred in the TFP series in the mid-1990s. Further, it was likely that the slowdown was likely due to a combination of adverse seasonal conditions and stagnant public R&D expenditure since the late 1970s.

The rate of return to public investment in broadacre agricultural research

Mullen and Cox (1995) conducted the original econometric analysis of the relationship between public investment in research and productivity growth in Australia's broadacre agriculture. Using a dataset extending from 1953 to 1994 they estimated that the rate of return to research was in the range of 15 – 40%. This original study was updated on several occasions (Mullen 2007) but the most comprehensive revision using a dataset extending to 2007 and an exhaustive estimation strategy based on Alston et al. (2010) was reported in Sheng et al. (2011).

Estimated models typically are variants of the following form:

$$\ln(TFP_t) = \alpha + \beta_1 \ln(TS_t) + \beta_2 \ln(EXT_t) + \gamma_1 \ln WEA_t + \gamma_2 \ln EDUC_t + \gamma_3 \ln TOT_t + \varepsilon_t$$

where TS is a stock of knowledge available to farmers generated by research, EXT is another knowledge stock variable this time generated by extension activities. Control variables include a measure of seasonal conditions (WEA_t) farmer's level of education attainment as a proxy for the unobserved human capital of broadacre farmers ($EDUC_t$) and the farmers' terms of trade for Australian agriculture (TOT_t).

Estimating models of this nature require consideration of a wide range of specification issues. Economic theory is not prescriptive with respect to these issues. Following in the spirit of Alston et al. (2010) but not as exhaustively, Sheng et al. (2011) conducted an extensive econometric analysis over a range of specification issues to identify a set of models with good econometric properties with a view to assessing how robust were findings with respect to rates of return to investment.

Ideally the focus of such empirical work should be the relationship between R&D and the technical change component of TFP. Other components of TFP are technical, scale

and mix efficiencies (O'Donnell 2010). Investment in extension accounts for technical efficiency but no account is taken in this model of gains in TFP from scale efficiency (Hughes et al. 2011).

A key issue is the derivation of knowledge stocks generated by R&D. They are normally derived as weighted averages of a past stream of annual investments. The weights depend on the length and shape of the distribution function used to define the impact of R&D through time on the knowledge stock. Sheng et al. considered five distribution functions for lag lengths of 16 and 35 years and a key property in discriminating between models was their root mean square error (RMSE). The distributions they considered were (see Figure 4):

- 'Trapezoid' used previously by Mullen with peak impact in years 9 -15;
- 'Gamma' with peak impact at 7 years;
- 'Gamma_T' with peak impact at 13 years similar to the Trapezoid;
- 'Pim' the permanent inventory method used in studies of industrial R&D at depreciation rate of 15 per cent from peak impact in year 1.
- 'Gamma_P' mimicking 'Pim'.

The distribution preferred by Sheng et al. was the unconstrained gamma model (even though the peak of research impact in year 7 is somewhat counterintuitive). However the Gamma T and Trapezoid models also had good econometric properties. They found the 16-year lag models had poor properties for all distributions.

Other key choices involved the treatment of private investment in broadacre R&D and foreign research activities that impact on productivity in Australian broadacre agriculture. Sheng et al. (2011) followed Mullen and Cox (1995) in omitting Australian private agricultural R&D largely because until recent years it has been very small relative to public investment and higher levels of investment in recent years are unlikely to have yet had much impact on productivity.

An important contribution of Sheng et al. is that they have successfully incorporated the influence of foreign research activities in their model. Problems with multicollinearity meant that the separate influences of the Australian public and US public knowledge stocks could not be estimated, but the model above, where the TS knowledge stock is the weighted sum of the two knowledge stocks (where the weight on the US stock was 0.1), was preferred to the original Mullen and Cox model which ignored foreign 'spilling'.

Other specification and estimation issues included choices about:

- Linear v log-linear v quadratic functional forms;
- OLS v ARIMA estimators.

A log-linear functional form and the ARIMA estimator were preferred.

Sheng et al. (2011) preferred the model where domestic and foreign public knowledge stocks were incorporated in TS derived from an unconstrained gamma distribution over 35 years estimated in log-linear form using an ARIMA estimator. From this model the estimated internal rate of return to a one-year increment in Australian public investment in R&D was 28.4%. Two counterintuitive aspects of this model are that peak research impact occurs around year 7 and that foreign 'spillins' contributed twice as much to broadacre productivity gains as domestic public R&D. The models based on the 'Gamma_T' and the Trapezoid distributions impose a peak impact in later years. Their results suggest that the influence of foreign and domestic R&D is similar and give estimated IRRs of 14% and 15.4%, respectively. The IRRs for the Mullen and Cox model ignoring foreign R&D were a few percentage points lower for each distribution type. The IRRs for models where research lags were constrained to 16 years were much larger. Sheng et al. found that when estimated over the shorter period since 1978 the returns to research increased (to 45.3% for their preferred Gamma model).

