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TRANSACTION COSTS, COLLECTIVE ACTION AND ADAPTATION IN MANAGING SOCIAL-ECOLOGICAL SYSTEMS*

Graham R. Marshall

Institute for Rural Futures, School of Behavioural, Cognitive and Social Sciences,
University of New England, Armidale NSW 2351 Australia
Email: gmarshal@une.edu.au

Abstract:

Adaptations in environmental management often involve complex problems of collective action. Institutions introduced to reduce the transaction costs of solving these problems often come at considerable cost. An Institutional Cost Effectiveness Analysis Framework (ICEAF) developed to provide a comprehensive and logical structure for economic evaluation of path dependent institutional choices in this domain, and a procedure for boundedly rational application of the framework, are proposed and illustrated in this article – including for the choice between water buy-back and infrastructure subsidy programs for recovering the 'environmental water' required to sustain the ecosystems of the Murray-Darling Basin. A research strategy developed to strengthen the knowledge base for applying this procedure is also proposed.

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1. Introduction

Adaptation has long been central to the subject matter of economics. The mainstream economic focus in this area, associated with conventional neoclassical economics, has been on individuals adapting to changes in demand or supply conditions of the markets where they transact with one another in pursuing their self interest. The focus has thus been on adaptation via transactions over private goods. It has been assumed that markets operate mechanistically and thus the consequences of changed conditions for adaptation decisions, or of adaptation decisions themselves, can be accounted for comprehensively using standard decision theory.

Attention from policy makers and scholars to understanding human adaptation has escalated over recent decades alongside recognition of the rapidly multiplying and intensifying adaptation challenges to be faced from changes in the behaviour of climate, freshwater and other natural systems. Indeed, some leading scientists have concluded that the Earth has already experienced a transition from the Holocene epoch of around the last 10,000 years, during which human cultures developed within relatively stable natural environments, to a new epoch, the Anthropocene, where 'the impacts of human activities are so pervasive and profound that that they could inadvertently alter the Earth System in ways that may prove irreversible and inhospitable to humans' (Biermann et al. 2010 p. 202).

These adaptation challenges differ in two key ways from the kinds of adaptation on which mainstream economics tends to focus. Firstly, 'the ability of societies to adapt is determined, in part, by the ability to act collectively' (Adger 2003 p. 387) and steer this action towards adaptation rather than mal-adaptation. Such collective action is required where effective adaptation involves the provision of collective goods (public goods and common-pool resources (Ostrom 1990)) which, because their benefits cannot be appropriated exclusively by those providing them (Olson 1965), will not be provided through market transactions. The focus of economists in analysing contemporary adaptation challenges therefore needs to be broadened to encompass adaptation via collective action. Secondly, the dynamics driving many contemporary adaptation challenges in managing natural systems are most appropriately characterised as those of a positive-feedback kind exhibited by complex adaptive systems (Ostrom 1999; Marshall 2010; Anderies et al. 2004). The mainstream economic assumption that such dynamics are mechanistic therefore needs to be reconsidered when analysing such adaptation challenges.

The gains from adaptation invariably come at a cost, and this cost normally comprises both transformation costs (otherwise known as production or abatement costs) and transaction costs. Due to the influence of the new institutional economics which has sought to integrate transaction costs within a conventional neoclassical framework, mainstream economics has come to accept the importance of accounting for transaction costs as well as transformation costs in comparing decision options. McCann et al. (2005 p. 527) found that transaction costs can represent a substantial proportion of the overall costs of environmental management initiatives and that these 'nontrivial magnitudes mean that transaction costs will affect the optimal choice and design of policy instruments'. However, they found that 'in practice, transaction costs are not normally included in empirical evaluations of alternative environmental or natural resource policies' and that this 'hinders comparative policy evaluation' (ibid. pp. 528, 538).

Paavola and Adger (2005 pp. 365, 358) 'argue[d] for 'institutional ecological economics' as a promising cross-over between a new institutional economics and ecological economics', while observing that 'the concept of transaction costs contributes to institutional ecological economics by facilitating detailed analysis of policy problems and governance solutions'. The aim in this paper is to contribute towards this emerging economic tradition in key ways related to the weaknesses

identified above of mainstream economics in analysing contemporary adaptation challenges in managing the environment. These contributions relate to:

- the collective action dimensions of adaptation in managing complex social-ecological systems (SES) (section 2 below);
- the roles of (adaptive) governance and institutions in dealing with these dimensions (section 3);
- transaction cost issues in managing these dimensions, including in respect of the path dependencies and surprises often encountered in such efforts (section 4);
- an appropriate framework and procedure for ex ante evaluation of institutional cost effectiveness in managing complex SES (section 5); and
- an appropriate research strategy for supporting the application of this framework and procedure (section 6).

2. Adaptation and collective action in environmental and natural resources management

Smit and Wandel (2006 p. 282) found that definitions of 'adaptation' in the human context usually refer 'to a process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity'. This concept refers both to the building of adaptive capacity, which strengthens the ability of individuals, associations, organisations, governments and other enterprises to adapt to changes, as well as to the conversion of that capacity to action by way of implementing adaptation decisions (Adger et al. 2005). Adaptive capacity is dynamic, influenced by interplay between multiple factors including: natural, economic and human resources; infrastructure; social capital; institutions; governance; human resources; technology; and levels of societal equity (Adger et al. 2005). Bridging barriers to implementation of adaptation options can be an important way of building adaptive capacity. Such barriers can arise from natural, technological, financial, cognitive and behavioural, social, or cultural constraints, as well as from market failures (e.g., collective goods and imperfect information) and policy and regulatory failures.

Whether as implementation of adaptation decisions or building adaptive capacity, adaptation in response to environmental changes often involves collective action (McCann 2013). This is the case when the benefits arising from adaptation efforts by individual enterprises (individuals, households, firms, organisations, government agencies, governments, etc.) constitute collective goods that cannot be captured exclusively by those enterprises.

Consider implementation of a farmer's decision to adapt to an expected decline in surface water availability for irrigation by reducing her pumping of groundwater in order to increase the volume of such water remaining available when access to surface water does decline. If the aquifer holding the groundwater is a common-pool resource shared by neighbouring landholders, this farmer will not be able to exclude these other landholders from sharing in the benefits from her implementation efforts of the additional groundwater remaining in the aquifer. Anticipating this problem with her adaptation plans, she may explore the option of strengthening her adaptive capacity in implementing those plans by lobbying the relevant government agency to develop a system of individualised groundwater property rights that would help overcome the excludability problem she faces. Again, however, she would not be able to exclude her neighbours from sharing in any benefits arising from these efforts to build her adaptive capacity. Their capacities to adapt to anticipated declines in surface water availability by individually 'storing' groundwater to be used in this eventuality would also be strengthened.

