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Technology Transfer from Publicly Funded Research for Improved Water Management: Analysis and Australian Examples

by

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Technology Transfer from Publicly Funded Research for Improved Water Management: Analysis and Australian Examples*

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Clem Tisdell†

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TECHNOLOGY TRANSFER FROM PUBLICLY FUNDED RESEARCH FOR IMPROVED WATER MANAGEMENT: ANALYSIS AND AUSTRALIAN EXAMPLES

Abstract

Considerable public funding is provided for research and development intended to improve the management and use of shared natural resources, such as water. In Australia the Land and Water Research and Development Corporation (LWRRDC) and Environment Australia are significant providers of such funds. These providers tend to judge the value of R & D projects supported by them on the basis of whether or not significant technology transfer and adoption takes place. Researchers involved in these projects and expected to be the prime movers of such transfer. However, it seems that research funders have been guided by over simplified models of processes of technology transfer and by false analogies with the transfer of industrial technology. There has been a failure to recognise that much of the new technology developed to improve the management of shared resources, such as water, affects the supply of social or collective commodities, a factor which materially alters the technology transfer process. Here processes of transferring publicly-funded intellectual knowledge are discussed and modelled, dynamic patterns of adoption of new technology are considered along with factors influencing adoption rates and barriers to adoption, particularly when the supply of social or collective commodities such as water, are involved. Some points from the analysis are illustrated by observations from a sample of LWRRDC-supported research projects.

TECHNOLOGY TRANSFER FROM PUBLICLY FUNDED RESEARCH FOR IMPROVED WATER MANAGEMENT: ANALYSIS AND AUSTRALIAN EXAMPLES

1. Introduction

The Australian Government, particularly through the Land and Water Research and Development Corporation (LWRRDC), and more recently the Heritage Fund administered by Environment Australia, has provided support for research and development designed to improve the management of Australia's water systems. Most projects appear to focus on inland waters and several are intended to enhance the ecological health of wetlands and floodplains. The ecological functioning of these wetlands have been adversely affected by increased water deprivation, by lowered and changed patterns of fluctuations in water levels and by reduced or altered water quality, e.g. due to increased salinity and nutrient loads. Research funding has been provided to undertake scientific research and prepare management plans to moderate these effects. Many public funding authorities make the transfer and adoption of resulting technology a test of the value of this research and appear to draw analogies from technology transfer in industry. But because collective or social commodities are involved, this analogy is of limited relevance – social, political and administrative factors influence the likelihood of adoption and transfer in this case. The problem of economic assessment of research projects in this area and technology transfer is discussed with particular reference to selected research projects funded by LWRRDC.

My interest in the technology transfer issues raised by publicly-funded research projects, stems from my joint involvement in a panel study of seven research projects and one research programme (consisting of several projects) partly funded by LWRRDC, an Australian Government corporation. The research projects studied were a selected set of those commenced in 1993 and reported on to LWRRDC by McGregor *et al.,* (1994), Harrison and Tisdell (1997) and Harrison *et al*., (1999), that is both as they were in progress and after the completion of most. Harrison *et al*., (1999) gave particular attention to the transfer of technology and the application of new intellectual knowledge arising from these projects. As a result, it became clear that most of the new technology and intellectual knowledge resulting from most of those projects required their application to social or collective commodities not private ones. Consequently, in this case, processes of technology transfer and application differ radically from those involving the transfer of industrial technology. This appears not to have been fully appreciated by the funders of such research and has been given little attention by analysts of science and technology policy.

The main purpose of this article is to outline and discuss some simple models of the process of technology transfer and to highlight factors which can be expected to be important for this process when the new technology or intellectual knowledge is to be applied to the supply of social or collective commodities, such as is often so in the management of water resources. In turn, the following will be discussed: processes of transferring intellectual knowledge; dynamic patterns of adoption; influences on adoption rates especially if application is to be to social commodities; and observations from some LWRRDC-supported research projects.

2. Processes of Transferring Publicly Funded Intellectual Knowledge

In the theory of science and technology policy, less attention has been to be given to the process of transfer and extension of intellectual knowledge than to processes of R & D itself. While models of innovation and diffusion of new technologies do exist, they are mostly of a mechanical nature, and do not give much attention to the processes involved in the transfer of knowledge. Nevertheless, even simple models of the processes involved can help to highlight important issues and bring order to a situation which otherwise might appear to be disordered.

