SUBMISSION TO THE PRODUCTIVITY COMMISSION'S RESEARCH STUDY ON PUBLIC SUPPORT FOR SCIENCE AND INNOVATION

from

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Executive Summary

This submission focuses on public support for science and innovation in the context of agricultural industries, reflecting UNE's rural location and history of world-class research in the agricultural sciences. A current manifestation of this involvement with the agricultural industries is UNE's core partner-status in agricultural CRCs. UNE also regards itself as being physically and socially embedded in the production and social systems that it serves.

UNE advises against overly-restrictive definitions and overly-prescriptive boundaries to guide the Commission's research study on public support for science and innovation research. In particular, it would be inappropriate to focus only on the "creation" side of research. The empirical research on improvement of research outcomes clearly shows that the issue is one of system efficiency, in which the capacity to adopt and the processes between invention and application are as important (arguably more important) than the technical innovation. The role of the non-experimental sciences should not be discounted.

In response to the Commission's request to have relevant studies brought to its attention, a number of key studies by agricultural economists are mentioned. Agricultural economists have been active in developing and implementing models for the evaluation of agricultural R&D and in drawing attention to, and analysing, some of the key developments in funding and other policies affecting agricultural R&D. Attention is also drawn to a recent study by the Australian Farm Institute that argues, *inter alia*, for a Productivity Commission study of support for innovation in the farm sector.

It is argued that the spillover effects of agricultural R&D (benefits to individuals beyond the intended beneficiaries) are ubiquitous and complicate the design of policies to ensure socially-optimal levels of investment in these activities. With respect to the Issues Paper, spillovers would seem to be particularly relevant to the Commission's concerns about benchmarking, measuring impacts and setting performance criteria—the existence of spillovers complicates all three. Attention is drawn to a number of studies highlighting the importance of spillovers and the complications they cause for measuring impacts and policy design.

Some general comments about the difficulties of measuring the impacts of agricultural R&D are offered and attention is drawn to the work done in this area by agricultural economists. Many studies report rates of return well in excess of the rates of return one associates with investments in stocks and bonds.

Agricultural economists and econometricians at UNE have collaborated with colleagues at the NSW Department of Primary Industries to measure the benefits from the research undertaken by three of the agricultural CRCs with which UNE is involved. Because of the long time lags involved, most of these estimated benefits are prospective rather than retrospective. In response to the Commission's request for quantitative estimates of economic impacts of publically-supported research, some of the results from this

empirical work are presented in the submission. In general, the economic impacts for Australia are positive and significant.

The submission draws attention to a number of broad issues that UNE believes should receive attention in the Commission's research study. First, UNE believes that the continuum of basic research, applied research and technology transfer is essential to maintain innovation flow. Attention should be given to how public support is best organised so as to preserve and strengthen this continuum.

Second, effective technology transfer requires skills upgrade as well as information transfer—lack of relevant basic skills may be an impediment to innovation in the farming sector which is characterized by an aging workforce. It would be useful if the Commission's research study addressed the issue of whether there are adequate arrangements in place to accommodate the need for skills upgrade.

Third, the decline in science enrolments at schools and universities must be seen as an important impediment to future innovation in all industries. It is argued in the submission that one of the causes of this situation is lack of clear career pathways for science graduates arising from a tendency towards the use of short-term contract employment arrangements. Some attention to this situation in the research report would be beneficial.

Fourth, research in Australian universities, particularly regional universities, is being impeded by poor infrastructure. The major source of equipment infrastructure for Australian universities is the Australian Research Council infrastructure scheme. This is a competitive scheme, with one of the criteria being equipment sharing between universities to foster and promote collaboration. While this is a laudable goal, it discriminates against regional universities because of their relative isolation from other institutions. Some attention to alternative funding arrangements for infrastructure would be welcomed.

Fifth, research in Australian universities is impeded by the inability of universities to pay internationally competitive salaries. Whilst Federation Fellowships have helped, more funding is required to allow universities to retain leading scientists.

Finally, UNE believes that science and innovation expertise should be concentrated according to topic and location with the required critical mass and community linkages. Locating agricultural research facilities in a regional university such as UNE where the community linkages exist would be an example. It is hoped that the Commission will give this suggestion favourable consideration.

