Aligning policy and real world settings: A theoretical and empirical analysis of the effectiveness of market based and community governance instruments in managing a commonly shared water resource

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Abstract

The actions of people interacting together to govern common pool resources are guided and governed by formal legislation and regulations and 'informal' attitudes, shared norms and heuristics. Tensions potentially arise when sets of rules intersect and interact, especially sets of formal and informal rules. If those crafting or changing formal rules do not understand how particular sets of rules affect actions and outcomes in a particular ecological and cultural setting, these rule changes may result in rapid, unexpected, and possibly perverse outcomes (Ostrom, 2005). Thus, the effectiveness and durability of a novel set of formal rules and entitlements depends on the degree of integration with existing institutions and the capacity of mechanisms enabling people to adjust to new and changing circumstances.

This paper formally evaluates the durability and cost effectiveness of a novel set of formal rules regarding water use in an irrigation region of Australia and their compatibility with extant informal rules. A rising saline aquifer in the Coleambally Irrigation Area, a corollary of water abstraction and irrigation application, constitutes a common pool resource, characterised by costly exclusion and rival utilisation for regional irrigators. We report on theoretical insights from institutional analysis, network theory and deliberative and participatory methods, and empirically based outcomes of different institutional structures observed in an experimental simulation. Experimental economics was used to test the efficacy of both formal market institutions and group crafted voluntary social contracts to manage the common pool water resource. Based on allied biophysical research, the experimental setting relies on a catchment analogue, which represents the economic decision-making and trading environment facing farmers. Observed behavioural responses to policy initiatives were compared according to two metrics: aggregate groundwater recharge and farm income (expressed as player payments) net of non-compliance penalties. The economic and environmental effectiveness and durability of a formal market institution existing with the set of informal rules is analysed and evaluated.

1. Introduction

Irrigation induced waterlogging, rising saline groundwater aquifers and subsequent increases in soil salinity is a well known problem in mature irrigation areas across Australia. The Coleambally Irrigation Area (CIA), located in the Murrumbidgee Catchment of the Murray Darling Basin is no exception. The consequences of salinity in irrigation areas include crop production losses, increased production costs and damage to environmental amenities and infrastructure assets in the region. Additionally, spatially dispersed and long term soil salinisation is increased by capillary action predicted when groundwater approaches the soil surface. Despite regulations limiting rice production and the application of irrigation water, the problem of rising saline groundwater and salinity persists (Khan *et al*. 2003).

In typical ground water recharge settings, declining groundwater levels constitute a common pool externality, arising as a result of the costly exclusion of beneficiaries and rival resource consumption (Ostrom 1998). When joint outcomes depend on multiple actors contributing inputs or actions that are costly and difficult to quantify and there is lack of institutional protocols to restrict usage, incentives exist for individuals to act opportunistically. Without coordinating institutions, individual appropriations occur to a level where resource overuse arises, groundwater levels drop and this imposes group shared costs on the common pool community such as higher pumping costs. Prohibitive costs of exclusion imply it is not possible to compel those who enjoy the additional benefit of appropriations to compensate those who incur additional costs. The porous, adsorptive capacity of the soil fraction between the soil surface and the aquifer water table in the CIA can be defined as common pool resource. That is, the application of additional irrigation water by an individual farmer appropriates and subtracts from the soil fractions total adsorptive capacity, reducing the opportunity of other irrigators to make use of the adsorptive resource. When aggregated, individual over-appropriation will eventually lead to rising water tables and lower crop productivity for all farmers (Khan *et al*. 2003).

The actions of people interacting together to govern common pool resources are guided and governed by formal legislation and regulations and 'informal' attitudes, shared norms and heuristics. For example, legislation or regulations about the management of weeds along riverbanks will guide how farmers manage their properties; and norms about the latest water use technology are passed on from neighbour to neighbour over the fence, or through the local industry newsletter. Tensions potentially arise when sets of rules intersect and interact, especially sets of formal and informal rules. If those crafting or changing formal rules do not understand how particular sets of rules affect actions and outcomes in a particular ecological and cultural setting, these rule changes may result in rapid, unexpected, and possibly perverse outcomes (Ostrom, 2005). Thus, the effectiveness and durability of a novel set of formal rules depends on the degree of integration with existing institutions and the capacity of mechanisms enabling people to adjust to new and changing circumstances.