Successful adaptation does not always involve collective action. Another way for the farmer in our example to adapt to declining surface water availability for irrigation would be to adopt technologies (e.g., tailwater recycling systems) that increase her water-use efficiency. Increasing her adaptive capacity in respect of adopting such technologies might involve commissioning consultants to advise how they would best be applied in her context, or else attending field days where relevant information is provided. The benefits from each of these adaptation efforts constitute private goods for this farmer in so far as they can be captured exclusively by her.

Nevertheless, societal capacities to adapt to environmental changes are normally influenced significantly by their abilities to act collectively (Adger 2003). Many of the fundamentals of adaptive capacity in this sphere – including social capital, institutions, governance arrangements, national economic wealth, research and development programs, public awareness and education programs, and monitoring and evaluation systems – are collective goods. Governments are themselves exercises in collective action. It is important then to understand the collective action dimensions of human adaptation to environmental changes.

3. Collective action, governance and institutions

3.1 Trust, reciprocity and collective action

The externality problem in providing collective goods becomes greater the larger the group of members who would benefit from the good. The larger the group, the smaller the proportion that individual members capture from the benefits of their respective contributions towards provision, and thus the less motivated each will be to contribute (Olson 1965). The term ‘group’ as used here refers to social entities comprising multiple members who share some interests; e.g. communities, voluntary associations, organisations and nations.

Olson (ibid.) observed that individuals with a greater interest in seeing a collective good provided typically contribute disproportionately to provision efforts. The expression ‘free riding’ was coined to describe the situation where individuals stint in their own provision efforts in the expectation that others with greater interest will contribute sufficiently that the collective good gets provided. Olson (ibid. p. 62) predicted that free riding would rule in groups large enough that ‘each member … is so small in relation to the total that his action will not matter much one way or the other’, thus making it irrational for individual members to incur the costs of monitoring and punishing each other’s free riding.

The free-rider problem became interpreted as one of assurance, where obstacles to collective action arise from the challenges group members face in assuring each other that they can be trusted to reciprocate one another’s contributions. Key insights into how such challenges might be overcome came from research by Axelrod (1984 p. 12) designed to test the hypothesis that: ‘What makes it possible for cooperation to emerge is the fact that the players might meet again. … The future can therefore cast a shadow back on the present and thereby affect the current strategic situation’. The hypothesis was supported by the research, which demonstrated that individuals following reciprocity strategies can in supportive structural settings compete successfully with others who are following free-rider strategies.

Nevertheless, it remained unclear how the shadow of the future could be strengthened sufficiently in the case of large groups to motivate a critical mass of members to adopt reciprocity strategies. An extensive review of empirical research led Ostrom (1998 p. 13) to conclude that ‘levels of trust, reciprocity and reputations for being trustworthy are positively reinforcing’, and that successful large-group provision of collective goods depends consequently on establishing and maintaining a

structural setting conducive to generating a shadow of the future strong enough to motivate individuals to improve their reputations as trustworthy reciprocators.

3.2 Governance, institutions and complex adaptive systems

An important element in establishing structural settings conducive to successful large-group collective action is governance by a third party (North 1990). Such third-party activity can bolster the shadow of the future by increasing the likelihood of free riders being identified and punished, thus preventing free riding from becoming so common that trust and reciprocity begin to unravel in a vicious cycle. The third party can be self-organised by the group or provided by some external entity.

Governance involves the 'formation and stewardship of the formal and informal rules that regulate the public realm, the arena in which the state as well as economic and societal actors interact to make decisions' (Hyden et al. 2004 p. 16). These rules are the 'rules of the game' that North (1990) defined as institutions and distinguished from the organisations that 'play the game'. A rule is an institution only if it is a 'working rule'; i.e. where most people subject to the rule are aware of it and expect other's compliance with it to be monitored and enforced (Ostrom 1990).

Governance has become widely recognised as a core element of societal capacities to adapt to contemporary environmental changes given (a) its role in creating, maintaining, enforcing and adapting the institutions upon which collective action in adapting to these changes depends, and (b) the significance of this collective action for societal capacities to adapt to these changes (Engle and Lemos 2010; Marshall and Stafford Smith 2010; Folke et al. 2005). Nevertheless, the contribution that governance actually makes to human capacities to undertake adaptations involving collective action cannot be taken for granted but must be carefully fostered and maintained.

Recognition of the need for 'adaptive governance' has grown rapidly in tandem with increasing awareness of the novelty of the kinds of environmental challenges often encountered nowadays (Dietz et al. 2003). With humans now the dominant driver of changes in the state of our natural environments, we have become 'fully part of the Earth System, interacting with other components' (Rockström et al. 2009 p. 22). The appropriate focus in adapting to environmental challenges is therefore on what have become known as social-ecological systems (SES); i.e. 'subsets of social systems in which some of the interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units' (Anderies et al. 2004 p. 3).

SES are complex adaptive systems driven by positive-feedback dynamics. Hence they exhibit emergent path-dependent behaviour typically characterised by Knightian or 'deep' uncertainty. Such uncertainty occurs when it is not possible to specify in advance all possible outcomes of a decision or to assign probabilities to each identified possible outcome occurring; e.g. in the context of climate change where 'novel ecosystems' are expected to emerge as 'surprises'; i.e. discoveries that previously unconsidered contingencies have occurred (Steffen et al. 2009). Surprises can also arise when the system at issue is mechanistic but the actual mechanics have yet to be identified accurately (e.g. before Newton identified the true mechanics of the solar system). Since standard decision analysis cannot account for surprises, applying it to problems where they are likely is 'naïve' and leads to mis-identification of optimal adaptation choices (Quiggin 2007, 2008).

3.3 Wicked problems and collective action

This realisation that once-for-all optimisation of decision making is not possible for many contemporary problems of societal collective action parallels insights from the literature on 'wicked problems'. Each such problem emerges as a 'mess' because no single governance enterprise has

sole jurisdictional responsibility, the different enterprises involved cannot agree on the problem since their divergent interests lead them to frame it differently, and each attempt to identify a solution changes the problem (Batie 2008). Deliberative processes are required to achieve temporary problem definitions from which the search for solutions can commence.

Such features of wicked problems are characteristic of many contemporary environmental adaptation challenges (Bellamy 2007; McCann 2013). This adds to collective action problems in managing these challenges, compared at least with how such problems were conceptualised influentially by Olson (1965). This canonical view presumes that agreement on the on-ground collective goods to be provided (and by implication on how problems are defined) is not an issue, so that significant problems of collective action arise only in minimising free riding in their provision (Olson 1965). With wicked problems, however, agreeing on the collective goods to be provided is itself a crucial collective good. The costs of collective action in providing the deliberative fora essential for such agreement will often be considerable (Hanna 1995).