There are some further considerations particularly relevant to UNE that are deserving of attention in the Commission's research study. The spillover values (in terms of both adoption, and secondary effects such as regional development, supporting less advantaged communities and sustainable production systems) are not taken into account

when DEST allocates research money to universities. UNE believes that the spillover value created by its research is large and that this funding failure disadvantages UNE.

Given its regional location, UNE's transaction costs (notably travel and communications) are relatively high, and this acts as an impediment to the pursuit of funding opportunities. For example, collaborative research funding mechanisms such as the CRCs and ARC Linkage grants intrinsically require that there be deep and sustained communication between the collaborating parties well prior to the winning of research funds and this is costly for a regional university. A targeted form of support would assist in reducing this barrier.

The imperative for UNE to maintain a sufficient scale of activities to properly carry out its core activities is not considered in science funding arrangements. In particular the need for UNE to ensure that it has a scale of research activities to allow it to maintain and develop its role in training the next generation of "knowledge brokers" is not taken into account. UNE believes that the issue of research scale and the link to teaching and knowledge transfer is a matter that should be addressed in the Commission's research study.

Finally, UNE has a strong emphasis on 'triple-bottom-line' sustainability. Some aspects of this (notably social and environmental) have low capacity for generating private research support but are essential to economic productivity. The funding for social and environmental 'public good' research is increasingly constrained. UNE believes that the issue of the interaction between these forms of research and production improvement research should be addressed, as should the question of funding for this work in its own right.

Overall, UNE believes that, in designing its research study, the Productivity Commission should: (a) consider the innovation system and the interactions that make the system work, rather than placing excessive emphasis on the "inventive step"aspect of that process; (b) consider the significance of research embedded in the communities who are expected to adopt, and the power that this embeddedness provides in ensuring research relevance, diffusion and adoptive potential; and (c) recognise the problems that are created through a pattern of funding allocation that is based purely on narrow technical criteria, without counting both the impact value and the cost effects of regional location, and the role of supporting industries that remain vital but which face their own economic challenges.

Focus of the Submission

It is noted that the Issues Paper prepared for the Commission's research study on public support for science and innovation is not intended to limit comment and that participants may submit information and views considered relevant to the terms of reference. This has been the approach adopted in this somewhat eclectic submission. However, the submission does address some of the specific requests made in the Issues Paper (e.g., information about relevant studies) and it has relevance to the three main areas of interest to the Commission, these being impact, impediments and evaluation of decision making principles and program design (Issues Paper, p. 5).

The submission has a focus on public support for science and innovation in the context of agricultural industries, particularly the impact of public support and impediments to the innovation system. UNE is well placed to make such a submission for several reasons:

- UNE is Australia's oldest regional university and it is located in a region heavily dependent on agricultural industries.
- UNE is a research-led teaching and learning institution with particular strengths in teaching and research directed at agricultural industries. Active research engagement is essential to UNE's capacity to develop and educate the next generation of technology adopters, and this development is in turn essential to the capacity of the rural community to adopt scientific discoveries.
- UNE serves the knowledge needs of natural resource-dependent production economies, and the communities that depend upon them, from an economic, social and environmental sustainability perspective.
- The spillovers from UNE's research are as important as the direct and immediate discoveries. These include the regional development function of the University and its role in stimulating more knowledge-intense primary production and greater interest in sustainable production.
- UNE has a high degree of cross-disciplinary integration achieved through staff engagement in research centres, involvement in agricultural CRCs and informal networking. This type of personal interaction is pivotal to the creation of true multi-disciplinary research.
- UNE is physically and socially embedded in the production systems and social systems that it serves. This ensures that the challenge of embedding science is something that UNE meets everyday. A regional location, whilst it poses many challenges in terms of research funding and networking, offers a real potential for improved adoption rates of new technologies.

Most of these characteristics have developed over time as UNE has worked with industry and found ways to construct and maintain relationships that have benefitted both parties. However, as discussed later, they also put us at a disadvantage when it comes to some of the research funding mechanisms that are in use.

Interpreting the Terms of Reference

It is pointed out in the Issues Paper (p.5) that potentially the research study could be broad in scope. The Commission indicates its intention to focus its work in line with its interpretations of the key concepts, these being science, innovation, innovation system and R&D.

UNE advises against overly-restrictive definitions and overly-prescriptive boundaries to the research study. For example, it would be inappropriate to focus only on the "creation" side of research. The empirical research on improvement of research outcomes clearly shows that the issue is one of system efficiency, in which the capacity to adopt and the processes between invention and application are as important (arguably more important) than the technical innovation. The relevant fields of research are those of institutional economics, innovation systems and path dependence. A good synthesis of the literature can be found in the Marceau et.al (1997) study for the Australian Business Foundation.

