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TOWARDS A RESOURCE ECONOMICS FOR ADAPTIVE MANAGERS

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Abstract

Adaptive management has become one of the catchphrases of the sustainable development literature, and is referred to increasingly in natural resource policy deliberations. Its advocates argue that natural resource sustainability issues are addressed more realistically and usefully as complex adaptive systems than as mechanistic systems. Resource economics has conventionally analysed such issues mechanistically, through the method of comparative statics. This paper explores the consequent limitations of conventional resource economics in supporting adaptive management, and offers signposts towards a resource economics with fewer of these limitations.

Keywords: adaptive management, cost-effectiveness, abatement costs, transaction costs, path dependence, increasing returns.

1. Introduction

The term 'adaptive management' is appearing with increasing regularity in Australian policy discussions and documents concerned with sustainable natural resource management (NRM). The call for adaptive management follows from recognition that the search for sustainability in NRM is often highly complicated, so that policy choices need to be made with incomplete knowledge. It therefore emphasises the need for learning, in particular from experiences gained from the policies that are chosen. It proposes that policies be treated as 'experiments' from which learning can occur (Berkes and Folke 1998).

Adaptive management has its origins in the 'adaptive environmental assessment and management' (AEAM) process developed at the University of British Columbia (Holling 1978). An early Australian application of AEAM was in the context of decision support for planning in the Blackwood River Basin in Western Australia (Ewing *et al.* 2000). Perhaps the staunchest Australian advocate of adaptive management has been Stephen Dovers who has proposed that environmental and resource policy in his country has been afflicted too often by " *ad hocery* and amnesia … [T]he potential lessons of both success and failure are not sufficiently pursued, absorbed and acted on to improve our capabilities over time" (Dovers 1999a p. 3).

Recent Australian appearances of the adaptive management concept in government policy documents include: (i) the Murray-Darling Basin Commission's (2002) discussion paper *Sustainable Land Use in Dryland Region's of the Murray-Darling Basin;* (ii) the Murray Darling Basin Council's (2001) strategy document *Integrated Catchment Management in the Murray-Darling Basin 2001-2010: Delivering a Sustainable Future*, where it is referred to as

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"active learning"; and (iii) the (NSW) *Water Management Act 2000 No. 92* (NSW Government 2000) as a water management principle (see Ch. 2, Part 1, Division 1).

As Dovers (1999b) observed, the concern is not that public policy will fail to 'muddle through' but that the muddling through that does occur resembles too often a random walk. In contrast, adaptive management involves a systematic (i.e., non-random) process of choosing policy experiments and learning from them (Berkes and Folke 1998). Such a process requires a theoretical or conceptual framework from which the best-bet hypotheses to be tested can be deduced, and with which experimental outcomes can be interpreted (Marshall 2001). In this paper, a conceptual economic framework for adaptive management is developed, the challenges of applying the framework are explored, and a methodology for addressing these challenges is proposed.

2. Insights from the economics of farmer adoption of agricultural innovations

There are no surprises for resource economists familiar with decision theory (e.g., as presented in Anderson, Dillon and Hardaker 1977) that choices are often made without complete knowledge – i.e., subject to uncertainty. This theory offers a logical framework that decision makers can follow to maximise their welfare (measured as expected utility) consistently with their subjective beliefs about the parameters they are unsure of.

Nor is it a surprise that there is economic value in learning from the experiences gained as a result of decisions one has made. Knowledge gained from experience can be incorporated into a decision maker's prior beliefs using Bayes' Theorem to form revised, or posterior, beliefs that are (depending on the quality of the knowledge obtained) closer to the actual values. The more that learning narrows the gap between beliefs and actual values, the more confident can we be that a 'correct' decision will be made (i.e., one that does actually maximise welfare). The value of the knowledge can be measured as the increase in expected welfare resulting from its availability.