4. Transaction costs

4.1 Definition

The benefits of governance and institutions for adaptations involving collective action do not come for free. Most directly, their provision involves transaction costs. A range of definitions of such costs were reviewed by McCann et al. (2005 p. 530) before devising the one following that they considered sufficiently broad for application to environmental management: ‘transaction costs are the resources used to define, establish, maintain, and transfer property rights’.

Property rights do not cover all the institutions with which we are presently concerned, however. They depend on deeper-level institutions for their creation, exchange and legitimacy and can thus be regarded as individual components of the sets of relationships comprising institutions (Brunckhorst and Marshall 2006; Schmid 1972). Furubotn and Richter (1992 p. 8) recognised the broader domain within which transaction costs arise when they defined them as ‘all those costs that are connected with (i) the creation or change of an institution or organisation, and (ii) the use of the institution or organisation’.

This definition is also more comprehensive than that of McCann et al. (2005) in its allowances for: (a) transaction costs in creating or changing institutions aside from those of defining and establishing the institutions; and (b) the likelihood of property rights and other institutions being changed (adapted, transformed or replaced) as outcomes of uncertainty become known or more predictable. Allowance (a) is important given the earlier discussion of the significant transaction costs that are often incurred in agreeing on the problems to be solved through institutional interventions. The transaction costs of creating or changing institutions encompass this class of costs. The classification of transaction costs presented by McCann et al. (2005 p. 533) also encompasses such costs in its class of costs incurred in ‘research, information gathering, and analysis associated with defining the problem’. However, their definition of transaction costs can too easily be interpreted as reflecting a presumption that the transaction costs of defining the problem to be solved institutionally are negligible and that significant transaction costs are only incurred once the process of defining institutional remedies begins.

The following definition addresses the concerns raised above and informs subsequent discussion in this paper[1]:

[1] The term ‘transfer’ included in the McCann et al (ibid.) definition is encompassed in this definition by the more general term ‘use’.

Transaction costs are the costs of the resources used to: define, establish, maintain, use and change institutions and organisations; and define the problems that these institutions and organisations are intended to solve.

4.2 Classification

Classifying transaction costs is important for ensuring that all relevant costs are accounted for in any particular evaluation and for informing the design of data-collection protocols for measuring and enumerating transaction costs. Application of a common classification scheme across multiple evaluations also enables the comparability of transaction cost estimates across the studies to be gauged (McCann et al. 2005).

Hanna (1995) proposed that transaction costs of environmental management are incurred in four phases. These phases can be translated in accordance with how transaction costs are defined in this paper, and its focus on institutions rather than organisations, as follows: (1) description of resource context; (2) design of institution; (3) implementation of institution; and (4) enforcement of institution. Hanna (ibid.) referred to the transaction costs incurred during the first two phases as ex ante transaction costs, since they occur prior to implementation, and those incurred during the latter two phases as ex post transaction costs.

More recently, McCann et al. (2005) presented a scheme distinguishing seven classes of transaction costs incurred in environmental management processes. These classes fit neatly into Hanna's (1995) ex ante and ex post phases of translation costs. The ex ante phase corresponds with the 'research and information', 'enactment or litigation' and 'design and implementation' cost classes of McCann et al. (2005), while the ex post phase corresponds with their 'support and administration', 'contracting', 'monitoring and detection' and 'prosecution and enforcement' cost classes.

McCann et al. (2005) listed their classes of transaction costs roughly in order of the typical life cycle of a policy. Their final stage in this life cycle was 'established program', which may be translated given the more general focus of this paper to 'established institution'. In this last stage the institution 'has become well-established, fully implemented, and part of the routine of the affected population … [T]his stage is ongoing …' (ibid. p. 535). To be consistent with the definition of transaction costs used in this paper, however, the further stage 'change of institution', and corresponding transaction cost class 'adaptation or replacement', must be added to the McCann et al. (ibid.) scheme to account for the likelihood that the 'established institution' phase will cease when circumstances, including outcomes of uncertainty, arise that prompt changes to the established institution. Consistency with this definition also requires the 'adaptation or replacement' class to be included as part of the 'ex post transaction costs' phase of Hanna's (1995) scheme which ends, as discussed above, with the 'enforcement of institution' stage.

4.3 Accounting for institutional path dependency

The likelihood of the established institution phase eventually ending is accounted for in Challen's (2000) classification framework for transaction costs. This was the first framework for economic evaluation of institutional options to account for the path dependency implications of such options for their costs. Given that many contemporary adaptation challenges in environmental management involve complex adaptive systems, failure to account for such implications creates real risks of misidentifying the most cost effective institutional option. Considering such implications is important also because 'what gets measured gets managed' and 'ignoring important costs, which are obvious to the agencies involved, [makes] the economics profession … less credible' (McCann et al. 2005 pp. 527, 528).

Challen's (2000) framework distinguishes 'static' and 'dynamic' transaction costs. Static transaction costs, as defined in Table 1, fall within the 'support and administration', 'contracting', 'monitoring and detection' and 'prosecution and enforcement' classes of transaction costs in the McCann et al. (2005) scheme.

Table 1: Definitions of the six classes of costs comprising the institutional cost effectiveness framework

Class of costs	Definition
Static transaction costs	The transaction costs incurred in operating under an institutional option.
Institutional transition costs	The transaction costs incurred in effecting change from existing institutional arrangements to a new institutional option.
Institutional lock-in costs	The additional institutional transition costs incurred by 'successor' institutional options (i.e. those eventually chosen as adaptations, transformations or replacements of the option under consideration) due to the impact on institutional path dependencies of the institutional option under consideration.
Static transformation costs	The transformation costs incurred in operating under the technologies or practices that are adopted subject to the influence of the institutional option under consideration
Technological transition costs	The transformation costs incurred in effecting change from existing technologies or practices to those adopted subject to the influence of the institutional option under consideration.
Technological lock-in costs	The additional technological transition costs incurred by 'successor' technologies or practices (i.e. those chosen under the influence of 'successor' institutional options) due to the impact on technological path dependencies of the institutional option under consideration.

Dynamic transaction costs are the costs incurred as a result of effecting institutional change. They comprise two types of costs which are defined in Table 1. The first of these is 'institutional transition costs'[2]. These fall within the 'research and information', 'enactment or litigation' and 'design and implementation' transaction cost classes of McCann et al. (ibid.), and correspond to the 'ex ante transaction costs' class of Hanna (1995).