Hence, the Sheng et al. (2011) findings are consistent with previous econometric studies by Mullen (summarised in Mullen 2007) of public investment in broadacre agriculture in Australia. They 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 RDCs.

Mullen (2004 and extended in later seminars) reported that the average Benefit-Cost Ratio (BCR) for 10 large projects evaluated by NSW DPI economists in 2003 and 2004 was 11.2:1 (ranging from 2 to 66:1). DAFF (2001) reported that Chudleigh and Simpson (2001) had found that the average BCR for a sample of projects across several of the RDCs was 7:1. Council of the Rural Research and Development Corporations (2010) in reviewing the PC (2007) report into Public Support for Science and Innovation identified 41 benefit cost analyses for rural R&D projects spanning a broad array of industries and types of research. A simple average of these results shows a BCR of 68.5. He also summarised evaluations commissioned by the Council of the RDCs in 2008 and 2009. He found that when benefits (excluding

unpriced environmental benefits) were estimated over 25 years, the average BCR was about 11:1 for about 90 randomly selected projects. Much of this material is referenced in the recent report from the Productivity Commission (2011).

Goucher also reviewed the study by Alston et al. (2000) of rates of return analyses worldwide. Alston et al. found that the average of the estimates of the rate of return to research only (from 1,144 studies) was 100% per annum. The range was wide, but less than 10 estimates (less than 1%) found a negative rate of return. Goucher summarised the findings from the 154 Australian and NZ studies reviewed by Alston et al. The average estimated rate of return from these studies was 87% p.a.

The broad conclusion from this substantial body of economic analysis of investment in publicly funded agricultural R&D both globally and in Australia is that returns are very high and this suggests that there may be a degree of underinvestment in agricultural research in Australia as well as globally.

Two further observations can be made here. First all the econometric analysis at an aggregate level and most of the project level benefit cost analysis focus on quantifying industry benefits, but 'spillover' benefits in the form of gains in environmental and human health and in social and scientific capacity are at best identified qualitatively. These 'spillovers' are widely accepted as a potential source of market failure requiring potentially some form of government intervention. One point of contention, however, is that the PC (and others) argue that providing industry benefits are sufficient there is no need for government intervention whereas some would argue that often, there is little incentive for industry to ensure that these 'spillover' benefits are actually taken up by the community and that some degree of public investment is required to ensure these benefits are captured by the community.

Second, the incentives facing farmers and RDCs are much higher than estimated returns to total investment in R&D. Let's say the rate of industry returns to investment in R&D is 20%⁶. At present RDCs fund about half the cost of a research project, the rest coming as an in-kind contribution from a research institution (a State Department for example). Hence, the return to the RDC investment is effectively 40%. Moreover farmers provide half the funds to RDCs and so the effective return to their investment (attracting the matching grant) is in the order

⁶ The focus is on industry returns rather than environmental and social returns.

of 80%⁷. Reducing the matching grant will mean that the incentive facing farmers for any levy funds beyond 0.25% of GVP would be 40% under this scenario (or 48% if a 20 cent per dollar invested uncapped grant is introduced).

The PC accepts that the preponderance of evidence supports the view that return to investment in research in Australian agriculture has been high. Nevertheless the PC argues that the matching grant (against the RDC levy) should be halved to 0.25% of GVP because it doubts that the matching grant has called forth much additional research from industry. It expects that were the government to reduce the GVP cap for a matching grant by 0.25%, the RDCs would increase their levies to offset this reduction. The public sector is 'crowding out' industry investment in other words.

Does the empirical evidence support the 'crowding out' or 'market failure' hypotheses?

It seems difficult (if not impossible) to develop a conclusive econometric test of either hypothesis. This is not an uncommon problem. The task is to see which hypothesis seems most consistent with limited empirical evidence and inferences or expectations based on the nature of agricultural research and the structure of the agricultural sector. Some of the following discussion is speculative and anecdotal but raises questions worthy of further research.