It is clear that if the adoption capacity of the proposed end-users is not in balance with the innovation supply side of the system, wasted R&D investment is the most likely outcome. The evidence is strong that investment in adoptive capacity is a key to ensuring high return on investment in development of new technology.

UNE submits that the interpretation of "science" that will guide the research study as outlined in the Issues Paper (p.5) is overly-restrictive in that it implies a focus on experimental sciences. Science is the purposeful pursuit of knowledge using the scientific method, and experimental science is only one of its forms (albeit a vitally important one). The interpretation in the Issues Paper is inappropriate as many of the sorts of science that are needed to deliver the benefits of science to the community are outside the realm of the experimental sciences. For example, research on value chains, contracts, management techniques, economics, law, and the like are important to delivering benefits from research but such research is discounted in the interpretation of science outlined in the Issues Paper. This is particularly a problem because much of the work associated with the adoptive capacity of industry and with the management aspects of the innovation system fall outside of the experimental sciences, but without these types of innovations the experimental sciences investment will be of reduced value.

Research shows that for science to deliver applied value, ideally it must: (a) reflect the needs of the potential or intended user; (b) be developed in a way that reflects the subtle understanding of the needs of the user; (c) be introduced into the marketplace with a network of relationships that make speedy adoption likely; and (d) fall within a market that is ready and able to adopt. Each of these elements requires a close and personal set of inter-relationships that cannot be replicated through mere market research or bolted-on "commercialization" or "diffusion". The evidence for this is strong (see, for example, von Hippel 1998).

For recent Australian information which highlights the government's belief in the importance of close linkages of the type described here the Commission is referred to: http://www.dest.gov.au/sectors/science_innovation/science_agencies_committees/prime_ministers_science_engineering_innovation_council/meetings/documents/unind_pdf.htm

The OECD has done considerable work on this suite of issues surrounding industry/university linkages. On knowledge systems research, for example, see: http://www.oecd.org/dataoecd/35/56/2101733.pdf

What this means in terms of policy is that there should be an emphasis on ensuring that the relationships are in place and that the social networks are supportive of technical capacity. A researcher working in isolation in a laboratory is not likely to have these linkages and sensitivities unless they are embedded in some way into the markets and social networks that they are serving. In some areas of science (say medicine), it is possible that the linkages will be easily established. In others, the creation of such linkages will not happen without deep interactions of the kind that come from daily interaction or involvement in teaching and learning as well as research. It is also the case that different markets have different adoptive propensities and capacity. If these are not strong, then development is likely to be required as a precondition for adoption. Without that development, rates of adoption will be low.

In relation to agriculture, a recent report from the Australian Farm Institute emphasises the need for "up-skilling" the farm workforce (Australian Farm Institute 2005, p.64):

> "The farm labour force is only as good as the quality of its new entrants and the skill development of its existing workforce. The increasing role of new technology and 'new management' techniques in farming as well as the increasing size and complexity of farm businesses will require a higher capability in the workforce at all occupational levels, including in people management and personal management skills. Fundamental to this is the capability for informal and formal continuous learning and much of this is dependant on literacy and numeracy skills that are essential to the acquisition, analysis, synthesis and application of data and information."

Based on 2001 data, 68 per cent of Australian farm-sector employers and self-employed were aged 45 and above and 27 per cent were aged 60 and above (Australian Farm Institute 2005, p. 23). Given this age profile, it can be expected that without some pre-conditioning work such as extension or education, the uptake of innovations will be low. At least with regard to the agricultural industries, UNE believes that separating research from these other aspects of the innovation system will be counter productive.

Our recommendation is that the Commission's study should focus on the innovation system and, if desired, the production aspects of research and that care is taken to *not* discount the role of non-experimental sciences. In this context UNE submits that the importance of embedding research in a framework which takes into account the transaction costs of adoption, the social networks that impact on the likelihood of

adoption and the importance of non-research factors in the success (or otherwise) of research should be considered.

Some Relevant Studies

The Commission invited participants to "…draw the Commission's attention to available material, to relevant sources of data and analysis and to comment on relevant Australian and international experience and reports" (Issues Paper, p.7). The Commission also points out in the Issues Paper (p.7) that many key issues relevant to the current research study were considered in the Industry Commission 1995 report into R&D.