The effectiveness and durability of a set of rules and how these impact on the capacity of people to adjust to new circumstances partly describes the concept of adaptive governance, which is a key feature of capacitated, resilient social-ecological systems. Adaptive governance refers to the ability of communities to adjust to the rules and institutions that govern individual and group behaviour in light of changing circumstances, including changes in information, preferences and technologies, and to adjust these rules as required (Dietz *et al.*, 2003).

The management of common pool resources offers a particular set of challenges for economic policy. For example, managing the environmental and economic consequences of rising groundwater and subsequent soil salinity loads is complex and likely to require a combination of economic instruments and community involvement in coordinating aggregate extraction strategies (Common, 1995; Randall, 1978). Ostrom *et al*. (1992), Poe *et al*. (2004) and Tisdell *et al.* (2004) have proposed a range of market-based instruments and group crafted coalitions, facilitated by communication and reinforced by punitive and non-punitive sanctioning mechanisms as possible policy solutions to social dilemmas of a similar nature.

Ensuring the enduring compatibility between formal and informal institutions is important for adaptive governance in such common pool resource management situations:

> *"If the individuals who are crafting and modifying rules do not understand how particular combinations of rules affect actions and outcomes in a particular ecological and cultural environment, rule changes may produce unexpected, and at times, disastrous outcomes."* (Ostrom, 2005, p. 1)

To further explore this statement, this paper formally evaluates the durability of a novel set of formal rules regarding water use in the Coleambally Irrigation Area of southern Australia and their compatibility with extant informal rules. In order to account for the impact of interactions between formal and informal rules, and thus to better align policy and real world settings, we analyse and report on theoretical insights and empirically based outcomes of different institutional structures to manage commonly shared water resources. The set of formal rules chosen as an institutional structure for comparison are a form of market-based instrument.

Theoretical insights from institutional analysis, network theory and deliberative and participatory methods and the behavioural responses observed in this experimental simulation are used to make inferences about the degree of integration of the new rule set of the market-based instruments (MBI) with existing rules, through evaluating economic and environmental effectiveness and durability. Broadly, institutional analysis seeks to understand the "prescriptions that humans use to organise all forms of repetitive and structured interactions" (Ostrom, 2005, p. 1), to understand "how and why they are crafted and sustained, and what consequences they generate in diverse settings" (*idem.*). Institutions define the operations of a social network. The pattern of social relations between people interacting to operationalise these institutions defines the structure of the social network. Network theory is used to gain insight into how the structure of social relations impacts on the functioning of a group. Deliberative and participatory methods contribute to the analysis by providing further input from behavioural psychology and sociology about how people operate in group environments.

The paper proceeds as follows. First, market-based instruments are introduced and current findings about their level of compatibility with other rules sets are reviewed. Second, theoretical insights from institutional analysis, network theory and deliberative and participatory methods are introduced and used to form hypotheses of the impact of various institutional structures. Third, the common pool resource issue of the Coleambally Irrigation Area and the economic experiment used to assess the potential of recharge credit trading are described. This is followed by discussion, and, where possible, testing of each hypothesis. Some are testable through the experiments and are evaluated based on two metrics: aggregate groundwater recharge and farm income (expressed as player payments) net of non-compliance penalties, others are evaluated by codification and comparison of formal and informal rules for integration and levels of compatibility. The final section concludes.