Starting with the 'crowding out' hypothesis we might wonder under what conditions would industry, in this case RDCs, not invest in research in the presence of public investment. The PC seems to be arguing that the present level of matching grant is not attracting 'additional' investment by industry. They speculate that this research would have been done anyway because of the high rates of return being earned and hence were public funding withdrawn as recommended, the RDCs would be able (at some time lag) to increase levies to replace these public funds. There does not appear to be any historical precedent (of a withdrawal of government funding) to test this 'crowding out' argument by the PC. However if it were true, then an obvious question, not addressed by the PC, is why more RDCs have not already raised levies beyond 0.5% in pursuit of these high returns (the GRDC and AWI are the exceptions).

Another more likely scenario in which investment by RDCs would be 'crowded out'

by the public sector is one where the returns to their investment in research were low relative to other investment opportunities available to farmers. Under this scenario withdrawing public funds might result in an increase in the returns to research investment sufficient to attract increased investment from the RDCs (providing the research production function is characterised by diminishing returns to investment at this point). Under this scenario one might also expect it to be common that RDCs set levies below the maximum 0.5% matching grant level.

Neither of these conditions is observed, in fact just the opposite. Few RDCs set levies below the 0.5% level and few set levies above this level. Further, as described above, the rates of return to public investment in research have been high for several decades.

Perhaps the 'crowding out' hypothesis is consistent with high rates of return if either the research production function showed a high degree of diminishing returns at this point where levies are set at 0.5% or if a constraint to research such as the supply of scientists becomes critically binding at this point. The arguments are reviewed here but the case is difficult to make.

In the first case the argument might run that RDCs are unwilling to invest beyond the 0.5% level because their incentives are sharply diminished past this point, but that up to this point they may be prepared to replace public investment because the returns are sufficiently attractive⁸. There are no historical precedents to shed some light on this, but there is some empirical evidence about the shape of the research production function.

Intuitively we would expect some degree of curvature but recent empirical analyses provide little evidence that it is strong. Sheng et al. (2011) estimated higher returns to research for a model estimated over the shorter time frame from 1978. Given that real public investment in agricultural R&D was at best stagnant over this period, this provides some circumstantial evidence of diminishing returns. However they also found that no gains in model performance could be had from using a quadratic functional form – conducive to the possibility of sharply diminishing returns to investment – instead

⁷ Let's assume that the incidence of levies and the distribution of the benefits from production focussed R&D are the same.

⁸ Note that the returns to farmers fall to 40% (under the assumptions of the illustrative example used here) as they go beyond the 0.5% level but they would also fall to this level were government to pull back from the 0.5% level.

of the preferred log-linear form⁹. It has already been noted that scientists are still confident that research opportunities remain to increase agricultural productivity.

There is some concern about the supply of scientists with inferences of a severe shortage based on the age profile of the research community and the closure or amalgamation of agricultural science departments and faculties¹⁰. Yet there seems little evidence either in terms of growth in employment opportunities or the demand for university places, or in terms of rising salaries, of strong growth in the demand for agricultural scientists. Perhaps demand pressures will emerge in coming years.

In summing up to date, neither empirical evidence nor a logical chain of inference provides much support for the 'crowding out' hypothesis. It is much easier to make a case in support of the traditional 'market failure' argument.

Few would argue that the non-excludability and non-rivalry characteristics of information generated by research mean that were farmers left to act individually, investment in agricultural research would be suboptimal from the viewpoints of both agriculture and society more generally. In Australia the RDC model has been developed to ameliorate the non-excludability issue while preserving the benefits of non-rivalry.

The debate however focuses on whether the RDC model is sufficient to largely solve the market failure problem. The PC clearly thinks it does, arguing, as we have seen, that in fact government is 'crowding out' industry at least with respect to research delivering largely industry benefits (although it does agree that some lower level of public funding is justified). Others argue that the high rates of return to research, prevailing for at least several decades, are evidence of continuing market failure. The question that then arises is why are RDCs unable to increase levies to enable industry to capture more of these high returns.

It should not be surprising that farmers understate their true willingness to pay for research under the common uniform levy of the RDC model. 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 they 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.

Concluding comments

Salient features of the agricultural research setting in Australia are first, rates of return to investment have been high for several decades at least and second, that farmers through the RDCs show little inclination to increase the levies they pay to finance R&D beyond the 0.5% of GVP that has attracted a matching Commonwealth grant (with the GRDC and AWI being notable exceptions). The unwillingness on the part of farmers to increase levy contributions is likely explained by the non-excludable characteristic of research and the heterogeneity of farming enterprises on the one hand and the impact of new technology on the other.