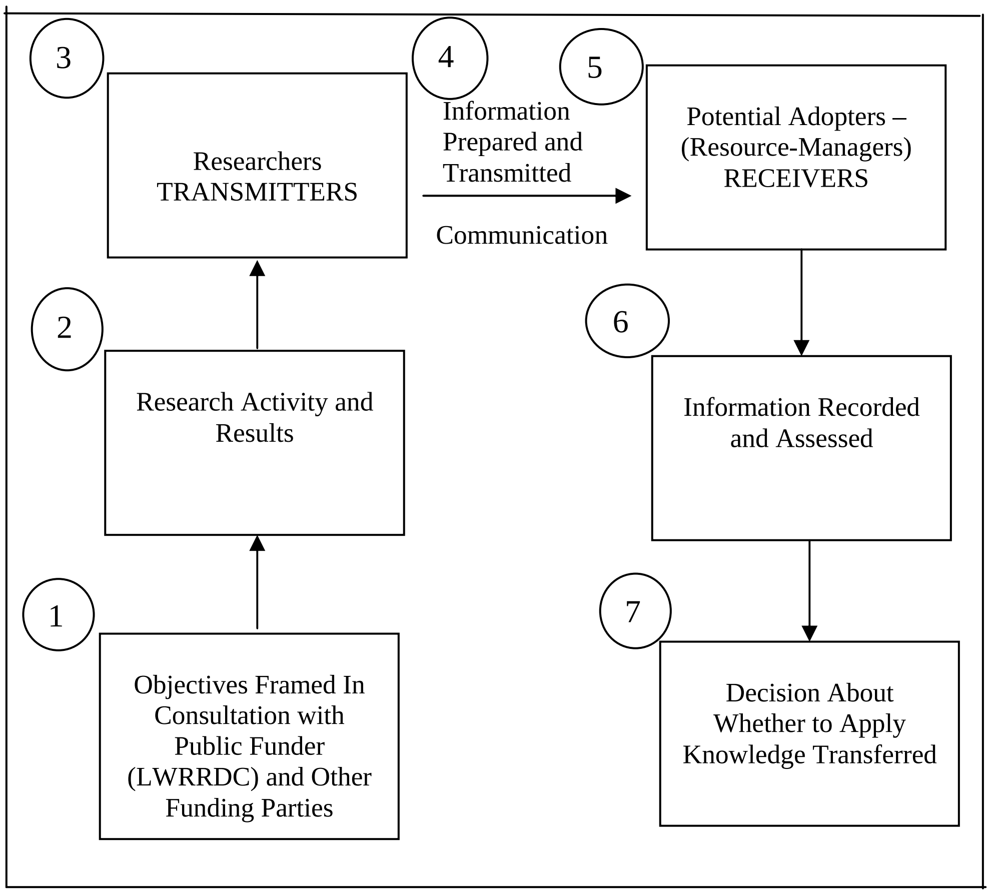

Figure 1: Simple uni-directional model with resource-managers perceived as clients.

A simple model of the process of transfer of technology/intellectual knowledge (which may have guided some of the thinking of LWRRDC and other public bodies on this matter) is illustrated in Figure 1. Researchers are seen as the transmitters who prepare information and transmit it to potential adopters (receivers), usually seen as resource-managers, who then process the information and decide whether or not to apply it to their management of resources. In this model, resource managers are often perceived as ‘clients’.

This model, however, is inadequate for the following reasons:

(1) It gives the impression of the desirability of top-down goal-setting because it is uni-directional. The only possibility for side-by-side direction seems to be in stage (1). That may occur but if the ‘client’ body consulted has a top-down structure, then possibly only those at the top have an influence on the research agenda.

(2) Emphasis is on researchers adapting their research results and communicating these in a form likely to be easily assimilated by potential adopters. This seems to put all the burden of communication on the researchers. Ideally, potential adopters should also search for new ideas. Two-way communication between researchers and potential adopters should exist.

(3) Whether or not resource-managers will take account of information transmitted to them by researchers depends on their receptivity or psychological set. This will be influenced in part by their goals and whether they see the information as relevant to meeting their goals.

(4) Taking into account their goals, resource-managers will decide whether or not to apply the information.

In relation to technology transfer, it is not only the motivation of potential adopters which matters, but also the motivation of researchers to communicate. The motivation of researchers to communicate and transfer their results, their ability to do so and the resources available to them for that purpose; will have an impact on technology transfer. Furthermore, their costs of communication and the effectiveness of it may depend upon the extent to which they are able to use existing networks for communication or must create new networks. Serious difficulties arise when available networks are disrupted, or destroyed by exogenous events, an example of which is given later.