2. Market-based instruments

Market-based instruments (MBIs) are aspects of regulation or laws that encourage behavioural change through the price signals of markets, as opposed to the explicit directives for environmental management associated with regulatory and centralised planning measures (Stavins, 2003). In a general sense environmental policy instruments are the tools available to policy makers to influence individual behaviour and societal processes such that they align with and remain compatible to defined environmental and social targets. These are made operational as policy objectives and their level of success is often expressed as measures of environmental effectiveness, economic efficiency and distributional equity. As a general rule MBIs, including tradeable rights, use markets and market like mechanisms to influence the choices made by land managers. Rather than rely on regulations to identify the best course of action, individuals are able to select actions that best meet the environmental target, based on typically superior individual information. The potential advantage of MBI approaches is that they can achieve environmental goals at a less and hence more affordable cost to the community. The primary motivation of MBI approaches is that if environmentally appropriate behaviour can be made more rewarding to land managers, then changing attitudes and ensuing land management behaviour will better align with more socially desirable alternatives.

There are three main categories of market-based instrument: (1) charges, payments or price based instruments; (2) tradeable credits or quantity-based instruments; and (3) market barrier or impediment removal. The type of instrument chosen for comparison in this study is a quantity-based instrument. An important advantage of quantity-based instruments over other policy options is a greater level of environmental certainty as a result of the prescribed and enforceable threshold or cap. Tradeable permits, such as water trading in the River Murray in southeast Australia or the potential for salinity trading in the Murray-Darling Basin and environmental offsets represent the two main variants of quantity-based MBIs.

Global experience indicates that many past attempts to implement tradeable permit schemes for both diffuse (e.g. ground water recharge) and point source emissions have failed because of inadequate attention to the design and timing of the market architecture deployed (Tietenburg, 1998). Additionally, the behaviour of individuals with non-market and social motivations may diverge substantially from theoretical predictions (Gintis, 2000; Ostrom, 1998; Ostrom *et al.*, 1992; Poe *et al.*, 2004; Tisdell *et al.*, 2004). As a corollary, variable behavioural responses to novel policy implementation, conditioned by social context, market design and institutional procedures, make *a priori* estimates of the volume and cost effectiveness of recharge reduction policies difficult and potentially unreliable. When implementing market-based policies, agencies may need to account for behavioural and informational processing limitations (Braga & Starmer, 2005), which currently lie outside the domain of market analysis (Simon, 1972; Smith, 2002; Sterman, 1987). For effective recharge policy, careful instrument sequencing and accounting for the costs of complex informational processing may need to be imputed.

In many cases MBIs may be advantageous, but in others the relative advantages over other instruments may be limited, poorly defined, state contingent and subject to change through time. For example a market-based instrument may be cost effective, but may not perform well in the dimensions of adoption rates, administrative and transaction costs, concentration of environmental consequences and political feasibility. When these are important policy objectives, the single model terrain of economic efficiency or cost effectiveness may not be sufficient to reliably inform policy makers of instrument performance.

There are a number of preconditions for a functioning and effective cap and trade scheme:

- There is credible and reliable science to establish a threshold level that is clearly understood and matches the resource condition target;
- There are cost effective monitoring schemes in place that are transparent, consistent and credible to all participants. There must also be a clear link between land management actions and the subsequent environmental outcome. In cases where the environmental outcome is not readily visible (for example recharge into groundwater aquifers) a proxy indicator may be necessary (such as the type of crop mix and irrigation regime in this case);
- The nature (toxicity) of the pollutant is such that market exchange will not result in localised concentrations, which may cause excessive environmental degradation or hoarding of entitlements;

- There is sufficient differentiation in individual abatement costs across the catchment. If there are no differences there is no incentive to trade;
- There are regulatory agencies with effective regional jurisdiction to monitor and audit compliance levels and effectively enforce individual breeches;
- There are sufficient numbers of participants to ensure cost effective exchange opportunities and satisfaction of trading requirements;
- The transaction costs of monitoring, gathering information, enacting the exchange and enforcement are low in relation to the potential benefits gained;
- There are adequate and effective administrative institutions to ensure a functional market; and
- It is politically feasible to develop transferable, enforceable and tradeable private property rights, to minimise government intervention and allow flexibility of decision-making.