Decision theory has been applied extensively in the economics literature concerned with adoption of agricultural innovations (e.g., Feder and O'Mara 1982; Lindner 1987; Abadi Ghadim and Pannell 1999). A particular parallel with adaptive management's view of policies as experiments to be learned from is the adoption literature's discussion of the value to farmers of trialling an innovation on a small scale before deciding whether to proceed with full-scale adoption. Although small-scale trialling of an innovation is unlikely to generate knowledge as quickly as launching into full-scale adoption, trialling is less prone to irreversibility provided it involves fewer sunk costs. Under conditions of uncertainty and dynamic learning, Abadi Ghadim and Pannell (ibid.) observed that postponing full-scale adoption has an 'option value' to the extent that this adoption involves sunk costs, and postponement therefore avoids loss of flexibility in adapting eventually to the 'correct' adoption decision. It follows that the option value associated with trialling exceeds that with full-scale adoption provided that sunk costs in trialling are lower.

3. Towards an economic framework for adaptive management

A normative economic framework for analysing policy choices between alternative institutional options has been developed by Challen (2000). The criterion for institutional choice is cost-effectiveness in achieving a given policy objective, where the relevant costs consist of transaction costs. North (1990) defined institutions as humanly-devised rules of behaviour that shape human interaction, while Furobutn and Richter (1992 p. 8) regarded transaction costs as "most easily understood as embracing all those costs that are connected with (i) the creation or change of an institution or organisation, and (ii) the use of an institution or organisation".

Challen (2000) distinguished 'static' and 'dynamic' transaction costs. He defined dynamic transaction costs as the costs incurred in effecting institutional change, and static transaction costs as the costs of decision making within a given institutional structure. As such, they correspond respectively with types (i) and (ii) in Furobutn and Richter's (1992) foregoing definition of transaction costs.

Two types of dynamic transaction costs were also distinguished by Challen (2000). The first of these comprises the 'transition costs' of decision making and implementation for institutional change in the current period. These costs arise as a function of the *status quo* institutional structure. The costs of the following aspects of institutional change were included as transition costs (ibid.):

- research and institutional design;
- negotiation, bargaining and decision making;
- political repercussions to decision makers;
- institutional creation, including the drafting of legislation, policies, regulations, etc.;
- implementation, including establishing regulatory organisations and programs and conducting education activities;
- obsolescence of organisations and human capital associated with pre-existing institutional structures;
- social displacement of individuals and firms affected by institutional change;
- compensation payments to persons or firms disadvantaged by institutional change;
- costs associated with lobbying and rent-seeking behaviour of interest groups; and
- increased perceptions of sovereign risk and policy uncertainty.

Challen (ibid.) argued that current institutional choices create future path dependencies and thereby affect future transition costs associated with changing to new institutional structures. He defined institutional path dependencies as:

> … occurring where opportunities for institutional reform are constrained by the current institutional structure. The constraints arise through a current institutional structure determining the costs of transition to alternative structures. An institutional *status quo* determines the processes for institutional change and also creates vested interests for certain groups within society who resist institutional changes that threaten these interests. Where the holders of these interests have the ability to impose costs on the political decisions makers for institutional reform, they can influence the costs associated with certain options for reform and hence the relative appeal to political decision makers of the different options (ibid. p. 7).

Accordingly, the second type of dynamic transaction costs were identified as 'intertemporal opportunity costs' that arise when institutional change in the current period increases the transition costs of possible future institutional changes. This will be the case when (a) uncertainty exists in relation to choosing the optimal institutional structure, and (b) institutional change is characterised by irreversibility, defined broadly as meaning that today's choice affects tomorrow's choice possibilities. Challen (ibid.) equated intertemporal opportunity costs with a loss of quasi-option value, in the sense that increased future transition costs reduce the capacity to adapt a current institutional structure in response to learning and new knowledge. Loss of such capacity thereby diminishes the prospect of moving to a 'correct' institutional structure within a given period.

4. Extending the framework to include abatement-cost effects

According to Challen's (ibid.) cost-effectiveness criterion for choosing between institutional alternatives, the optimal institutional structure is that which minimises a sum of static transaction costs, transition costs and inter-temporal opportunity costs. However, this criterion does not consider all the relevant costs. Institutional choices influence abatement costs as well as transaction costs. It is conventional wisdom amongst resource economists, for instance, that market-based institutional instruments achieve an aggregate abatement target with lower abatement costs than is the case with command-and-control instruments. In some cases the transaction cost advantages of an institutional alternative may be outweighed by disadvantages in terms of abatement costs (McCann and Easter 1999). Comprehensive cost-effectiveness analysis in institutional choice therefore involves identifying the institutional alternative that minimises the sum of abatement and transaction costs in achieving a policy objective.