To a considerable extent, the motivation of researchers to communicate their results to adopters depends on their personal benefits or organizational benefit obtained by them. In business, such transfer can translate into extra profit for the firm where a saleable product is involved and possibly future promotion or other economic benefits for the staff members involved . But in academic organizations such benefits are less likely. Publications in academic journals are given more weight than technology transfer in academic organisations. This reduces the motivation of academics to engage in technology transfer. However, the gains to a researcher in this case may come via future grants from bodies which emphasize the transfer aspect, personal satisfaction and extended networks.

Thus to the simple model in Figure 1, we should at least add an extra box or cell to the top row to indicate a number of he factors which influence researchers in their communication of research results. Hence, the top portion of Figure 1 would now look like that shown in Figure 2.

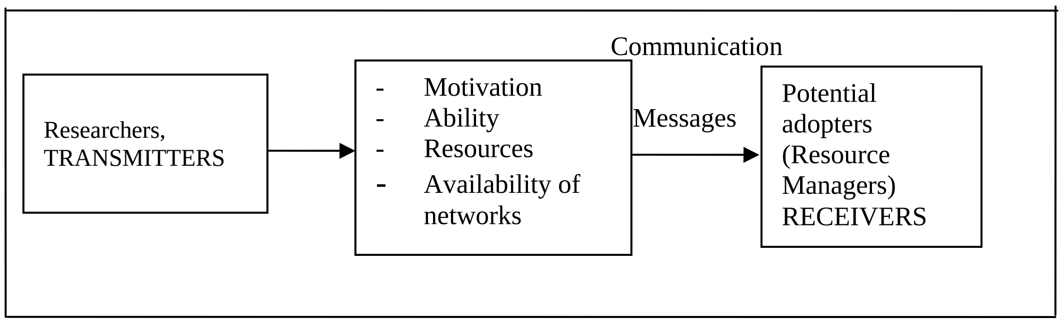

Figure 2 Several factors influence the willingness of researchers to communicate and the effectiveness of communication for technology transfer.

The timing of the communication of research results also has to be considered. First, the results must be such that they are useful from a managerial point of view. Secondly, it is necessary to have confidence in their scientific validity. While early reporting of results has advantages, if there is a risk of communicating results that are insufficiently tested, a degree of caution must obviously be exercised.

Figures 1 and 2 suggest that communication for technology transfer should be focussed on potential adopters. Therefore, it is important that potential adopters be identified by the researchers ideally even before the research commences.

Observe that technology transfer model 1 (Fig. 1) and extended model 1 (Fig. 2) indicate that resource-managers are clients and ought to be targeted for communications by researchers and technology transfer. This focus seems to arise from analogy with transfer of industrial technology for which business managers are the appropriate target group. But in the case of technology with collective application, effective transfer may depend on community or public pressure groups (that is public consumers) demanding application of the technology and signalling this to managers of water or other shared resources via political processes.

Therefore, in cases where collective or social commodities are being supplied as a result of the research findings or a reduction in significant environmental spillovers can be expected from application of the research findings, a range of pressure or interest groups (stakeholders) may have a demand for the research results. This may for example, include environmental interest groups of various kinds, fishers, hunters and so on. In fact, application of these techniques may hinge on such groups exerting sufficient social demand to entice resource-managers to adopt these techniques. This is particularly so for methods or techniques having a substantial impact on collective commodities. Communication with special interest groups extends the number of parties requiring messages and adds to costs of communication by researchers. It also raises the question just how far scientists should be expected to promote communication to foster processes which can become highly political.

Given the importance of public groups for the adoption of technology or intellectual knowledge which may improve management of a shared resource, an additional vertical element should be added to the chart in Figure 1 (and as modified by Figure 2) to capture this. This is indicated in Figure 3. As indicated in Figure 3 by the broken lines, public interest groups will have an influence on decisions by resource-managers to adopt such technology but some of this influence may be indirect, e.g. through politicians.