Agricultural economists have been active in developing and implementing models for the evaluation of agricultural R&D and in drawing attention to, and analysing, some of the key developments in funding and other policies affecting agricultural R&D. Important works have appeared since the 1995 Industry Commission inquiry. Many of these works have an international focus but are certainly relevant to Australian agricultural R&D. Indeed, some of the leading contributors in this area have been Australians working in US institutions. Some examples of this literature are provided in the Appendix.

The Commission may already be aware of a recent study undertaken for the Australian Farm Institute (see Australian Farm Institute 2005). One of the recommendations from that study was that "…the Productivity Commission initiate a review, at both a national and state level, of existing arrangements policies and processes supporting innovation in the farm sector." (p.80). The study has interesting observations about innovation in the agricultural industries such as the appropriateness of the commodity-specific rural R&D corporation (Australian Farm Institute 2005, p. 80):

> "…it needs to be acknowledged that the structural changes introduced through the 1980s to arrangements supporting agricultural R&D have dramatically improved the relevance of R&D to the established industries, and the support for R&D from those industries. The policy question for the future is not whether these arrangements have been ineffective but whether we now have the best balance of approaches for the coming decades.
>
> Critical points for analysis include:
>
> - The extent to which the industry-by-industry structures limit innovation across existing industries and in alternative industries and other farm based activities.
> - …
> - The nature and extent of transaction costs inherent in existing project funding arrangements."

Spillovers

Payoffs from research investment often include spillovers. These include direct benefits to parties who had no role in undertaking or funding the research (for example, farmers in the developing world have benefited greatly from agricultural R&D undertaken in rich countries), academic by-products such as enhanced teaching and learning capacity and societal and environmental impacts such as regional development and sustainable production systems. Indeed, the linear concept of research payoffs, whereby invention leads to diffusion or commercialization which in turn lead to economic gain, is the (desired) exception rather than the rule.

Optimising the institutional and economic framework to encourage research and innovation becomes a difficult task given the presence of spillovers. With respect to the Issues Paper, spillovers would seem to be particularly relevant to the Commission's concerns about benchmarking, measuring impacts and setting performance criteria—the existence of spillovers complicates all three. An important reference on the ubiquity of spillovers in agricultural R&D and the problems they cause for the design of research policy is Alston (2002). The abstract of the paper provides an overview of the problems caused by spillovers:

> "Interstate and international spillovers from public agricultural research and development (R&D) investments account for a significant share of agricultural productivity growth. Hence, spillovers of agricultural R&D results across geopolitical boundaries have implications for measures of research impacts on productivity, and the implied rates of return to research, as well as for state, national and international agricultural research policy. In studies of aggregate state or national agricultural productivity, interstate or international R&D spillovers might account for half or more of the total measured productivity growth. Similarly, results from studies of particular crop technologies indicate that international technology spillovers, and multinational impacts of technologies from international centres, were important elements in the total picture of agricultural development in the 20th Century. Within countries, funding institutions have been developed to address spatial spillovers of agricultural technologies. The fact that corresponding institutions have not been developed for international spillovers has contributed to a global underinvestment in certain types of agricultural research."

The importance of spillovers is acknowledged in the Productivity Commission's staff working paper by Shanks and Zheng (2006). A number of studies by Brennan *et al*. (1995, 1997, 1999, 2002) highlight how Australia has benefitted from research conducted at some of the international agricultural research centres. However, the complexities caused by spillovers in terms of, for example, deciding on optimal levels of public funding for agricultural research seem to be not well understood or, at least, not foremost in the minds of policy makers. This seems especially so for international spillovers. Australia has been innovative in designing a funding mechanism to address spatial spillovers among Australian states, namely, the use of federally-mandated compulsory levies on producers of some crops and livestock to fund research, with matching federal

funding up to 0.5 percent of gross value of production. There is a challenge for independent research agencies such as the Productivity Commission to contribute to the design of funding arrangements to address international spillovers.

Impacts: General Comments on Measuring Impacts of Agricultural R&D

A considerable amount of work on assessment of the impacts of agricultural R&D has been undertaken by agricultural economists. Some sample contributions have been mentioned in the Appendix. The work has been on two fronts: trying to improve the methodology for impact assessment and actual measurement of impacts. A lot of this work has been in relation to agricultural R&D undertaken in other countries, including the work undertaken by the international agricultural research centres that operate under the auspices of the Consultative Group on International Agricultural Research. But there has been considerable work in Australia too. The staff working paper by Shanks and Zheng (2006) makes reference to the work of Mullen and Cox (1995). A number of studies by Brennan on how Australia has benefitted from international spillovers are included in the reference list to this submission. In the next section some of the work that has been undertaken at UNE is described.