The second type is 'institutional lock-in costs', which fall within the 'adaptation or replacement' transaction cost class added above to the McCann et al. (2005) scheme. Constraints imposed by path dependencies on adaptation to environmental changes have been acknowledged by economists concerned with institutional and transaction cost issues in natural resources management (e.g. Grolleau and McCann 2012; Garrick and Aylward 2012; Garrick et al. 2013; McCann 2013). Challen (2000) was particularly concerned with the path-dependency implications of decentralising water property rights from the state (a large group) to individuals (groups of one) where, following the logic of Olson (1965), it is easier for a group to organise to defend its interests the fewer its members. He reasoned on this basis that an institutional change involving decentralisation of property rights from the state to individuals will increase the degree of institutional path

[2] Aside from 'static transaction costs' and 'dynamic transactions costs', the terms used here and below for the classes of transaction costs distinguished by Challen (2000) are modified from those he used.

dependency or 'lock-in' faced in subsequent attempts to adapt or otherwise change the property rights system, and thereby generate positive institutional lock-in costs.

Correspondences between the classes of transaction costs distinguished in the modified Hanna (1995) and McCann et al. (2005) schemes and the Challen (2000) scheme are shown in Table 2.

Table 2: Relationships between the three transaction cost classification schemes discussed

Modified Hanna (1995) classes	Modified McCann et al. (2005) classes	Challen (2000) classes	
Ex ante transaction costs	Research and information Enactment or litigation Design and implementation	Dynamic transaction costs	Institutional transition costs
Ex post transaction costs	Support and administration Contracting Monitoring and detection Prosecution and enforcement	Static transaction costs	Static transaction costs
	Adaptation or replacement	Dynamic transaction costs	Institutional lock-in costs

5. Ex ante evaluation of institutional cost effectiveness

5.1 Conceptualising a framework

Although the costs incurred most directly in employing institutions to solve problems of collective action in adaptation are transaction costs, the purpose of institutions here is ultimately to facilitate on-ground adaptations by members of groups facing these problems. Comparisons of the cost effectiveness of different institutional options must therefore account not only for the transaction costs of their application but also, because institutional choices typically influence technological choices and thus transformation (including production and abatement) costs, for the transformation costs incurred under their influence in implementing on-ground adaptations. The transaction cost advantages of one institutional option relative to another can be outweighed by its transformation cost disadvantages, and vice versa (Marshall 2005; McCann et al. 2005).

Evaluating the cost effectiveness of institutional options in achieving a given adaptation target therefore requires comparison of the total cost impacts (i.e. summed impacts on transformation and transaction costs) of the options relative to a consistent do-nothing (i.e. maintain status-quo institutions) scenario[3]. These impacts include not only the costs added relative to that scenario due

[3]Cost effectiveness analysis assumes that the benefits of alternative options are equal. This assumption is valid in the present context when the benefits of all alternative institutional options are limited to achieving the given adaptation target. It is violated if one or more of the options confer benefits additional to achieving this target (e.g. by helping to

to undertaking an option but also the costs under that scenario that are avoided by undertaking the option. Marshall (2005) presented a cost-effectiveness framework to fill this need by operationalising North's (1990) concept of adaptive efficiency. This framework extended Challen's (2000) earlier framework, which accounted only for transaction cost impacts of institutional options, to also encompass their transformation cost impacts.

This extension recognised that, as with transaction costs, static and dynamic types of transformation costs can be distinguished. The static transformation costs of a particular institutional option are defined in Table 1. The dynamic transformation costs of an institutional option in this context are the transformation costs incurred in effecting changes in on-ground technologies and practices due to implementing that option. As with transaction costs also, two types of dynamic transformation costs can be distinguished. These two types, 'technological transition costs' and 'technological lock-in costs', are defined in Table 1. As for institutional transition costs, important for technological transition costs are the costs of overcoming constraints on present choices from path dependencies that have arisen from earlier institutional choices. Technological lock-in costs arise to the extent that reversing an institutional choice is unable to fully reverse the technological choices made under its influence (e.g. due to sunk assets, network externalities, or the technological choices having driven the relevant social-ecological system across a threshold into a new regime).

Challen's (2000) observation that positive institutional lock-in costs represent a loss of quasi-option value applies also to positive technological lock-in costs. Quasi-option value is forfeited to the extent that a current institutional choice increases the institutional or technological transition costs of future institutional options, thereby reducing subsequent possibilities for the experimentation and learning needed to inform ongoing processes of institutional adaptation.

Although Challen's focus was on a class of institutional options (involving decentralisation of property rights) that he reasoned would reduce quasi-option value and thus increase institutional lock-in costs, institutional changes can also increase quasi-option values and thus reduce institutional lock-in costs. Consider institutional options involving centralisation of property rights from smaller groups (e.g. firms) to larger groups (e.g. the state); i.e. the reverse of the case with which Challen was concerned. According to his reasoning, such options will (a) reduce the degree of institutional lock-in faced in subsequent attempts to change the property rights system, thereby increasing quasi-option value by strengthening subsequent adaptive capacity, and thus (b) reduce institutional lock-in costs. More generally, claims that institutional arrangements like adaptive governance or adaptive co-management (e.g. Cundill and Fabricius 2010) strengthen collective adaptive capacities imply that institutional lock-in costs are reduced by implementing such arrangements.

Similarly, institutional options can increase quasi-option values by motivating implementation of on-ground practices that are more adaptable than those currently used. For instance, Gordon et al. (2005) found in Australia's Murray-Darling Basin that existing irrigation technologies were constraining adaptation by vignerons to irrigation salinity problems the more that these technologies were specific to vineyard enterprises. Institutional options that motivated replacement of vineyard-

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solve other adaptation challenges) and the level of additional benefits conferred differs between options. In such cases CEA provides an incomplete measure (i.e. focused on efficiency in achieving the single target) of the economic efficiency of the alternative options. The elements of the institutional cost-effectiveness framework developed below could be incorporated within a framework for institutional benefit-cost analysis (BCA) capable of providing complete measures of economic efficiency, but this awaits further work. Pannell et al. (2013) discuss a heuristic approach to accounting for transaction costs in BCA of environmental choices that could be drawn from in developing the institutional BCA framework envisaged here.

specific technologies with technologies more transferable to other enterprises would therefore increase vignerons' quasi-option values and reducetechnological lock-in costs.

Accounting for these additional cost considerations in Challen's framework means that the appropriate criterion for evaluating institutional cost effectiveness in achieving a given adaptation target involves identifying the option that minimises the sum of the cost impacts (measured monetarily and discounted for time preference) incurred in respect of the following six classes:

- static transaction costs;
- institutional transition costs;
- institutional lock-in costs;
- static transformation costs;
- technological transition costs; and
- technological lock-in costs.

5.2 Illustrating the framework's applicability to institutional options in the Murray-Darling Basin for accumulating stocks of 'environmental water'

Let us consider how this Institutional Cost Effectiveness Analysis Framework (ICEAF) applies to evaluating the cost effectiveness of institutional options in a particular environmental management context: Australia's Murray-Darling Basin (MDB) where there is a need to accumulate a stock of 'environmental water' that can be allocated towards conserving the Basin's threatened ecosystems. Of all the water diverted from the Basin's rivers, 96 per cent is consumed by irrigated agriculture (Connell 2011). The public's concerns over threats to the Basin's ecosystems from escalating consumptive uses of water resources began from the 1980s to elicit responses from policy makers. The ecological health of 20 of the 23 major river valleys in the Basin is either poor or very poor (Williams 2011).