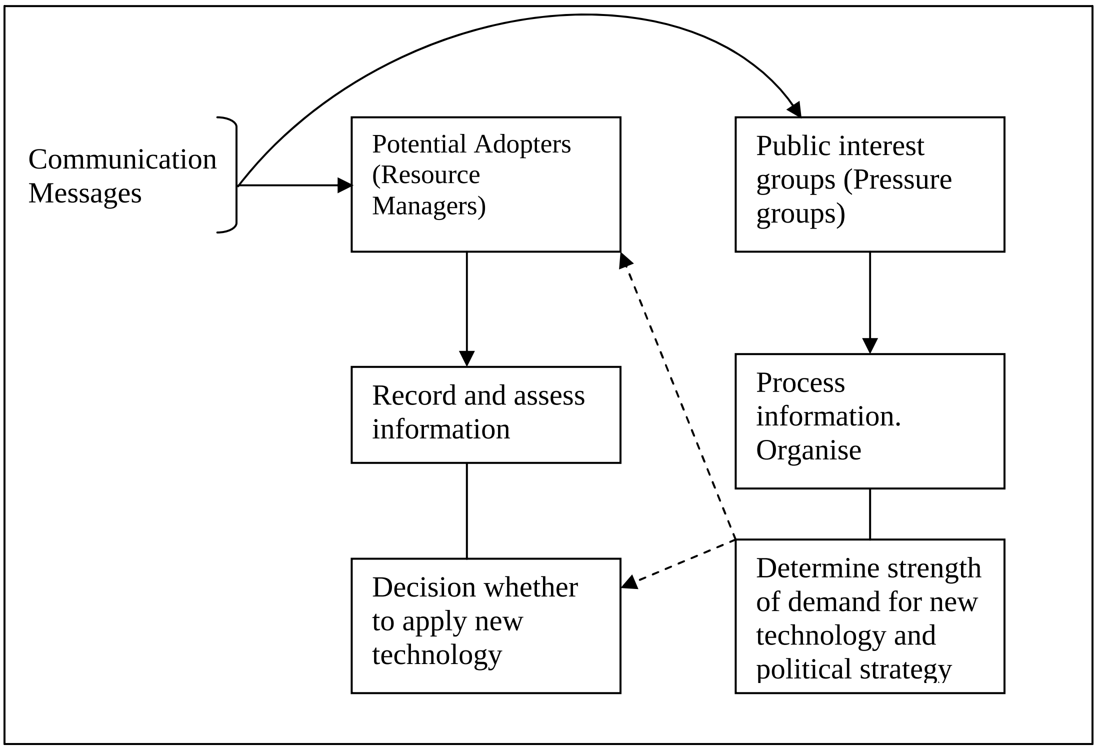

Figure 3 Public interest groups often play a significant role in the transfer of new technology with application to shared resources, such as shared water resources or similar environmental assets.

3. Dynamic Patterns of Adoption of New Technology

The economic benefits from a new useful discovery depends on how long it takes to be adopted and how widely it is used. As explained in Harrison and Tisdell (1997, Ch. 14) the faster the rate of adoption of a new discovery and the more widely it is applied, the higher are its economic returns, other things equal. Because there is usually a significant lag between the completion of research and the successful transfer of results from it, transfer and diffusion patterns for the new knowledge normally remain uncertain for some time after the completion of a research project.

In order to make progress in analysing this matter, it is useful to consider some standard patterns of adoption and diffusion of new discoveries considered in the literature (Cf. Tisdell, 1981, Ch. 3). It is often supposed in the relevant literature (Cf. Griliches, 1957; Mansfield, 1968) that the pattern of adoption of a new useful idea or discovery is likely to take the form shown in Figure 4. There is usually a considerable lag between the discovery and its initial adoption by a potential adopter, that is innovation. Enos (1963) found that lags of fourteen years or so are common in industry between an invention and corresponding innovation, but the length of lags vary widely. If initial trials of a new technique show it to be a success, it is likely then to be adopted at an increasing rate and then at a declining rate as the pool of remaining potential adopters becomes increasingly reduced.

The initial adopters may be the more innovative of the potential adopters and/or those who feel they are likely to gain most by adopting the new practice. The length of the lag to first adoption is likely to be longer, the greater is the uncertainty surrounding the new technique, the higher penalty which applies if it turns out not to be an economic success in practice and the less effective is communication.