Shanks and Zheng (2006) rightly point to the fact that measurement of impacts of R&D is fraught with difficulties and measurement outcomes are sensitive to assumptions made. But the methodology is improving and problems such as sensitivity of results to assumptions made are being addressed through, for example, equilibrium displacement models coupled with Monte Carlo simulations in which unknown parameter values, such as demand and supply elasticities, are drawn from specified probability distributions with results also reported as probability distributions. An example is provided in Zhao et al. (2000, 2001). Shanks and Zheng (2006) estimated a rate of return to public agricultural R&D of 24 per cent which is within the range (15 to 40 per cent) of returns to Australian broadacre agricultural R&D estimated by Mullen and Cox (1995). These rates of return are large when compared with returns on many other forms of capital investment such as stocks and bonds. But this is a common finding from studies in other countries as evidenced in the meta study by Alston et al. (2000).

Impacts: CRCs with which UNE is Associated

The 2005 study undertaken by The Allen Consulting Group on the economic impacts of the CRCs rightly pointed to the lags involved in receipt of benefits from the CRCs. That study used a strict definition of "benefit" in order for the benefit to be included among the economic impacts. For example, the benefit must have already been delivered (or be commenced but ongoing). The study acknowledged that this strict definition resulted in a partial accounting of the actual benefits.

The University of New England is a core partner in CRCs that have a focus on agriculture and the impacts of agricultural R&D follow the research investments generally with a considerable time lag. This point is made well by Pardey and Beintema (2001) in their aptly-titled study, "Slow Magic: Agricultural R&D a Century After Mendel", p. 1:

> "Despite the buzz about biotechnology, informatics, and a myriad other technologies, the lag between investing in innovation and reaping the rewards is still substantial—measured in decades, not years. This is especially true for biologically based sciences like agriculture.
> …Today's scientists stand firmly on the shoulders of those who went before them. While investments in research give rise to new ideas, know-how, and innovations in the near term, these innovations draw directly on the efforts of past research. It is the *accumulation* of research results over the long haul that accounts for the differences in agricultural productivity observed around the world."

The strict definition of "benefit" used in the Allen Consulting Group study meant, for example, that the only benefit from the CRCs with which UNE is associated included in the impact assessment was gross revenue from the sale of vaccines and gene marker tests developed by the CRC for Cattle and Meat Quality ($6 million between 2001 and 2005).

Agricultural economists and econometricians at UNE have collaborated with colleagues at NSW Department of Primary Industries to measure the benefits from the research undertaken by three of the CRCs with which UNE is involved. Because of the long time lags involved, as noted above, most of these estimated benefits are prospective rather than retrospective.

The Australian Sheep Industry CRC commenced operations in 2002 and will receive Commonwealth and industry funding totalling about $30 million over its seven-year period, as well as in-kind contributions from core and supporting parties with an approximate value of $60 million. UNE is a core partner in this CRC. A mid-term evaluation of the expected benefits from the science programs of the CRC was done in late 2005 (Vere et al. 2005), Important input data into the DREAM economic modeling framework such as productivity growth estimates, technology adoption levels and lags, and production cost differences were derived from a consensus data approach, involving the program leaders and the CRC industry advisory panel. The total potential benefit from the CRC science programs was estimated to be around $275 million in Net Present Value (NPV) terms over the 25-year period of the simulation. Benefits from individual research programs ranged from $72.2 million for genetics research that improves the supply of wool, to $1.7 million from research that impacts on sheepmeat supply under wool science research. The range of the Benefit Cost Ratios (BCRs) is between 17.5:1 for research into parasite management that impacts on wool demand and 1.6:1 for nutritional research that affects the supply of sheepmeats. All areas of research generate positive NPVs and BCRs that are greater than unity.

Australian sheep producers gained about 75 per cent of the total net benefit because they could directly access the new technologies. NSW sheep producers gained a significant share of the overall producer benefit, approximately in proportion to NSW's share of Australian sheep and lamb numbers. Sheep product consumers in all regions gained from the lower product prices that followed the supply increases, while sheep

producers in competing supplying regions lost economic welfare valued at $113.6 million in NPV terms over a 25 year evaluation period from the price spillovers because they could not adopt the cost-saving technologies.