This last criterion translates into a broader set of formal and informal rules existing both within formal institutions – government departments, for example – and within community groups, such as groups of irrigating farmers. The enduring compatibility between the formal rules of a cap and trade scheme and the formal and informal rules of government and community processes impacts on the ability of the MBI to achieve the goals set for it, and hence, the adaptive governance of the institutional arrangement created through the combination of formal and informal rules. The *status quo ante* property rights arrangement in the Coleambally Irrigation Area is characterised by a lack of explicit requirements for farmers to manage levels of recharge resulting from their irrigation practices. Nor are there currently well defined and enforceable arrangements that would allow those who may suffer adverse consequences of increased soil salinity to compensate farmers causing salinity to reduce impacts. In essence what does exists is an implicit but poorly defined right of farmers to manage recharge as they like.

3. Theoretical insights and empirically based outcomes of different institutional structures to manage commonly shared water resources

Institutional analysis, network theory and deliberative and participatory methods offer theoretical insights about successful adaptive governance of common pool resources based broadly on the enduring compatibility of formal and informal rules and the capacity of communities to adapt to changing circumstances through their structures and processes. The experimental method enables the formal testing of developed hypotheses, articulating the predicted interaction of formal and informal rules. In the experiments, the behavioural responses of two coordinating institutions are observed and enumerated. First, a cap and trade system, both with socialised and individual penalties is considered. Second, provision of information and a process for communication between participants is evaluated.

Communication through group discussion and the structure of relations among community members are considered to define, in part, the set of informal rules guiding recharge decisions. Other hypotheses from network theory and deliberative and participatory methods will be discussed but have not been tested using the empirical outcomes of the experiments.

3.1 Institutional analysis

Institutional analysis, as it is applied in this paper, uses rules as the analytical unit. Rules, in this sense, are statements about what may, must or must not be done in a particular situation. Rules may have sanctions, or 'or else' conditions attached. In analysing the rules of a situation, institutional analysis seeks to understand the prescriptions that guide and govern human behaviour and interaction, and to understand how different sets of rules, or institutional arrangements, can operate to effectively manage actions in particular situations. Institutional analysis thus emphasises the close link between theory and practical problems of a public-policy nature, for example, the management of common pool resources. As such, institutional analysis offers key insights into the institutional arrangements of information provision and communication, which can enhance the likelihood of effective common pool resource management.

Communication and information

The provision of information is necessary to achieve effective management, but is unlikely to be sufficient in itself (for example, Smith, 1987, 2002; Tisdell *et al.*, 2004). Provided or available information additionally requires either formal or informal institutions to coordinate individual behaviour to achieve inspirational collective action. Theoretical insights (for example, Ostrom, 1998; Ostrom *et al.*, 1992; Vatn & Bromley, 1995) suggest that common pool resources can be effectively managed if there are information and communication options available to those using the resource. This is supported by empirical evidence (Cardenas, 2000; Ostrom *et al.*, 1992; Poe *et al.*, 2004; Tisdell *et al.*, 2004) showing that the provision of a formal and controlled forum for discussion leads to robust and effective voluntary social contracts with high levels of contract adherence. In contrast to game theoretic predictions (Ledyard, 1995), which consign communication to non-effectual cheap talk, Ostrom argues that communication both elicits attributes of reputation and buttresses reciprocal behaviour, for the collective management of shared resources. There is considerable experimental and field data indicating that in certain cases communication can be effective in aligning the outcome of resource dilemmas with policy objectives. Compared to impersonal communication, face-to-face communication has been shown to be the most effective means of promoting and reinforcing the formation of social compacts (Ostrom *et al.*, 1992).

We assume that communication between irrigating farmers includes communication about recharge conditions and coordination and broader goals for the region. We also assume that communication and information together with a market represents a set of formal rules that have been structured to be as compatible as possible with existing informal rules of communication and information-sharing. We hypothesise that recharge, and therefore resulting salinity levels, will be significantly reduced when the formal rules of a market for recharge credits are combined and reinforced with a communication mechanism compared to market exchange in isolation.