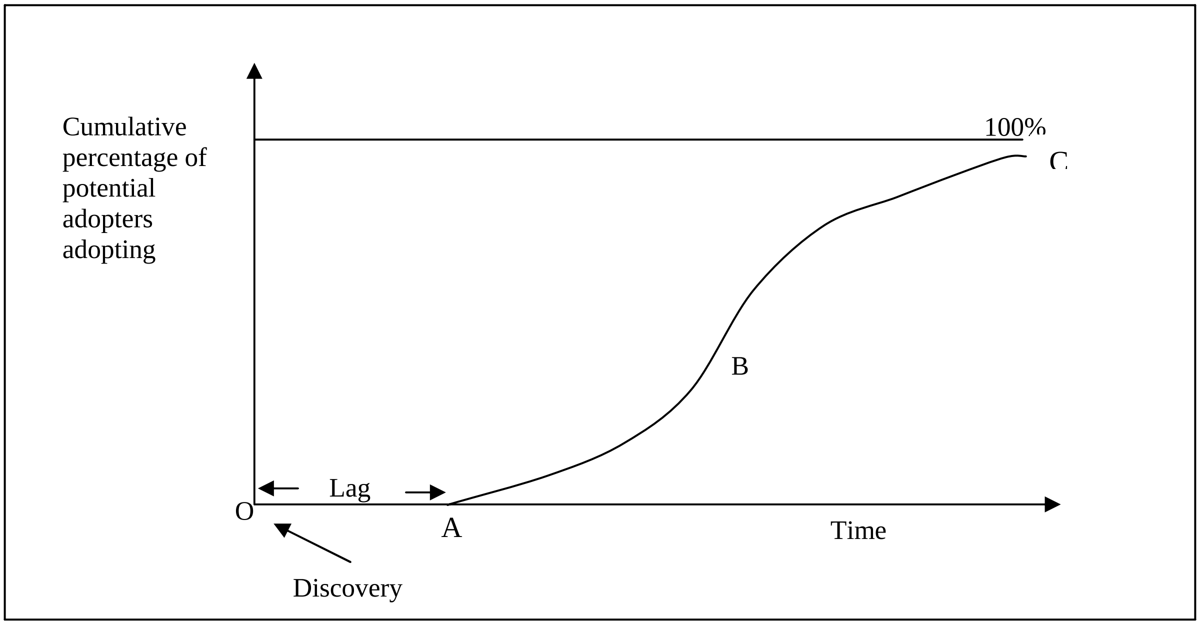

Figure 4 Lagged logistic pattern of adoption of a new discovery

The adoption pattern shown in Figure 4 is of a lagged logistic form or sigmoidal, the latter being the cumulative summation of the normal relative frequency distribution. In some management texts, it is assumed that the distribution of potential adopters is of a normal form with those on the lower tail of the normal distribution being described as innovators or thrusters and those on the upper tail being described as laggards. Sometimes contagion models are used to explain diffusion of processes, as is done by Ozga (1960).

Often, new ideas, products and techniques follow a cycle. They frequently become obsolete after a time and are replaced by superior ideas, products and techniques. Therefore, the adoption curve is liable in some cases to turn down after a point, e.g. point C in Figure 5. When new techniques evolve and result in obsolescence of existing techniques, we may have an adoption pattern for a technique like that illustrated by

Figure 5. In this case, the life of the research project is assumed to be OK and transfer of results begins just before the end of the research project. In some cases, however, transfer may not effectively commence until the research project ceases, as in the case of UMO18. In any case transfer is likely to occur quite late in the life of most research projects.

A number of limitations of this model should be noted. Often a discovery does not occur at a particular point, but continually evolves and develops. This would for example, be true of the list of sensitivity of organisms to salinity developed as a part of LWRRDC project UMO18. Furthermore, no allowance is made for the possibility that some adopters may only partially adopt a new technique and extend its use later if it proves to be successful according to their experience.

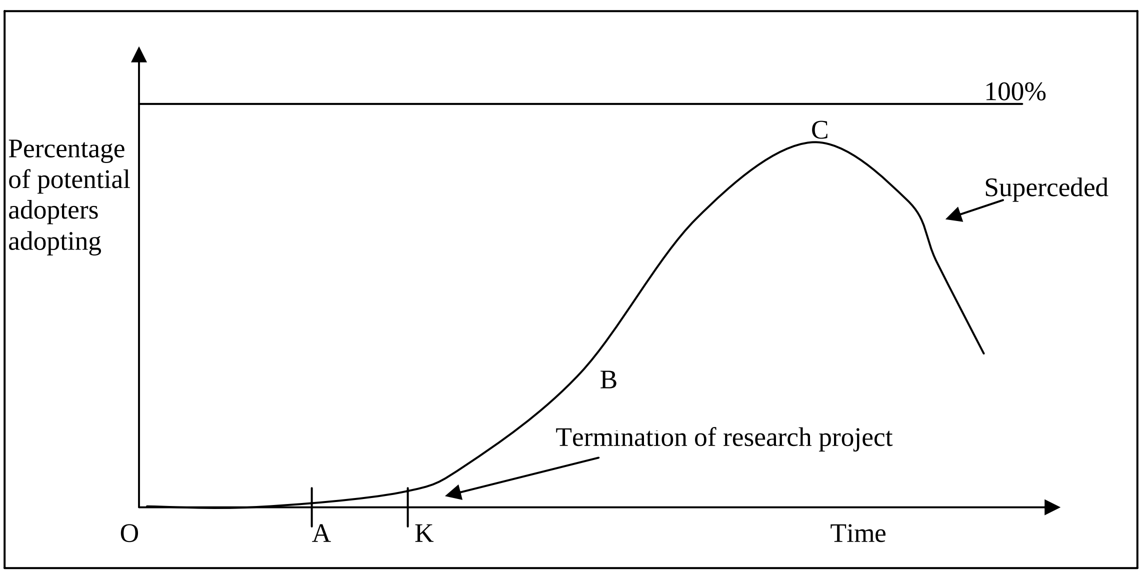

Figure 5 Possible adoption pattern when techniques or management methods may become superceded.