As for transaction costs, static and dynamic types of abatement costs can be distinguished. Static abatement costs are the costs of operating a given abatement technology. Dynamic abatement costs are the costs arising from changing abatement technologies in response to a given institutional change. As with transaction costs again, two types of dynamic abatement costs can be distinguished. The first type comprises the transition costs of implementing an abatement technology change in the current period. These costs will here be called technological transition costs (as distinct from institutional transition costs, which Challen (2000) called transition costs).

As discussed in Section 2, abatement decisions are irreversible to the extent that implementing them involves sunk costs. Hence, irreversibility of current institutional choices does not arise only from any effects these choices have on the transition costs of moving in the future to alternative institutional structures. It arises also from any effects these current institutional choices have on future transition costs arising in changing to alternative abatement technologies. Consider, for instance, two institutional options involving command-and-control prescription of what abatement technology should be adopted by a particular group of farmers. The technology prescribed by each option is different, but the total cost of implementing each is the same. However, the technologies differ in the extent to which their total costs are made up of sunk costs. Adoption of the technology with the higher share of sunk costs would be more irreversible. Hence, the institutional reform effort (e.g., in terms of the magnitude of financial incentives needed to induce adoption) required to effect a shift to a superior abatement technology would be greater for the high-sunk-cost technology.

Hence, the second type of dynamic abatement costs arises from the effect of a current institutional choice on the technological transition costs of possible future institutional or technological changes. This type of dynamic abatement costs will here be called inter-temporal abatement costs, as distinct from inter-temporal transaction costs. Inter-temporal transaction costs were called intertemporal opportunity costs in Challen's (2000) framework.

When Challen's (ibid.) cost-effectiveness criterion for optimal institutional choice is modified in view of these considerations, it becomes one of identifying the institutional structure that minimises the sum of transaction costs (static and dynamic) and abatement costs (static and dynamic) associated with satisfying a given policy objective. Once the transaction and abatement costs are broken down as described above, the criterion involves finding the institutional structure that minimises the following sum (discounted appropriately, since these costs arise over time):

Static abatement costs

+

Technological transition costs

+

Inter-temporal abatement costs

+

Static transaction costs

+

Institutional transition costs

+

Inter-temporal transaction costs

5. Applying the framework

Given that this criterion explicitly considers the consequences of current institutional choices for learning, and thus for ongoing societal capacities to adapt towards 'correct' choices, it offers a conceptual economic framework upon which to base decision making in adaptive management (provided that the societal distribution of abatement and transaction costs is assumed to affect economic welfare only to the extent that it affects the sum of these costs). However, *ex ante* application of this framework to actual institutional choices presents a real challenge. It involves predicting the effects of each institutional alternative in terms of each of the cost components included in the framework.

Although far from simple, we might expect prediction to be easiest for static abatement costs and technological transition costs. Indeed, resource economists have conventionally based their comparisons of NRM policy alternatives on comparisons of these costs. We can expect the task of predicting static transaction costs and institutional transition costs to be considerably more difficult. Challen (2000 p. 207) remarked that rigorous practical application of his framework "is impeded by a lack of techniques and methodology for *ex ante* estimation of transaction costs". He attributed the problem of predicting these costs to "their diversity, uncertain functional relationships between the costs and their determinants, many costs being implicit or indirect, and many costs not being easily quantified in dollar terms" (ibid. p. 192). Nevertheless, he was somewhat optimistic that the problem might eventually be overcome. Indeed, significant progress has been made in developing typologies of transaction costs (e.g., Thompson 1999) that at least provide a coherent structure for *ex ante* estimation of static transaction costs and institutional transition costs.

The problems faced in predicting technological and institutional transition costs will arise also in predicting inter-temporal abatement and transaction costs, respectively, since the inter-temporal costs comprise future effects on transition costs. In addition, as observed by Challen (2000 p. 192), prediction of inter-temporal transaction costs (as measured by quasi-option values) faces the formidable complication of learning not being stochastically predictable since the possible learning scenarios and their probabilities cannot be known *a priori*. This observation applies also to prediction of inter-temporal abatement costs.