The Australian cattle and beef industry and the associated RD&E community recently developed a successful proposal for a third CRC related to this industry—the ***CRC for Beef Genetic Technologies.*** The focus of the CRC is on gene discovery and gene expression, and accelerated adoption. Seven major industry outcomes have been targeted across some 20 individual project areas. The Commonwealth provided $30 million in cash, and core and supporting partners provided another $90 million in cash and in-kind resources. UNE is a core partner in this CRC.

The expected benefits from the proposed scientific programs of the renewed CRC were estimated using the DREAM economic modelling framework. Net estimated benefits from the CRC are in the order of $1.831 billion in NPV terms over a 25-year evaluation period. This results in a BCR of 19.7:1. The marginal returns to the NSW beef industry from funding the CRC were also estimated. Under the same assumptions made in the aggregate assessment, it was estimated that the Beef CRC will generate $251m in economic benefits to the cattle producers, beef processors and marketers, and beef consumers of NSW, in net present value terms.

Based on the results reported in Zhao et al. (2000, 2001,2003), it is expected that cattle producers receive about one-third of the benefits from the adoption of new technology in the beef industry, beef consumers receive about a half, and the remainder is distributed across the other input suppliers in the beef marketing chain.

Some additional benefits were also enumerated. First, using CGE modeling, it was estimated that an extra $111m in benefits in net value terms would flow through to the broader NSW economy, beyond those accruing to the cattle producers, beef processors and marketers, and beef consumers of NSW. Many of these additional benefits would flow to rural communities in the form of induced additional economic activity resulting from the CRC. Second, net feed intake is a major research area of the new CRC and it is now accepted that selection for more feed efficient cattle will lead to a reduction in greenhouse gas emissions from the beef herd. It was estimated that a minimum value for the saved methane output due to adoption of NFI genetics in the NSW beef herd is in the order of $28m in net present value terms, over the 25 year simulation period. A substantial proportion of that expected benefit could be assigned to the new CRC through further development and adoption of the net feed intake technology.

Using a partial equilibrium approach, Sinden *et al.* (2005) estimated that the cost of weeds in Australia across all crops was $1.518 billion per annum, and across the livestock industries was $2.409 billion per annum. ***The CRC for Australian Weed Management*** has recently submitted a rebid proposal, "The Invasive Plants CRC". An economic analysis similar to those mentioned above was undertaken (Jones et al. 2006a,b). The benefits from reducing the impact of weeds across the beef, sheepmeat, wool and cereal cropping industries were estimated using the DREAM model over a 25 year simulation period. The expected net benefit attributable to the investment in the

Invasive Plants CRC is a NPV of $2.642 billion. The beef industry is the largest beneficiary from the Invasive Plants CRC ($881m), followed by the grains industry ($660m). Funding the CRC is expected to result in a BCR of 34:1.

The methods used in the above studies certainly have their weaknesses and these are recognized by their authors. However, the general impression one is left with after reading these studies is that the economic returns from public investment in these three CRCs are substantial.

It should be mentioned that a substantial amount of agricultural research is undertaken at UNE in addition to that undertaken through the CRCs. The CRC research has been highlighted here because of the Commission's wish to have examples of economic impact evaluation.

Suggested Broad Considerations for the Inquiry

UNE wishes to pose the following items as matters deserving attention in the Commission's research study.

- *The continuum of basic research, applied research and technology transfer is essential to maintain innovation flow.* New knowledge acquired via fundamental research is the underlying basis of all innovation. Applied research can take basic research and provide a commercial or community outcome, but in itself it is innovative only in its treatment of novel starting material. Technology transfer then translates the innovation into commercial or community gain. There are two imperatives here. First, it is essential that basic research be supported for its own sake, knowing that commercial and community outcomes may be some years away. Second, institutions that have the capacity and capability for all three links of the chain have the greatest potential to deliver commercial and community outcomes. Plant tissue culture is a good example of this. The technique was first developed as a basic research tool to study plant physiology, with no intent or expectation of commercial application. Applied researchers saw the potential application for plant propagation. Technology transfer has resulted in a huge international industry in plant propagation and breeding via tissue culture.