While the type of adoption function shown in Figure 4 may be common other patterns may occur e.g. the adoption relationship could have a number of plateaus, each representing encounter with groups with different degrees of resistance to adopting the new idea. Furthermore, for computational or operational purposes, it may be necessary to approximate the adoption function by a stepped function.

4. Factors Influencing Adoption Rates and Barriers to Adoption

The emphasis in this section is on the factors that may influence adopters to adopt a new technique rather than on communication by researchers, as was mainly so in the previous section.

In relation to industrial techniques, it has been found that new techniques are likely to be more quickly adopted:

(1) the greater is the expected return from their adoption,

(2) the smaller is the amount investment or cost involved in introducing these, and

(3) the smaller is the perceived risk associated with the adoption (Cf. Mansfield, 1968).

Risk will be lower if incremental adoption is possible and if reversibility of the decision is easy. Incrementalism allows for learning-by-doing and only exposes the adopter to low risks initially. Easier reversibility implies greater flexibility and less likelihood of sunk costs being incurred if the adoption does not turn out as expected. Where a new technique requires the use of very specific techniques, and *may* cause irreversible ecological or other damages, this would deter its adoption in land and water management.

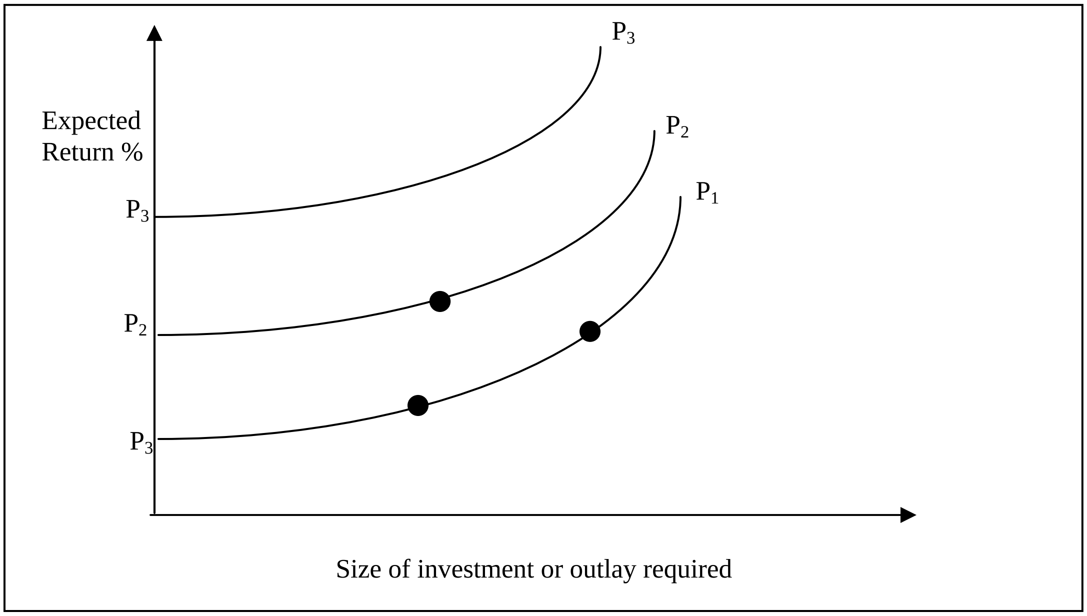

Figure 6 Two variables likely to influence the rate of adoption of new techniques.

In a very simplified case, the relationship between the likelihood of an adopter adopting a new technique in a given interval of time might be like that shown in Figure 6. The curves marked P_1 P_1 , P_2 P_2 , P_3 P_3 represent equi-probability contours. For example, any combination such as that at A or B on P_1 P_1 has an equal probability of adoption but that corresponding to C would have a greater probability of adoption.

While some of the new techniques developed as a result of LWRRDC-supported research will be adopted by private businesses, e.g. improved management of soil compaction and best management practices for cotton growers using pesticides, most appear to depend on adoption by institutions and water regulators, e.g. salinity management in wetlands and riverine areas (UMO18), ecological processes for the management of wetlands and floodplains (DEP1), capacity sharing (UNE11) and so on. In such cases, the process of adoption is liable to be much more complicated than when private businesses are the main adopters. Private businesses are likely to be motivated by private gains.