An important stage in the public policy process of responding to the Basin's ecological problems commenced in 2004 when the Council of Australian Governments (comprising the federal and state / territory governments of the federation) introduced the National Water Initiative. There have been two main institutional options pursued under this Initiative in addressing these problems: funding programs for buy-back of water entitlements from willing irrigator sellers ('water buy-backs'); and programs for subsidising the upgrading irrigation infrastructure to increase water use efficiency and leave more water for ecosystems ('infrastructure subsidies') (Crase et al. 2013).

The 2007 (Commonwealth) Water Act established the MDB Authority and required it to develop a Basin Plan (made law in 2012) that specifies sustainable diversion limits and environmental water plans (Garrick, Lane-Miller et al. 2011). The Water for the Future initiative, with a 10-year budget of $12.9 billion, was established under 2008 amendments to the Act to acquire water for reallocation to the environment. This initiative includes two programs: Restoring the Balance (RTB) with a $3.1 billion budget for water buy-backs; and the Sustainable Rural Water Use and Infrastructure (SRWUI) program with a $5.8 billion budget for infrastructure subsidies. The Basin Plan set a baseline target of 2,750 gigalitres (GL) of environmental water to be recovered. The Commonwealth recently pledged to spend a further $1.7 billion to increase the volume recovered to 3,200 GL.

Cost items that are relevant for cost effectiveness analysis (CEA) of these two institutional options in this context in accumulating a given volume of environmental water are identified in Table 3, where the items are allocated to the relevant cost classes of the ICEAF. These options are confined

Table 3: Illustrating how the ICEAF applies to the choice between two institutional options for recovering environmental water for the Murray-Darling Basin

Cost class	Fund a water buy-back program	Fund an infrastructure upgrade program
	Relevant cost items	
Static transaction costs	Added costs incurred (a) in administering the program and (b) by private entitlement holders in transacting with the program	Added costs incurred (a) in administering the program and (b) by prospective infrastructure upgraders in transacting with the program
Institutional transition costs	Added costs incurred in establishing the water buy-back program in respect of: research and stakeholder consultation; negotiating program goals and design; lobbying for, legislating and implementing the program; and negotiating and institutionalising the rules and policies for program administration Costs of administering privately-owned water entitlements that are avoided by buy-back	Added costs incurred in establishing the infrastructure-upgrade program in respect of: research and stakeholder consultation; negotiating program goals and design; lobbying for, legislating and implementing the program; and negotiating and institutionalising the rules and policies for program administration Costs avoided in administering infrastructure made redundant by the program
Institutional lock-in costs	Costs added due to emergence of parties with vested interests (e.g. public agencies administering the program, prospective sellers to the program) in opposing changes to the program contrary to those interests Costs associated with path dependencies arising from existing water entitlement arrangements that are avoided by reallocating entitlements from private to public ownership[a]	Costs added due to emergence of parties with vested interests (e.g. public agencies administering the program, irrigators and their input suppliers benefitting from the program) in opposing changes to the infrastructure upgrade program contrary to those interests
Static transformation costs	Nil. (Program is concerned with accumulating environmental water, not with influencing the technologies for applying this water.)	Added costs of operating and maintaining the upgraded infrastructure and any new irrigation technologies adopted due to this upgrading
Technological transition costs	Economic rents from irrigated production that are foregone due to sales of water entitlements to the program[b] Costs of operating and maintaining irrigation infrastructure and technologies that are avoided when properties shift to less irrigation intensive (or dryland) production due to sale of water entitlements	Added costs of the infrastructure upgrades supported by the program[c] Costs avoided in operating and maintaining irrigation infrastructure and technologies that are made redundant by the program
Technological lock-in costs	Costs associated with path dependencies arising from existing investments in irrigation infrastructure and technologies that are avoided when producers shift to less irrigation intensive (or dryland) technologies due to sale of water entitlements Costs associated with path dependencies arising from investments in less irrigation intensive (or dryland) technologies that are added when producers shift to such technologies due to sale of water entitlements	Costs associated with path dependencies arising from existing irrigation infrastructure and associated technology that are avoided by upgrading this infrastructure and technology Costs added due to path dependencies arising from investments in infrastructure upgrades and associated adoption of new irrigation technologies.

[a] Challen (2000) argued that path dependency is stronger, and by implication lock-in costs are greater, the more that property rights are decentralised towards private ownership (since individuals and small groups tend to be more able than large groups to organise to defend their interests). The buy-back program reallocates water property rights from individuals to the state (representing the large group comprising the electorate), and thus may be expected to avoid some of the lock-in costs associated with allocation to individuals.

[b] Since the prices paid for water entitlement buy-backs are regarded in economic evaluations as transfers rather than costs, it is not appropriate to use them automatically as measures of these foregone economic rents. Where buy-back programs are designed efficiently, however, the prices paid for entitlements may approximate the foregone economic rents closely enough to be used as estimates for them.

[c] The full costs of these upgrades are relevant here, not only the value of the upgrade subsidies paid through the program.

to accumulating a specified volume of environmental water; they do not encompass the subsequent steps of allocating that volume and applying specific technologies to achieve particular ecological goals. In accordance with how institutional and technological transition costs, and also institutional and technological lock-in costs, are defined, these cost impacts need to be assessed against the do-nothing (i.e. status quo institutions) scenario, and thus account for costs that are avoided as well as added by undertaking an option. Under the do-nothing scenario the water entitlements that would be reallocated into public ownership under the water buy-back option remain privately owned. The infrastructure upgrade option involves no changes to how property rights in respect of water use and infrastructure management are allocated, although it does, like the water buy-back option, involve institutional change by way of introducing a new government program involving rules (regulations, policies, etc.) and the organisational arrangements required to administer and enforce these rules.

Although a number of economic studies (Grafton 2007; Lee and Ancev 2009; Grafton 2010; Productivity Commission 2010; Qureshi, Schwabe et al. 2010; 2011; Crase, O'Keefe et al. 2013) have reported findings on the cost-effectiveness of voluntary water buy-backs and infrastructure subsidies, these findings accounted for only one of the six types of costs distinguished in the ICEAF; i.e., technological transition costs. These costs were in each case assumed equal to the government budget expended directly in recovering environmental water. Although Grafton (2010) and the Productivity Commission (2010) justified the approaches they followed given the Commonwealth's (Department of Environment Water and Heritage Australia 2009) stated intention to achieve 'value for money' from its outlays on the RTB and SRWUI programs, neither acknowledged this criterion as narrower than justified by the conventional welfare economics focus on impacts across society. Based on this narrow interpretation of CEA, each of the studies cited in this paragraph found the buy-back option to be markedly more cost-effective than the infrastructure option.