6. Increasing returns, path dependency and multiple equilibria

This problem of stochastic unpredictability derives from the path dependencies responsible for both inter-temporal abatement and transaction costs. In turn, these path dependencies result from sunk costs. If the only sunk costs were those incurred in making and implementing an initial institutional choice, predicting the consequences of the associated irreversibility would not be so hard. However, as highlighted in Challen's (ibid.) discussion of institutional path dependencies quoted above, it is in the nature of institutional choices that the rest of the economic system is shaped by the new incentives these choices create. The new incentives affect agents' choices within that system and thus the sunk costs *they* incur. This influence on agents' choices also affects what they are likely to experience, and thus the beliefs they come to hold. Any change in beliefs affects their next round of choices, and thereby sets each agent off down an unpredictable evolving path of actions, sunk costs and irreversibilities. Given the centrality of beliefs to human self-identity, moreover, coming to hold new beliefs can also often lead to sunk costs of an emotional kind (North 1990).

As agents within an economic system respond to an initial institutional choice and the system changes as a consequence, this creates new patterns of incentives to which the agents respond once again, thus creating a yet newer pattern of incentives, and so on. Complexity economists such as Arthur (1999) refer to this kind of co-evolving relationship as a complex adaptive system. The elements of such systems "adapt to the world – the aggregate pattern – they co-create. … As the elements react, the aggregate changes; as the aggregate changes, elements react anew" (ibid. p. 107). The process of co-evolution between the system and its elements is driven by positive feedbacks, which economics refers to as increasing returns. By reinforcing an initial change in an economic system, such as an institutional change, increasing returns contribute to path dependency and thus affect inter-temporal abatement and inter-temporal transaction costs. Increasing returns also reinforce small random events (e.g., weather changes, chance meetings, unintended non-cooperation, serendipitous discoveries, etc.) met anywhere in the system. As a result, the trajectory of a path commenced by making an institutional choice, and thus the inter-temporal abatement and transaction costs associated with that choice, is shaped randomly to a significant degree.

7. Path dependency in adoption of abatement technologies

While path dependency has received considerable attention from economists in respect of institutional choices, there seems to have been little explicit recognition of its relevance for landholders' choices of abatement technologies. Nevertheless, implicit recognition of this relevance by resource economists is sometimes evident. For instance, Pannell (1999a p. 3) observed as follows how sunk costs associated with farmers adopting abatement technologies can lead to irreversibilities, losses of option value and thus (implicitly) to path dependency in their adoption choices:

> [I]f a conservation practice is itself irreversible to some extent (or expensive to reverse), then there is an option value in not adopting it. For example, this would apply to the planting of trees on crop land to avert salinity.

He also recognised, as follows, that farmers' experiences with previous adoption decisions can affect their subjective beliefs and consequently their subsequent adoption decisions:

> [F]armers are likely to come to any radical innovation with scepticism, uncertainty, prejudices and preconceptions. Unless they are new to farming, they will have trialed other innovations in the past and concluded that at least some of them fell far short of the claims made for them (ibid. p. 2).

And:

> Even if farmers are not discouraged by uncertainty *per se*, they may well be discouraged by the consequences of that uncertainty, particularly if it results in inaccurate perceptions or misinformation. … If a farmer perceives incorrectly that an innovation is not consistent with their objectives, this misperception is an impediment to adoption. … If a farmer does not conduct trials, a chance to correct the misinformation is missed. Indeed, if the farmer is badly misinformed, this in itself may cause the farmer to believe that a trial is not worthwhile, trapping him or her in a state of ignorance (ibid. p. 3).

Moreover, he argued that inter-farmer learning cannot always be relied upon to provide an escape from this trap:

> Information from observing other farmers' experiences with the innovation provides a potential way out of this vicious cycle, but in cases where adoption levels are persistently low (as with some conservation measures) even this solution is unavailable. The social process of diffusion of innovation is very unimportant …, but it depends on early adoption by a minority to seed the process (ibid. p. 5).