Institutions, because they are often involved in the control of resources with collective or social uses, must take account of political considerations in their decision-making. Frequently some of the ecological services provided by the management of these institutions are not marketed or are only partially marketed. For example, control of waterflows can affect the conservation of biodiversity and the ecological health of wetlands and riverine areas and these ecological services are not marketed. Demand for these, as a rule, can only be expressed via political mechanisms and social movements, the latter being a part of the so-called civil society. The discovery of methods enabling ecological services demanded by the public to be provided at reduced cost will increase the net social or collective demand for these – they increase the net benefit of providing the services. Furthermore, research which increases the awareness of the cost of losing ecological services may increase public demand for maintaining such services.

The demand for social or collective commodities, such as ecological services provided by water, can be complex because social conflict may arise. The application of new technology may favour one social group at the expense of another, although on occasions no such conflict may exist. When social conflict exists, it may delay the application of new techniques or managerial methods. For example, proposals to introduce increased fluctuations in river levels to improve the ecological health of wetlands and floodplains may be delayed by such factors, as might any new management method which requires greater allocation of freshwater for ecological purposes. While those wishing to improve the ecological health of wetlands may support such measures, *some* farmers, e.g. irrigators, may oppose these measures.

Public choice or political economy factors influence the adoption of techniques which have an impact on the supply of collective or social commodities. A number of the factors which may influence the rate of adoption of such techniques are set out in Table 1. Adoption is likely to be slowed by group conflict, institutional inertia, e.g. because of political caution and slow decision-making processes by resource-managers, institutional rent-seeking, absence of pressure groups to foster politically the adoption of the techniques, and low political capacity of public groups favouring application of the new technique. Commercial groups often have greater political capacity than environmental groups in relation to political decisions about the supply of collective or social commodities. Partly this is because commercial interests are relatively well defined and industries mostly have well-developed networks and associations to support them. On the other hand, environmentalists/conservationists may not be very pro-active due to free-riding, particularly where many members of the public benefit from a conservation activity but each gain by a small amount. In this case, the type of problems arising in the case of supply of public goods, as discussed in the literature, are liable to occur. In fact, accelerating the adoption of techniques for social application may require a degree of *institution building*, such as that being undertaken by Wetland Care Australia.

Nevertheless, the extent to which researchers supported by public institutions should engage in institution building for the purpose of increasing the rate of adoption of techniques is problematic because it goes well beyond the process of scientific inquiry.

Table 1: Factors Likely to Influence the Adoption of Techniques the Application of which Affects the Supply of Social or Collective Commodities

1	**Group Conflict** – If some individuals lose and some gain, this may slow adoption, e.g. changes in riverflows may result in such conflict.
2	**Institutional inertia and self-interest** – Existing management or regulating bodies may have an interest in maintaining the *status quo* and can be quite cautious in making changes. This may, for example, mean that capacity sharing arrangements are slow to be adopted. The exercise of institutional self-interest in maintaining the *status quo* is sometimes described as rent-seeking.
3	**Pressure groups** in existence with well developed networks. Depending on the composition of pressure groups, this may facilitate or hinder the adoption of new techniques. For example, if the group favouring adoption of a technique is poorly organised and its opponents are well organised, adoption is likely to be slowed.

4	The stronger **the social demand for adoption** of a technique the more likely it is to be adopted. Demand is liable to alter as a society develops and awareness will play a role in influencing this demand which in turn can influence resource-managers.
5	The **relative political capacity** of groups in conflict will help to determine outcomes concerning the adoption of technique having a social or collective impact.

5. Observations about Transfer of Intellectual Knowledge from a Sample of LWRRDC-supported Projects

From the above discussion, one might expect, other things equal, longer delays in the adoption of new intellectual knowledge/technologies by public resource-managers controlling the supply of shared resources than in techniques applied to private commodities. The sample of LWRRDC-supported research projects which my colleagues and I have examined (McGregor *et al*., 1994; Harrison and Tisdell, 1997; and Harrison *et al*., 1999) provide some support for this observation. In the sample of one programme and 7 projects, two required adoption of new management techniques by private firms, namely best management practices in use of pesticides by cotton-growers, and methods to avoid soil compaction on cropping lands in the subtropics. While adoption of these practices involves some favourable environmental externalities, basically the decision to adopt is a private decision. These techniques have been adopted relatively quickly. This is more so in relation to techniques to avoid soil compaction which give a high private rate of return. Improved pesticide management in cotton is driven more by the collective fear of loss of rights to use endosulfan if these practices are not adopted in the industry rather than by private profitability. It is being promoted by cotton growers' associations rather than by *individual* profit considerations. The final pattern of adoption has yet to be seen.