Despite concluding that buy-backs are more cost-effective than infrastructure subsidies in recovering environmental water, the Productivity Commission (2010 pp. xxxv, 140) 'recognises that this [SRWUI infrastructure subsidy] program can be seen as the price the Australian Government was prepared to pay to make progress on important reforms ... [T]he program was needed to convince the states to a truly Basin-wide approach to water planning and to elicit the irrigation sector's support for increasing environmental water allocations'. Such costs of overcoming path dependencies are central to institutional transition costs. As well as tangible resources required to overcome opposition to reforms, also relevant here are the opportunity costs to policy makers and citizens of failing to move on and free up time, attention and windows of opportunity (Kingdon 1995; Olsson, Gunderson et al. 2006) to address other (including reform) priorities. The relevance of such transaction costs to MDB water resources management was highlighted by Marshall, Wall et al. (1996). Garrick et al. (2012) accounted for institutional transition costs when examining the performance of water reform efforts for environmental conservation in the USA's Columbia River Basin.

Also outside its CEA calculations, the Productivity Commission (2010) observed that a disadvantage of infrastructure subsidies is that they impede adaptation of irrigation communities by perpetuating dependence on external support. It would have been appropriate to account for this disadvantage in terms of the lock-in cost categories of the ICEAF. As indicated in Table 3, water buy-backs are also likely to generate lock-in costs. Path dependencies that arise from the vested interests emerging from those buy-backs can be expected to increase the costs of reforms to MDB buy-back programs that may eventually be required.

Given these significant weaknesses of existing economic studies of the cost effectiveness of MDB water recovery programs, prudence would suggest their consensus finding that water buy-backs are more cost effective than infrastructure subsidies – and likewise the Productivity Commission's

(2010 p. 264) conclusion on the basis of these findings that ‘as much as possible of the funds currently ear-marked to the [MDB] infrastructure program should be recovered and used for other purposes [including water buy-backs]’ – be heeded with significant caution.

5.3 Challenges of empirical application

Empirical application of the ICEAF presents considerable challenges. Predicting values for the six cost categories will normally be easiest for static transformation costs and technological transition costs. Indeed, CEA by environmental economists has conventionally been limited to consideration of these costs. To the extent that transaction costs have been accounted for in ex ante economic evaluations, the focus has been exclusively on static transaction costs and institutional transition costs. Even given this limited scope, access to the required data has been a major problem and has meant that ‘most of the transaction cost measurement studies to date use words like ‘crude’ or ‘approximate’ to qualify their results’ (McCann et al. 2005 p. 539).

Problems faced in predicting technological and institutional transition costs arise also in predicting technological and institutional lock-in costs, respectively, since the lock-in costs constitute effects on transition costs of future institutional options. In addition, the conventional neoclassical economic framework applied in prior empirical evaluations of static institutional costs and institutional transition costs (McCann et al. 2005), as well as of static transformation costs and technological transition costs, is appropriate only when it is reasonable to assume that each cost arises mechanistically and thus has a single possible equilibrium value. This assumption is not reasonable for evaluation of institutional and technological lock-in costs which, as discussed previously, tend to emerge as surprises from the non-mechanistic, path-dependent dynamics of complex adaptive systems. Such dynamics typically lead to multiple possible equilibrium values. The equilibrium that eventuates can be highly sensitive to any one of many small ‘random’ contingencies the occurrence and/or significance of which cannot be foreseen (Arthur 1999).

Let us consider these empirical challenges in the context of applying the ICEAF to the two aforementioned institutional options for accumulating a stock of environmental water for the MDB. Research concerning the cost-effectiveness of these options has focused to date on their respective consequences for transformation costs, and particularly on what in this framework are referred to as technological transition costs; i.e. costs of transitions from the technologies employed under the do-nothing scenario to those employed under each option.

Crase et al. (2013) estimated accordingly from previous research that the transformation costs attending the water buyback option are around $A2,500 for each megalitre (ML) added to the stock of environmental water, while the equivalent costs for the infrastructure-upgrade option seem to be within the range of $5,600 to $10,000 per ML (i.e. from 2.24 to 4 times higher). These costs fall more specifically within the subset of transformation costs referred to in the ICEAF as technological transition costs. The infrastructure upgrade option is more costly also in terms of static transformation costs given that (a) any upgrades need to be operated and maintained, and (b) the water buy-back option (which as defined above involves only holding onto water entitlements once they are purchased) entails no such costs. Although this cost difference has not been estimated to date, calculating such an estimate would be feasible. Estimates of the static transaction costs and institutional transaction costs for the two options are also yet to be estimated. Although the task of deriving these estimates is challenging (Challen 2000), it is far simpler, for the reasons given above, than estimating the institutional lock-in costs and technological lock-in costs of the two options. We return in section 5.5 to the challenge of accounting for these lock-in costs.

5.4 Importance of accounting for lock-in costs

An extensive literature documents how past institutional choices generally (e.g. North 1990) and in environmental governance specifically (e.g. Heinmiller 2009) continue to strongly influence present costs of changing institutions and the technologies adopted subject to their influence. Backward-looking examples of this kind highlight the importance when considering present institutional choices of accounting carefully for how these choices will affect the costs of adapting or otherwise changing the institutions selected, and the technologies adopted subject to their influence, when those institutions come to be recognised as poorly suited to new circumstances (Challen 2000).

Heinmiller (2009), for instance, demonstrated how water apportionment institutions chosen early in the histories of basin-level water management in the Murray-Darling Basin (MDB), the USA's Cororado Basin and Canada's Saskatchewan-Nelson Basin continue to heavily constrain present efforts to reform water management institutions to ensure a greater focus on environmental concerns. Walker et al. (2009) described how institutional choices in the late 19th century to invest in irrigation infrastructure for the Goulburn-Broken catchment of the southern MDB have led to mindsets and configurations of vested interests that continue to propel irrigation-infrastructure-dependent adaptations to irrigation salinity problems when a more transformative response involving substantial revegetation of the catchment seems required to sustain the region's SES. Marshall (2009, 2011) discussed how past institutional choices by Australian governments favouring paternalistic approaches to changing farmers' land management practices fostered norms of dependency or opposition that remain significant obstacles to governments achieving their environmental objectives given their limited resources for motivating practice changes through financial incentives or enforced regulations.

5.5 A procedure for boundedly rational application of the ICEAF

If institutional and technological lock-in costs cannot be predicted through the mechanistic, deductive approach of conventional neoclassical economics, does this mean that the ICEAF is of no use in accounting empirically for the consequences of path dependencies and surprises for the cost effectiveness of institutional options? No, it does not, but it does mean that economists need to look beyond the conventional neoclassical approach when accounting for these costs.