In contrast, Lindner (1987 p. 146) argued as follows, admittedly in reference to agricultural production technologies which typically involve less uncertainty than abatement technologies (Pannell 1999a,b), that each landholder will eventually arrive at the 'correct' decision for him or her as a result of learning through their own trial and error and/or that of other landholders:

> [D]iffusion of an innovation amongst a population of potential adopters essentially involves a transition over time and space from a situation of incomplete knowledge to one of complete knowledge. Many individuals, through ignorance, initially make adoption decisions which are not in their own best interest, but progressively such errors are corrected through the accumulation of knowledge.

Lindner's (ibid.) presumption, following Schultz (1975), was that the framework of comparative statics is appropriate for economic analysis of the diffusion process for an agricultural production technology. According to this framework, a new technology becoming available for adoption disturbs the existing equilibrium and establishes a unique new equilibrium. The economy arrives eventually at this new equilibrium once learning by farmers has provided them each with compete knowledge about the new technology and they thus come to make the adoption decisions that are 'correct' for each of them.

Where increasing returns and consequently path dependency are expected to impact significantly on adoption choices, and thereby on learning, analysing these choices on the basis of comparative statics is not appropriate. As Alfred Marshall (1920/1890) observed long ago, use of the comparative statics framework assumes that increasing returns are sufficiently unimportant for the problem at hand that they can be safely quarantined in "a pound called *Caeteris Paribus*" (ibid. p. 92). When increasing returns *are* important for the problem at hand, we can expect a multiplicity of possible equilibria, with the equilibrium chosen depending on random events, or perhaps even continuing non-equilibrium. In such cases a complex adaptive systems framework seems more appropriate, portraying as it does the relevant economic system "not as deterministic, predictable, and mechanistic but as process dependent, organic, and always evolving" (Arthur 1999 p. 109).

8. Applying the framework inductively

The foregoing discussion indicates that the task of applying a cost-effectiveness criterion to NRM institutional choices is even more challenging than Challen (2000) found it to be. Continuing development of techniques for *ex ante* estimation of static transaction costs and institutional transition costs would undoubtedly lessen this challenge to some extent. Estimation of these costs would certainly be a major advance on the current situation where most *ex ante* economic comparisons of NRM policy options consider only the implications for abatement costs (see McCann and Easter (1999) for an exception).

Progress in overcoming the serious difficulties of predicting inter-temporal transaction and inter-temporal abatement costs seems likely to elude us, however, until we adopt a methodology that is well-matched to the complexities of the task at hand. Arthur (1994) has argued that the conventional economic methodology of understanding human behaviour through rational deductive reasoning (i.e., deriving a conclusion by perfect logical processes from well-defined premises, as exemplified by comparative statics) demands too much of human cognitive capacities once a certain level of complexity is exceeded. As he observed, modern psychology tells us that humans faced with complicated problems:

> … look for patterns; and we simplify the problem by using these patterns to construct temporary hypotheses to work with. We carry out localized deductions based on our current hypotheses and act on them. As feedback from the environment comes in, we may strengthen or weaken our beliefs in our current hypotheses, discarding some when they cease to perform, and replacing them as needed with new ones. … Such behaviour is inductive (ibid. 406-07).

Inductive reasoning of this kind seems a promising strategy for resource economists to pursue in attempting to cope with the complexities of comparing the cost-effectiveness of NRM institutions. Indeed, Challen (2000) and Marshall (2001) have suggested that the inductive approach used by Ostrom (1990, 1998) for identifying 'design principles' for common-property institutions be adapted by resource economists in order to deal with a wider diversity of institutional forms. These design principles would serve as heuristics (or 'rules of thumb') for predicting the performance of particular institutional arrangements). One candidate for such a heuristic is Challen's (2000 p. 178) assertion, based on the reasoning below, that inter-temporal transaction costs tend to be higher the more that property rights are decentralised:

> Generally speaking, the political ramifications of institutional change are greater if the costs and/or benefits of change are incurred by small and/or concentrated groups in society that are able to mobilise resources for political lobbying, as opposed to large and/or dispersed groups. Consequently, it is relatively easy (low cost) for political decisions to be made that transfer property rights from a large dispersed group to a small concentrated group, but relatively difficult (high cost) to make the reverse change.