This set of phenomena readily fits with a traditional hypothesis that present levels of investment in research are likely to be suboptimal from society's viewpoint even where the outcomes of research are predominantly economic (industry oriented) in nature. Public sector investment remains an important means to overcome this market failure.

However present levels of public sector investment in Australia remain under threat with the PC again recommending that the Commonwealth matching grant be halved although the recommendation that a 20 cent per industry dollar uncapped grant (beyond the 0.25% GVP cap) be introduced seems a sensible change in the incentives for industry to invest in R&D. The PC argument is based partly on a contested assessment, not pursued here, that public support for agricultural research is much higher than for research in other sectors, and partly on a notion that the public sector is crowding out the private sector such that were the Commonwealth levy halved, the RDCs would increase the levies raised from farmers. However, 'crowding out' 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

⁹ Mullen (2007) using a quadratic functional form found some evidence of increasing returns but this finding is not supported by the more recent Sheng et al. study.

¹⁰ It should be noted that the people who point to supply constraints also point to falling public investment as a key cause.

empirical evidence to support their recommendations.

In Australia, as in some other developed countries, productivity growth in agriculture is slowing and a decline in public investment in R&D is likely to have contributed to this slowdown. The long lags over which R&D impacts on productivity exacerbate this attribution problem, but also mean that any current slowdown in public investment will influence productivity growth in agriculture for several decades at a time when global population is still growing and costs associated with climate change are emerging. It would seem prudent to maintain public support for agricultural research rather than risk losses in economic welfare in Australia and poor countries somewhat reliant on technologies generated in Australia on the basis that public investment is crowding out private investment; a basis that has little empirical support.

The hypothesis that there remains some degree of underinvestment in agricultural research in Australia is supported by prevailing high rates of return to research investment and by a sound rationale as to why the RDC model cannot be expected to arrive at a levy on farmers fully reflective of the value of research to industry and society.

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Appendix

Table 1: Productivity growth per annum in sectors of Australian broadacre agriculture

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

Figure 1: Real public investment in agricultural R&D in Australia

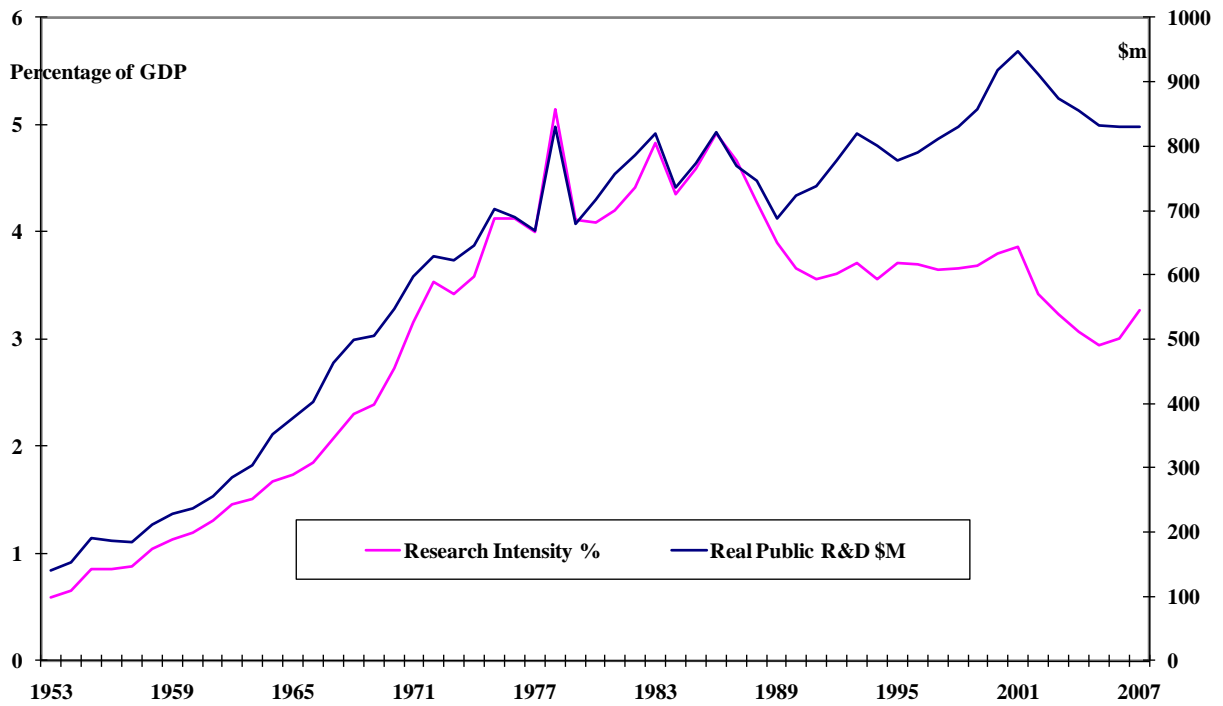


Figure 2: Trends in multifactor productivity and the terms of trade for Australian broadacre agriculture