- *Effective technology transfer requires skills upgrade as well as information transfer.* In an increasingly complex world technology takes many forms and industries are rapidly changing both what they do and how they do it. New knowledge can be applied to develop new products and methods, but if these are not familiar to current practitioners, then uptake and adoption will not occur. In many cases industries require skills upgrade, in the form of education and training, before innovation can be understood and adopted. A crude example is the change from horse-drawn to motor vehicle transport. Presentation of the principles of the internal combustion engine to a blacksmith or to a stable hand would not produce the desired change in behaviour and uptake of the technology. Skills upgrade would be required to equip the blacksmith or stable hand to adopt

the new technology. An example closer to the present is the rapid change in providing the farming sector with information and decision tools software. In many cases, farmers require training in computer use and software navigation before the potential of new products can be realised.

- *An important impediment to future progress is the decline in science enrolments at schools and universities. This must be reversed.* Science enrolments are declining because of the perceived poor career structure for scientists. Lawyers, accountants and doctors, among others, are perceived as having greater earning power and job stability. The conversion from the traditional model of the permanent job for life, to the capitalisation of short-term contract-based opportunities is welcomed by most young people, provided there is continued expectation that well-skilled people have a place. But declining employment opportunities for professional scientists by State Government departments, federally funded groups such as CSIRO and tertiary institutions means that those who might have been interested in postgraduate study in agriculture or natural resources see no clear career pathways and therefore are not proceeding to develop the skills base that will be needed in the next decade to provide the scientific base for land and resource management. This new paradigm of short-term contract employment is failing in the case of science as the dwindling supply of funding jeopardises the prospect of repeat employment. The reality is that in science, talent, achievement and hard work are not passports to the next position and many must make the difficult decision to make a career change to pay the bills. Faced with this scenario, prospective students perceive that science is not a realistic option for the future and make their course decisions accordingly. Until the funding situation for science is improved, enrolments will continue to fall, and Australia will soon be left with a science and innovation void.

- *Research in Australian universities is being impeded by the inability of universities to pay internationally competitive salaries.* Federation Fellowships have helped retain some research talent within Australia but there needs to be more funding to Australian universities to enable them to retain more leading scientists. The United States continues to be the preferred place of work for many Australian scientists.

- *Research in Australian universities is being impeded by poor infrastructure. Infrastructure must be improved.* Equipment infrastructure in particular is ageing and is limiting innovation flow. This is a particular problem for regional universities which have difficulty fulfilling ARC requirements for shared equipment. Cutting edge equipment is essential to facilitate continued innovation flow. The major source of equipment infrastructure for Australian universities is the Australian Research Council infrastructure scheme. This is a competitive scheme, with one of the criteria being equipment sharing between universities to foster and promote collaboration. While this is a laudable goal, it discriminates against regional universities (see discussion of distance considerations below). There are two issues here. First, the decline in equipment infrastructure is a major

limiting factor to science and innovation output in Australia. Second, the decline is more marked in the regions.

- *Science and innovation expertise should be concentrated according to topic and location with the required critical mass and community linkages.* Australia is a large country with a small population. While it may be desirable to have all disciplines and activities represented at all major locations, this is increasingly untenable as the costs of science activities rise. Critical mass of personnel, equipment and relevant industries is essential if Australia is to keep up with other innovation-driven countries, let alone remain at the cutting edge. Hard decisions need to be made to concentrate expertise at the locations best suited to deliver. This should not be left to market forces, as the large populations in the cities will dictate that centres are thus located, so further exacerbating regional decline. The rural sector is an excellent example of an area where expertise and capability is best located where the community linkages exist.

Considerations Particularly Relevant to UNE

UNE would also like to see attention given to some considerations that are particularly relevant to its situation.

- *The spillover values (in terms of both adoption, and secondary effects such as regional development, supporting less advantaged communities and sustainable production systems) are not taken into account when DEST allocates research money to universities.* UNE believes that the spillover value created by its research is large and that this funding failure disadvantages UNE. Hopefully this matter will be addressed by the Commission.
- *UNE's transaction costs (notably travel and communications) are relatively high, and this acts as an impediment to its pursuit of funding opportunities. A targeted form of support would assist in reducing this barrier.* For example, collaborative research funding mechanisms, such as the CRCs, ARC Linkage or more recently the CERF funding, intrinsically requires that there be deep and sustained communication between the collaborating parties well prior to the winning of research funds. From a regional area, this involves very high costs. It requires substantial funds for travel (typically over $500 for each one-day visit to Sydney and much more to other major centres) and a disproportionate time investment. As the success of such collaborations is never assured, on a risk-weighted as well as purely cost basis, this is a serious disadvantage to UNE's participation in many mainstream funding bids even where UNE has the capabilities. The additional costs of interaction are very high compared to urban universities. This places UNE at a disadvantage when it comes to the increasing requirements for collaboration with technically leading (but often less well-embedded) institutions.
- *The imperative for UNE to maintain a sufficient scale of activities to effectively undertake its core activities is not considered in science funding arrangements.* In particular, the need for UNE to ensure that it has a scale of research activities to allow it to maintain and develop its role in training the next generation of