Contrasting cases can be identified where resource-managers in public institutions are likely to be the main adopters. Technology transfer in a number of these cases has been impeded by a variety of social factors.

For example, technology transfer and development of LWRRDC-supported research project UMO18 studying the effects of increased salinity on riverine and wetland biota was amongst other things impeded by rapid major restructuring of government institutions in Victoria during the life of the project. In the Victorian government system, water management changed from being relatively centralised to being highly decentralised. As a consequence researchers in this project, lost their initial government contacts and networks. Effective contact with the players in the decentralised system could only be established after completion of this project. The applications of the results of the project were therefore sensitive to variations in public institutions – an aspect beyond the control of the researchers. In this case, there was scope for technology transfer after the completion of the original research project but no available funding for this purpose. In early 1999, the principal researcher was still trying to obtain further public funding to undertake additional technology transfer.

Some worthwhile observations can be made about LWRRDC-supported research project DEP1, ecological processes for the management of wetlands and floodplains which was principally intended to draw on other studies to develop water management practices to improve the ecological performance of wetlands and floodplains (principally on the lower

Murray River) and encourage their adoption. The principal researcher was a senior officer of the South Australian Department of Environment and Heritage. The project had a variety of components. For example, it focussed on:

1. Measures to increase the amplitude of fluctuations in river levels on the lower Murray River, e.g., by manipulation of water releases from weirs.
2. Re-institution of wetting and drying cycles in wetlands.
3. Flushing of wetlands with freshwater to reduce salinity levels and move nutrients into the river.

Wetting and drying cycles have been a normal feature of Australian inland wetlands. But due to engineering works, fluctuations in river levels in the rivers such as the Murray have been reduced. So some former wetlands are rarely flooded. Others are permanently flooded due to the construction of weirs. Increasing variations in river levels will help to restore the ecological functioning and health of the first mentioned wetlands. In the case of permanently flooded wetlands, levy banks may be used to dry out portions of these and flood gates raised after sufficient drying out to flood these areas again. The last strategy, unlike the one mentioned first, can be adopted on a small scale and piecemeal.

Application of this technique to rehabilitate permanently flooded wetland is already occurring with community involvement. It is being promoted by Wetlands Care Australia (formerly Ducks Unlimited Australia) a community volunteer group. In fact this group's principal researcher has joined this organisation on leave from her government Department. Plans are in hand to rehabilitate a significant amount of wetland in this way.

Progress in getting authorities to manipulate water levels in the Murray River with a view to improving the ecological health of wetlands has been slow. Such management involves both winners and losers, e.g., property holders with low lying land will lose. Nevertheless, political pressure is continuing and there are good prospects that a scheme to manipulate fluctuations in river levels on the lower Murray River will be introduced in the foreseeable future. The principal researcher in this project has been active politically and administratively in fostering the application of the proposed water management techniques – all of which involve the use of a shared resource. Use is being made of both right hand branches of the chart in Figure 3. This case illustrates the importance of both resource-managers and public interest groups for the application of new management techniques which affect the supply of collective commodities.

Another LWRRDC-supported research project worth mentioning is UNE11 which was concerned with developing methods for management of water in a market environment using capacity sharing. These methods allow water-users e.g. environmental users, agriculturalist irrigators, to trade in water rights. However, this approach has not been adopted in Australia principally since water authorities wish to retain institutional control of supplies. While the principal researcher effectively transferred the technique to water resource-managers via workshops, their institutional interest was such that they did not apply it. The principal researcher did not target public pressure groups who could have made a political input. Political pressure from water-users (irrigators and environmentalists) seems to be needed to ensure the necessary institutional change in this case.

6. Concluding Comments

This article demonstrates that processes of technology transfer and application of technologies which affect the supply of public or collective goods are much more complex than the transfer of technology to be applied to the supply of private commodities When supply of collective or social commodities is involved, effective transfer usually requires communication not only with resource mangers, but with public interest groups. Socio-political processes are usually involved in decisions about the adoption of techniques influencing the supply of public or social goods. This needs to be recognised by funders of such research. Furthermore, the importance of socio-political processes may make for a slower rate of adoption of such techniques in comparison to techniques to be applied to private commodities, assuming that adoption is of comparable economic value. In essence, greater transaction costs can be expected to be encountered in the case technologies to be applied to the supply of social commodities compared to those to be applied to private commodities. Consequently technological progress may exhibit a bias towards the supply of private commodities rather than public ones, even when R & D is publicly funded to some extent, as it often is for the improved management of shared resources, such as water.

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