A way forward is suggested by Quiggin's (2007, 2008) work on operationalising the precautionary principle by moving beyond naïve application of decision theory to a more sophisticated approach that recognises the bounded rationality of decision makers facing complex problems. Recognising that boundedly rational decision makers cannot foresee the particular surprises that may arise from decision options, he observed nevertheless that they may often be able to use heuristics to assess whether an option is likely to lead to a domain of favourable or unfavourable surprises. A domain of (un)favourable surprises is a set of option outcomes that involves a large number of surprises that are mostly (un)favourable from the perspective of the decision maker.

These observations led Quiggin (2008) to propose a two-stage interpretation of the precautionary principle in which the principle constrains how decision theory is applied to complex problems. The first stage involves applying naïve decision theory (i.e. ignoring surprises) to the options under consideration for change to the institutional status quo. The second stage, which involves applying the precautionary principle until the problem becomes amenable to comprehensive decision-theoretic evaluation, is invoked if the first favours an option that the decision maker's heuristics suggest would lead to a domain of unfavourable surprises.

This two-stage procedure can be followed to make more tractable the challenge of accounting empirically for the lock-in cost components of the ICEAF discussed above. The first stage of the

procedure in this context involves naïve evaluation (i.e. accounting only for static transaction costs, static transformation costs, institutional transition costs and technological transition costs) of the cost effectiveness of the institutional options available for achieving a given adaptation target. The second stage involves:

(i) selecting as the preferred option the highest-ranked one in terms of naïve cost effectiveness that is not expected to lead to a domain of unfavourable surprises for either institutional and technological lock-in costs (where a domain of unfavourable surprises in this context is one in which lock-in costs are higher than under the institutional status quo), or,

(ii) if no such option exists, invoking the precautionary principle and thus retaining the institutional status quo.

The set of possible outcomes from applying this procedure to a case where only two institutional options (A and B) are available is shown in Table 4. Application of this procedure to a case involving four available options (W, X, Y and Z) is illustrated numerically in Table 5. Option Y is the preferred option in this example because it is the highest ranked option in terms of naïve cost effectiveness that does not invoke the precautionary principle. Indeed, it is the only option to not invoke this principle. In the absence of this option, therefore, the procedure would recommend retaining the institutional status quo until options capable of achieving the adaptation target without invoking the precautionary principle can be developed.

Let us return now to the illustrative case study presented in section 5.2. This concerns the institutional choice between a water buy-back and an infrastructure upgrade program for accumulating a stock of environmental water for sustaining MDB ecosystems. As discussed in section 5.3, the cost data that are currently available for comparing the cost-effectiveness of these options are limited to the technological transition costs of the options (on a per ML of environmental water accumulated basis).

Even then they cover only one of the two technological transition cost items listed for each option in Table 3 (the item ‘economic rents from irrigated production that are foregone due to sales of water entitlements to the program’ in the case of the buy-back option, and the item ‘added costs of the infrastructure upgrades supported by the program’ in the case of the infrastructure upgrade program). The technological transition cost item for which data are unavailable for the buy-back option concerns the ‘costs of operating and maintaining irrigation infrastructure and technologies that are avoided when properties shift to less irrigation intensive (or dryland) production due to sale of water entitlements’. The corresponding item for the infrastructure upgrade option concerns the ‘costs avoided in operating and maintaining irrigation infrastructure and technologies that are made redundant by the program’. Even if the magnitude of the second of these avoided-cost items were judged to exceed that of the first, it seems unlikely that the difference could be judged great enough to compensate for the cost advantage of the buy-back option in terms of the technological transition cost items for which data are available. Hence, it seems reasonable to conclude that technological transition costs are lower overall for the buy-back option than for the infrastructure upgrade option.

We can also conclude, as reasoned in section 5.3, that the static transformation costs of the buy-back option are lower than that of the infrastructure upgrade option. Even if the static transaction costs of the buy-back option were higher than that of the infrastructure upgrade option, it seems unlikely from the relevant entries in Table 3 that the difference would be great enough to outweigh the buy-back option’s seemingly significant cost advantage in terms of technological transition costs and static transformation costs.

Hence, the decisive factor in determining which option is naïvely most cost effective seems to be whether institutional transition costs are sufficiently higher for the buy-back option, compared with

Table 4: Choice between two institutional options and status-quo arrangements given various possible combinations of surprise domains for lock-in costs[a]

		Option B, ranked 2nd in terms of naïve cost effectiveness			
	Combination of surprise domains for lock-in costs associated with option	**+ TLC + ILC**	**+ TLC – ILC**	**– TLC + ILC**	**– TLC – ILC**
Option A, ranked 1st in terms of naïve cost effectiveness	**+ TLC + ILC**	Prefer option A	Prefer option A	Prefer option A	Prefer option A
	+ TLC – ILC	Prefer option B	Invoke precautionary principle (prefer status quo)	Invoke precautionary principle (prefer status quo)	Invoke precautionary principle (prefer status quo)
	– TLC + ILC	Prefer option B	Invoke precautionary principle (prefer status quo)	Invoke precautionary principle (prefer status quo)	Invoke precautionary principle (prefer status quo)
	– TLC – ILC	Prefer option B	Invoke precautionary principle (prefer status quo)	Invoke precautionary principle (prefer status quo)	Invoke precautionary principle (prefer status quo)

[a] TLC = technological lock-in cost; ILC = institutional lock-in cost. Domains of favourable and unfavourable surprises for lock-in costs are indicated by + and – , respectively.

Table 5: Applying the ICEAF to a case with four institutional options: an illustrative application

	Institutional options available for achieving the adaptation target			
	W	**X**	**Y**	**Z**
Static transaction costs ($K)	100	80	60	200
Institutional transitional costs ($K)	20	40	90	70
Institutional lock-in costs (domain of surprises)[a]	–	+	+	–
Static transformation costs ($K)	150	140	160	90
Technological transition costs ($K)	40	40	100	160
Technological lock-in costs (domain of surprises)[a]	–	–	+	–
Naïve total cost impact of option ($K)	310	340	410	520
Naïve cost effectiveness rank	1st	2nd	3rd	4th
Satisfies precautionary principle?	No	No	Yes	No
Preferred option			√	

[a] Favourable and unfavourable domains of surprises for lock-in costs are indicated by + and –, respectively.

the infrastructure upgrade option, to outweigh the former's apparent cost-effectiveness advantage overall in terms of the three other 'naïve cost classes' (i.e. those included in a naïve evaluation). The discussion in Crase et al. (2013) of the considerable challenges experienced to date in overcoming opposition from vested interests (particularly irrigators and the industries and communities dependent on their business) to water buy-back programs, even where sale of entitlements to such programs is voluntary, and of the strong support from such interests for infrastructure upgrade programs, indicates that this latter option may indeed have a significant advantage in terms of institutional transition costs (particularly in terms of the costs of overcoming political opposition), and that this advantage could possibly be large enough to outweigh its apparent cost-effectiveness deficit in terms of the three other naïve cost classes.