'knowledge brokers' is not taken into account. UNE believes that the issue of research scale and the link to teaching and transfer is a matter that should be addressed by the Commission.

- *UNE has a strong emphasis on 'triple-bottom-line' sustainability. Some aspects of this (notably social and environmental) have low capacity for private support, but are essential to economic productivity over the short, medium and long term.* The funding for social and environmental 'public good' research is increasingly constrained, and as a result is of declining attractiveness to us as well as others. The question is 'if we do not do it, who will?' UNE believes that the issue of the interaction between these forms of research and production improvement research should be addressed, as should the question of funding for this work in its own right.

Overall, for the reasons outlined above, UNE believes that the Productivity Commission should, in designing its research study of public support for science and innovation:

- consider the innovation system and the interactions that make the system work, rather than to place excessive emphasis on the inventive step aspect of that process
- consider the significance of research embedded in the communities who are expected to adopt, and the power that this embeddedness provides in ensuring research relevance, diffusion and adoptive potential
- recognise the vicious cycle that is created through a pattern of allocation purely on the basis of narrow technical criteria for allocation of public research funding, without counting both the impact value and the cost effects of regional location, and a role of supporting industries that remain vital but which face their own economic challenges.

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Appendix

Some Annotated References on Measuring Returns to Agricultural Research and Related Matters (Chronoligical Ordering).

Julian M. Alston, George W. Norton and Philip G. Pardey (1995), *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*, Cornell University Press, Ithaca. Provides a comprehensive coverage of the economic models used in measuring returns to agricultural R&D and methods used in research priority setting. Strong policy orientation.

Alston, Julian M., Philip G. Pardey and Vincent H. Smith (1998), "Financing Agricultural R&D in Rich Countries: What's Happening and Why", *Australian Journal of Agricultural and Resource Economics* 42(1), 51-82. A quantitative analysis of trends in funding for agricultural R&D in 22 OECD countries (including Australia) plus an account of institutional developments in five countries (including Australia).

Alston, Julian M., Michael S. Harris, John D. Mullen and Philip G. Pardey (1999), "Agricultural R&D Policy in Australia", in Alston, Julian M., Philip G. Pardey and Vincent H. Smith (eds), Paying for Agricultural Productivity, Johns Hopkins University Press, Baltimore, 118-171. Reviews Australia's public-sector R&D institutions and provides an empirical analysis of the roles of different research providers and sources of funds. Outlines institutional changes over time.

Alston, J. M., C. Chan-Kang, M. C. Marra, P. G. Pardey, and T. J. Wyatt (2000), *A meta-analysis of the rates of return to agricultural R&D: Ex pede Herculem.* IFPRI Research Report No. 113.Washington, DC: International Food Policy Research Institute. Provides a statistical analysis of the entire body of evidence on returns to agricultural R&D since 1953.

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Outlines how equilibrium displacement modelling can be used as a tool for evaluating the returns from research and their distribution. Application is to the beef CRC headquartered at UNE.

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Philip G. Pardey and Nienke M. Beintema (2001), "Slow Magic: Agricultural R&D a Century after Mendel", Agricultural Science and Technology Indicators Initiative, International Food Policy Research Institute, Washington D.C. Takes stock of trends in investments in, and institutional arrangements for, agricultural R&D and discusses concerns re the changing roles of the private and public sectors especially in the light of revolutionary changes in underlying sciences.

Alston, Julian M. (2002), "Spillovers", *Australian Journal of Agricultural and Resource Economics* 46(3), 315-346. Presidential address to the Australian Agricultural and Resource Economics Society emphasising the ubiquity of research spillovers, their substantial value in dollar terms and the complications they cause for the design of agricultural research policy.

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