3.2 Network analysis

Network theory provides insight into how the way in which humans are connected to each other in a community or economy affects the dynamics and functioning of that community or economy. Based on the mathematics of graph theory, the science of networks has two fundamental building blocks: elements and connections, also known as components and linkages, or nodes and edges. A graph can be used to represent different types of networks where elements, for example, people or organisms, are connected to each other in different ways. What is of interest is the particular way in which the elements of a network are connected to each other, how these connections change through time, and the dynamics that this connective structure (and change in connective structure) give rise to.

The importance of network structure for a variety of social processes has been demonstrated in several domains, including market organisation (Kirman, 1997), interpersonal influence (Friedkin, 1998), the spread of disease (Klovdahl, 1985; Kretzschmar & Morris, 1996), and information diffusion (Valente, 1995). Different network structures and sizes can impact on adaptive governance. For example, larger networks may be less capable of self-organising to sustainably govern common property resources (Baland & Platteau, 1996; Wade, 1988), and groups of people with clearly defined boundaries may be more capable of such self-organisation (Ostrom, 1990; Wade, 1988). The network perspective is thus an important mode of analysis for understanding adaptive governance because it acknowledges that the structure of human interactions affects how rules and rule changes percolate throughout a system.

The key insight from network theory that influences institutional durability is that the structure of relations animate and determine market outcomes. In particular to this study, the existence and opinion of key players in the network may impact on the acceptance or rejection by the whole group of a new institutional arrangement.

Key players in the network

Network analysis can reveal the implicit roles that certain nodes (*viz.* people, organisms or organisations), play within a network. Those nodes with the most direct connections in the network are called ‘connectors’ or ‘hubs’. These nodes are very active, and, more importantly, they connect the otherwise unconnected. Hubs are ‘brokers’ when they connect two or more clusters. The weak connections between clusters of densely connected individuals are called ‘structural holes’ and brokers play a critical role in filling them (Burt, 1992). These nodes have a high degree of ‘betweenness’ and can be very powerful in that they have great influence over what flows through the network. However, they can also be points of vulnerability in that their impairment or removal could have significant impact on the integrity of the whole network and its functional ability unless there is some redundancy at those points (Albert *et al.*, 2000).

Networks with strong leadership have high correlations with adaptability (Krebs & Holley, 2002). Knowing who is a hub or other key player is important for focusing influence over the network: “influencing a small number of well-connected nodes often results in better outcomes than trying to access the top person or calling on random players in the policy network” (*ibid.*, pp. 2-3).

We assume that there are a number of key players within any common pool resource community and that the opinions of key players in the network impact on the acceptance or rejection by the whole group of a new institutional arrangement and hence, its durability. We hypothesise that group acceptance of a new institutional arrangement of a level required for institutional durability requires acceptance by a simple majority of all hubs in a social network. This is based on threshold models of collective behaviour that postulate that an individual will engage in a behaviour based on the proportion of people in the social system already engaged in the behaviour (Granovetter, 1978).

3.3 Deliberative and participatory methods

Deliberative and participatory methods have arisen in the context of needing to recognise connections between and influences on individuals as they make choices. Such methods have their basis in notions of social equity and procedural fairness (Habermas, 1984; Rawls, 1971;

Sen, 1995), especially when considering the allocation and fate of community, or common pool resources. The main interest in deliberative techniques stems from their ability to incorporate and reveal a range of connections within any decision-making context, including the connections between people, ideas/perceptions, cultures, and ecological realities. It is argued that these approaches can ensure the inclusion and consideration of matters pertaining to social equity (Jorgensen, 2002; Wilson & Howarth, 2002), power interests (De Marchi *et al.*, 2000) and institutional factors (Meppem, 2000).