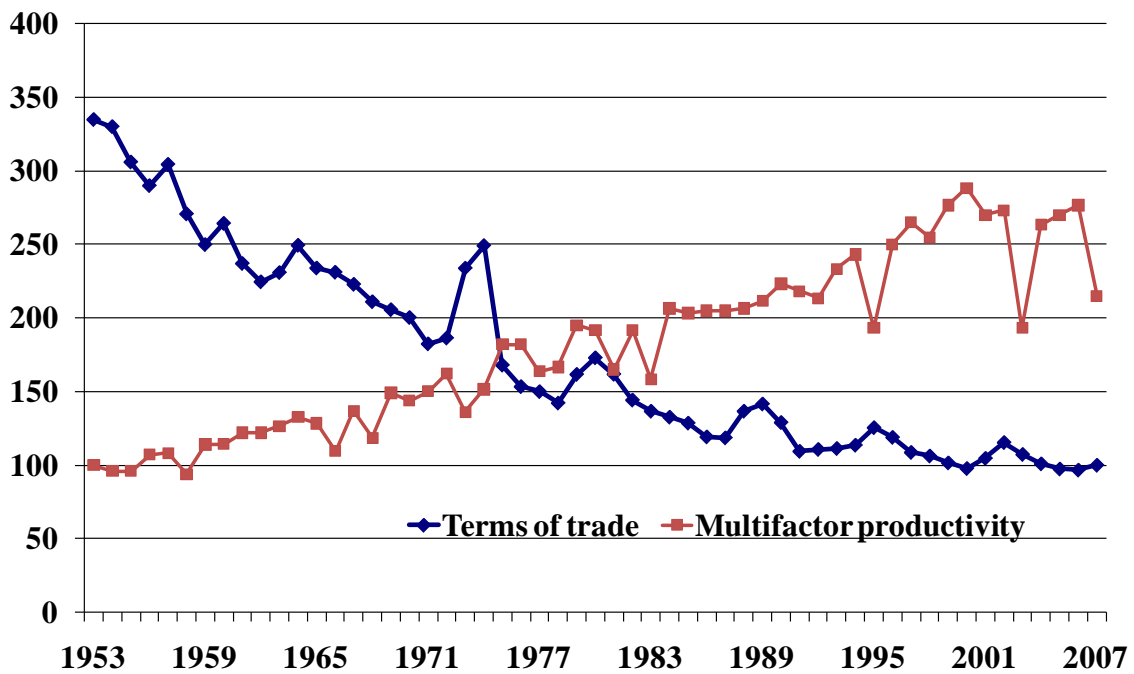
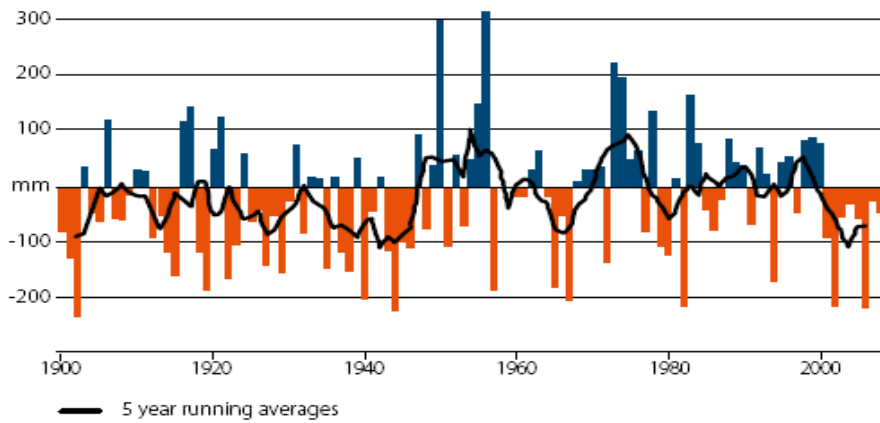


Figure 3: Annual rainfall anomalies in the Murray-Darling Basin



Source: Australian Bureau of Meteorology.

Figure 4: Gamma, trapezoid and geometric distributions for research knowledge stocks