An inductive approach to identifying institutional design principles involves searching for regularities in the behaviour and performance of particular institutional forms across multiple case studies. A meta-theoretical framework can help to store, organise and interrogate the data from the case studies systematically, in order to facilitate recognition of robust patterns in the data that might serve as design principles. Ostrom (ibid.) and others have used the Institutional Analysis and Development (IAD) framework for this purpose. The rational-choice foundations of this framework make it particularly well suited to resource economists. Design principles emerging from such an approach will never give precise indications *ex ante* of the performance of particular institutional options. However, they can at least offer rough indications grounded in empirical evidence.

9. Summary and conclusions

This paper has sought to contribute towards a resource economics capable of addressing the concerns prompting increasing interest in an adaptive management approach to NRM policy. This interest seems to stem from a growing acceptance that NRM policy choices are often subject to such uncertainty that there is a low chance of making the 'correct' choice at the outset. The best that can be hoped for in such situations is to continue seeking better knowledge, including through treating the institutional options chosen as 'experiments' to be learned from, in order that we might at least move closer to the 'correct' choice over time.

Accordingly, a resource economics framework for adaptive management needs to be able to account for the consequences of particular institutional choices for subsequent learning opportunities. The search here for a conceptual framework with such capability began on ground that would be familiar to many resource economists; namely, in the economics literature concerned with adoption of agricultural innovations. A useful insight from this literature is that the choice of whether or not to adopt an innovation, or whether to conduct a trial prior to considering full-scale adoption, affects future learning opportunities by influencing sunk costs. To more that sunk costs are incurred as the result of a choice, the more costly will it be to reverse that choice, and therefore the fewer opportunities will there be to learn from experience, *ceteris paribus*. This loss of learning opportunities is referred to in this literature as a loss of option value.

The search continued by considering a cost-effectiveness framework for institutional choice developed by Challen (2000). This framework contributes in two ways to a resource economics framework for adaptive management. First, it provides a vehicle for *ex ante* assessment of the (transaction) costs of making and implementing institutional choices. Until now, very few *ex ante* comparisons of institutional options by resource economists have considered these costs. Second, it recognises that current institutional choices reduce future learning opportunities by increasing, through path dependency, the transaction costs of possible future institutional changes. Challen (ibid.) proposed that this loss of learning opportunities be understood in economic terms as a loss of quasi-option value.

This cost-effectiveness framework for institutional choice accounts for only the transaction-cost consequences of any choice, overlooking in the process the abatement-cost consequences. Choices between institutional options will typically affect abatement costs as well as transaction costs, and abatement-cost effects can be expected to vary considerably between options. Challen's (ibid.) framework was therefore extended to account for both the abatement- and transaction- cost implications of institutional choices. The consequences of a current institutional choice for future flexibility in adoption choices, through affecting sunk costs and also through other mechanisms of path dependency, is accounted for in the extended framework. The loss of learning opportunities due to reduced future flexibility in adoption choices can be interpreted in economic terms as a loss of quasi-option value.

Practical application of the extended framework presents a formidable challenge to say the least. The greatest difficulties lie in *ex ante* estimation of the quasi-option values, since these values evolve path-dependently within complex adaptive systems. Given the complexity of attempting to predict these values through the method of deductive logic conventionally used in economics, an inductive approach appears to offer better prospects of predicting the quasi-option values with some level of confidence. The aim of such an inductive approach would be, through looking systematically for patterns across multiple case studies, to derive institutional design principles capable of generating at least coarse predictions regarding the implications of particular institutional options for quasi-option values (and perhaps also for other values for the other variables in the cost-effectiveness framework).

Despite the real difficulties involved in applying a cost-effectiveness framework for institutional choice, the framework developed will be of significant practical value if it prompts policy makers to consider more consciously and comprehensively the implications of alternative institutional options when they choose between them. A further practical benefit would arise were the framework to enhance the learning that does occurs from institutional choices, by identifying the range of considerations of relevance for assessing *ex post* the economic performance of the options tried.

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