Group processes are influenced by the individuals composing the group, and in turn, influence people's decisions about whether to accept or reject, or make use of a new institutional arrangement such as a trading scheme, for example. Individual characteristics such as socio-economic demographics, attitudes and perspectives, reasoning ability and prior knowledge and opinion will impact on the opinions people form and decisions they make. In group situations, which some aspects of many common pool resource management scenarios are, these individual characteristics and the composition of a group will influence the dynamics and decisions of the group. Such group processes may include the formation of group norms, polarisation and groupthink (Blamey *et al.*, 2000).

The key insight from deliberative and participatory methods that influences institutional durability is that the composition of a group of resource extractors and government officials coming together to manage a common pool resource and the dynamics this gives rise to will impact on how well a new set of rules works within an existing set of community processes. In particular to this study, the strength of key players' personal perspectives either in support of or against may impact on the acceptance or rejection by the whole group of a new institutional arrangement. This is combined with the overall number of key players in support or rejection as discussed for the hypothesis from network theory insights.

We assume that there are a number of key players within any common pool resource community and that the strength of opinions of key players in the network impact on the acceptance or rejection by the whole group of a new institutional arrangement and hence, its durability. We hypothesise that group acceptance of a new institutional arrangement of a level required for institutional durability requires strong acceptance by a simple majority of all hubs in a social network.

4. Testing the research hypotheses

We now turn to testing the hypotheses developed in the previous sections. These are:

Hypothesis one: Providing information on individual contributions to recharge and periodic crop damage will significantly reduce recharge levels.

Hypothesis two: Providing a forum for discussion, allowing the formation of a voluntary social contract to coordinate management decisions, will significantly reduce recharge levels.

Hypothesis three: Providing a market mechanism to trade voluntary recharge entitlements will significantly reduce recharge levels and increase income.

Hypothesis four: Providing a market mechanism in concert with a forum for discussion will result in further significant reductions in recharge levels compared to either coordinating institution in isolation.

We first describe the physical, policy and experimental setting.

4.1 The Coleambally Irrigation Area and experimental treatments

The Coleambally Irrigation Area (CIA) is located in the Murrumbidgee Catchment of the Murray Darling Basin in Australia (Fig. 1). Farmers in the CIA are experiencing irrigation induced waterlogging, rising saline groundwater aquifers and subsequent increases in soil salinity, which is a well known problem in mature irrigation areas across Australia. The consequences of salinity in irrigation areas include crop production losses, increased production costs and damage to environmental amenities and infrastructure assets in the region. Despite regulations limiting rice production and the application of irrigation water, the problem of rising saline groundwater and salinity persists (Khan *et al.*, 2003).