For the sake of illustrating the two-stage procedure, however, let us assume that naïve cost-effectiveness evaluation has identified the water buy-back program as the preferred institutional option. Might this option be expected to avoid domains of unfavourable surprises for both institutional and technological lock-in costs? The entry in Table 3 for technological lock-in costs indicates that the buy-back option will add to such costs in one way (contributing new lock-in costs by leading to investments in less irrigation-intensive production technologies) and reduce them in another way (avoiding current lock-in costs associated with investments in irrigation infrastructure and technologies by leading some producers to sell water entitlements and thus shift to less irrigation-intensive production methods). If we assume that lock-in costs increase with the value of investments undertaken (reasoning that investors have a greater interest in maintaining the status quo the more they have invested in it), and that this value increases with the irrigation intensity of the systems invested in, it follows that the lock-in costs avoided under this option will exceed the lock-in costs that are added – thus leading us to conclude that the buy-back option is unlikely to lead to a domain of unfavourable surprises for technological lock-in costs.

Similarly, the relevant entry in Table 3 for institutional lock-in costs indicates that the buy-back option will add to such costs in one way (by leading to emergence of parties like environmentalists and program staff with vested interests in opposing changes to the program that are contrary to those interests) and avoid such costs in another (by reallocating water entitlements from private holders in a particular sector (irrigated agriculture) who are relatively capable of organising to oppose reallocation of their entitlements to environmental water entitlements, to public holders who represent a diverse and large group of electorate members whose interests on average are more aligned with the 'public interest' goals of the program and who also are less able to organise to pursue their sectional interests. The earlier comments about the formidable obstacles posed by opposition from irrigators and associated interests to establishment of a buy-back program indicate that the institutional lock-in costs avoided by introducing the program are likely on balance to outweigh the value of such costs that are added. Hence, we might reasonably expect that the buy-back option will not lead to a domain of unfavourable surprises in respect of institutional lock-in costs.

Given our assumption that the water buy-back program is more cost effective by the criterion of naïve decision analysis, and the foregoing judgements that this option is unlikely to lead to domains of unfavourable surprises for either institutional or technological lock-in costs, the two-stage boundedly rational procedure proposed above leads us to conclude from this stylised application of the ICEAF that the buy-back program is the preferred institutional option once all six cost classes in the framework are accounted for.

6. Research to support the procedure

The value of this procedure for applying the ICEAF depends on decision makers having available the heuristics they need to assess with reasonable confidence whether particular institutional options

are likely to lead to favourable or unfavourable domains of surprises in respect of both institutional lock-in costs and technological lock-in costs (Quiggin 2008). Heuristics of value for particular classes of complex problems are identified inductively (Quiggin 2008).

Many decision makers faced with institutional choices in respect of environmental management would already have heuristics derived from ad hoc interpretations of past experiences that they could apply to speculate upon the lock-in cost impacts of the kinds of institutional options with which they are familiar. A research strategy designed to inductively identify heuristics capable of more confidently anticipating such cost impacts, or at least the domains into which they are likely to fall, across a wider range of institutional options for adaptive environmental governance was proposed in Marshall (2005 pp. 132-146). The strategy involves accumulating a dataset of ex post evaluations of the cost impacts (including lock-in cost impacts) of institutional options across diverse settings, where these evaluations have all been structured by a consistent analytical framework in order to ensure the cross-evaluation comparability needed for valid identification of patterns in the cost impacts of particular institutional options.

The framework chosen for this purpose was the Institutional Analysis and Development (IAD) framework (Ostrom 1990), although the 'diagnostic framework for the study of social-ecological systems' (or SES framework) is now more suitable for this purpose since it was adapted from the IAD framework to address critiques from natural scientists that the latter accounts insufficiently for the biophysical details of SES (Ostrom 2009). As the dataset of studies performed under such a research strategy accumulates, the capacity to identify patterns in the lock-in cost impacts of institutional options will grow, thus facilitating inductive identification of heuristics for decision makers to use with increasing confidence in assessing the likelihood of particular options leading to favourable or unfavourable domains of surprises for the two categories of lock-in costs.

Although 'the predictions we can hope to make [from this research strategy] will at best be rough and highly contingent on how random events unfold' (Marshall 2005 p. 146), it is crucial that precision does not become the enemy of strengthening existing highly limited capacities for institutional decision making in environmental management. As McCann et al. (2005 p. 532) observed, 'for the differing purposes of transaction cost measurement, how precise do our estimates need to be? As an initial screening across policy instruments, rough 'orders of magnitude' may be good enough and would represent an improvement over current practice'.

7. Concluding comments

Contemporary adaptation challenges faced in environmental management often involve complex problems of collective action. Appropriate institutions, or working rules, can foster a structural setting within which the trust and reciprocity required to solve these problems is created and maintained. However, defining these problems, and identifying, establishing and operating the institutions needed to solve them, involves costs (most directly, but not exclusively, transaction costs) which need to be weighed against the benefits of solving them. Given the complexities and uncertainties associated with many adaptation challenges faced in contemporary environmental management, it is necessary also to account for the impacts of current institutional options on the costs of institutional changes that eventuate as problems come periodically to be redefined.

An Institutional Cost Effectiveness Analysis Framework (ICEAF) that was developed to provide a comprehensive and logical structure for economic evaluation of institutional choices in this context was considered in this paper. Given the surprises likely to arise from institutional choices, a boundedly rational procedure for applying the framework is required. Such a procedure, within which recommendations from applying standard decision theory to institutional choices are accepted if they are expected to satisfy the constraint of not invoking the precautionary principle,

was proposed and outlined. Applying this procedure depends on decision makers having access to heuristics that they can use with reasonable confidence in anticipating whether a particular institutional option is likely to satisfy this constraint. A research strategy designed to support the procedure by identifying heuristics that can be applied more confidently in making such assessments was also outlined. It is hoped that these three elements – the ICEAF, the boundedly rational procedure for its application, and the research strategy to support this application – will be taken up by others responding to the call by Paavola and Adger (2005) for development of an 'institutional ecological economics' that applies to social-ecological problems those elements of the new institutional economics that are consistent with recognising the complexities and uncertainties that are often central to those problems.

None of this is to suggest that the task of applying standard decision theoretic approaches to evaluating institutional choices is made easy if the likelihood of surprises arising from these choices is ignored. However, perfecting application of these approaches is not enough. Evaluations of institutional choices in many contemporary settings of environmental management will continue to systematically misidentify the most cost effective options until they come to account in an appropriate boundedly rational manner for the surprises likely to arise from these choices.

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