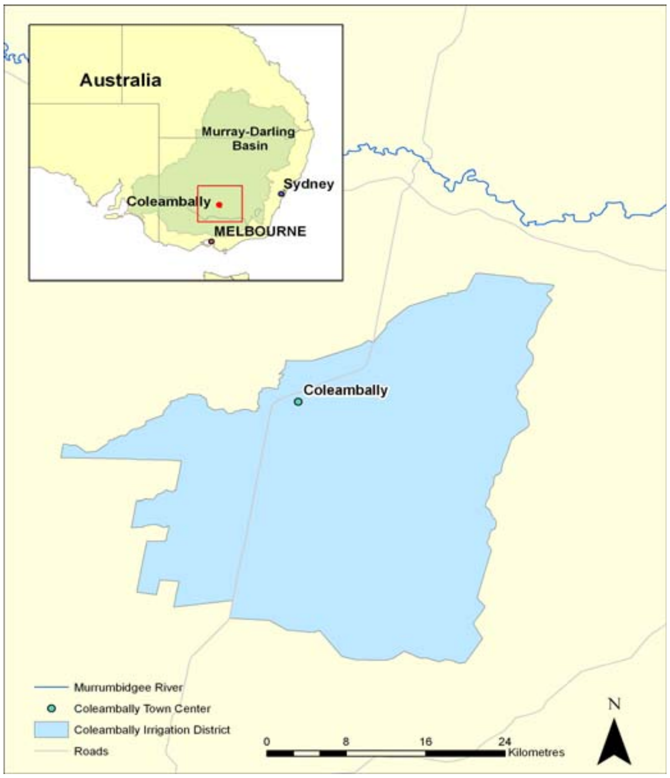

Figure 1: Map of the Coleambally Irrigation Area

The porous, adsorptive capacity of the soil fraction between the soil surface and the aquifer water table in the CIA can be defined as common pool resource. A social dilemma occurs when individuals are tempted by short-term gains to over appropriate the common pool resource, thereby imposing group-shared costs on the common pool community. Additionally the opportunity exists for some individuals to free ride and benefit from the reduction in recharge by others. Individual over appropriation will eventually lead to rising water tables and lower crop productivity for all farmers (Khan *et al.*, 2003).

Tradeable credits or quantity based instruments involve establishing an enforceable threshold for management, either as maximum effluent levels, prescribed resource usage or minimum environmental provision; distributing entitlements among participants or sources as specific units; and allowing trade of those units among those in the scheme. The environmental objective is to ensure the total number of units does not exceed the prescribed threshold for a given accounting period (usually one year). To satisfy compliance obligations, each participant in the scheme must be able to surrender units equal to their entitlement at the end of the accounting period. Therefore, participants can choose to alter land actions in response to individual management capacity, landscape attributes and production costs. Non-compliance incurs individual penalties, which are typically greater than the costs of complying.

While imposing a cost on individuals, the opportunity to trade has the potential to compensate that loss or reduce the cost burden. Some individuals will choose to use more than their quantum (and incur a debit), and others will choose to use less (being rewarded with credits). This results in a tension in the contracting process. There is a need to negotiate contracts so there is sufficient differential in the system to encourage trade but not so much that the negotiated output prevents a feasible solution. A challenge for policy is to create the opportunity for a frictionless market setting where participants could quickly learn to understand the advantages of trade with low learning and exchange costs relative to trade benefits. Information from market exchange, expressed as coherent prices signals, would reveal any differences in returns to management options that reduce environmental consequences and these would be immediately discovered and exploited.

To improve *ex ante* predictions of potential policy outcomes, experimental economics was employed to provide empirically based analysis of observed behavioural responses to the implementation of possible economic and community governance instruments to reduce recharge. In a controlled decision environment, calibrated to represent the economic and biophysical features of the CIA catchment, experiments were applied to formally test and evaluate the impacts of combining a formal market institution with a communication institution that best reflects the community's own set of rules for coordinating use and managing conflict.

The experiments were designed with field calibrated hydrological, biophysical and economic modelling relating recharge and opportunity cost to actual farm activity choices in the trial area. Experimental farms are thus heterogenous and represent the main relationships between landscape positions, farm management regimes, farm income and groundwater recharge specific to the CIA. The development of a recharge and salinity accounting tool has been detailed by Khan *et al*. (2003) in the SWAGMAN model. Experimental farm characteristics are detailed in Ward (2004) and an example is tabled in Appendix A.

The full experiment involved seven treatments. Only treatments one, three, four, five and six are described in the text, although for comparative purposes the figures illustrate the results from all seven treatments. The baseline treatment (treatment one) was designed to represent the status quo; farmers make decisions with little information about their impact on recharge, there are no binding recharge allocations or opportunities to trade allocations, losses due to rising water tables are shared among all farmers in the catchment and are not known in the short run. In this scenario, there is little incentive for individuals to limit their contribution to recharge, as the benefits in the form of increased income are private while the subsequent crop losses are shared. The cumulative increase of soil salinity caused by excess recharge and the crop losses shared by the common pool community cannot be solved by a single farmer acting alone.

Treatment three provides the participants with increasing amounts of information. In treatment three they are informed how their decisions impact on total recharge, based on data from the SWAGMAN model plus they learn how much income they stand to lose due to excessive recharge at the end of each period rather than at the end of the experiment. By examining the effect of information alone, it is also possible to distinguish the effects of the institutions used in subsequent treatments from the information that must be provided with them.

In treatment four, participants were provided with the same information as in treatment three. Additionally, before each experimental period they were brought together and allowed to discuss coordinating their decisions. This communication institution best represents the community's own set of rules for coordinating use and managing conflict, and will be used to test the impact of combining a communication institution with the formal institution of the market.

Treatment five consisted of information plus a closed call market for trading recharge allocations. In a closed call market potential buyers submit sealed bids to buy and potential sellers submit sealed offers to sell. The market is called, bids ranked and trades executed by a clearing-house, in this case the experimental recharge management authority. The authority computes a single equilibrium price at which all trade takes place based on the aggregate supply of and demand for credits. When the price has been computed, the authority notifies successful traders and announces the market price and informs successful traders of the individual volume traded only.

Treatment six combined the market with the communication treatments, providing a discussion forum before each period. The design of the experiments and the details of provided information, institutional rules, market exchange and associated penalties are summarised in Table 1 (relevant treatments are highlighted). An experimental session is comprised of 10 independent, repeated periods of annual management decisions, market trading or a forum for discussion. Each session was replicated twice.

Table 1: Experimental design to test levels of information and coordination in the CIA

Treatment		Individual recharge information	Institution		Penalty			Replicates
			Commun-ication	Market	Socialised	Individual	Timing	
1	**Control**	✗	✗	✗	✓	✗	**End of session**	**2**
2	Recharge information	✓	✗	✗	✓	✗	End of session	2
3	**Recharge + crop loss information**	✓	✗	✗	✓	✗	**Each round**	**2**
4	**Communication**	✓	✓	✗	✓	✗	**Each round**	**2**
5	**Market**	✓	✗	✓	✓	✗	**Each round**	**2**
6	**Market + communication**	✓	✓	✓	✓	✗	**Each round**	**2**
7	Market + individual penalty	✓	✗	✓	✗	✓	Each round	2

Details of the development of the experimental CIA catchment, player payments and penalties and characteristics of the experimental settings are provided in Appendix B.

4.2 Experimental Results

Observed data measuring behavioural responses to treatments were analysed using One Way Analysis of Variance (ANOVA). For both ANOVA (*F*) and pairwise *t*-tests, * indicates significantly different values at α=0.05. Homogeneity of variance between treatments was tested by Levene's statistic and found to be significantly different (p<0.05) for all treatments. Therefore, Dunnett's T3 *post hoc* test was used for pair wise comparison and described by subscript letters across the *mean value* row. Differences in subscripted letters across rows indicate the *post hoc* comparison is significantly different at α=0.05. Data are tabled for the seven treatments as: Total recharge (MLs), total crop loss ($); Nett player income ($); and for the market treatments: Market price ($); Quantity traded (MLs) and Gains from trade ($). The model prediction of total farm recharge represents the policy objective of a zero water table rise (1610 MLs) and corresponds to players acting as profit maximisers, responding optimally to available information.

The experimental results are as follows. Observed Total Recharge was highest in the baseline and information only treatments (Fig. 2, treatments 1-3). The coordinating institutions, communication and market treatments (4-5), were both associated with a significant (p<0.05) decrease in overall recharge compared to the information only treatments and the control. Combining the market and communication treatments significantly (p<0.05) reduced recharge still further (treatment 6). Treatment 6 is not statistically different ($p \geq 0.05$) from the modelled prediction of a zero water table rise. In all other treatments the rise in water table was statistically less than the predicted maximum.

The results indicate that observed Crop Loss was zero with the individual non-compliance penalty, and significantly less in the in the market-communication treatment (T_6) compared to treatments 1-5, (see Figure 3 and Table 3). Crop loss was significantly higher in the market only (T_4) and communication only (T_5) treatments compared to T_6, and significantly higher still in the information only treatments ($T_{1\text{-}3}$). The market only and communication only treatments were not significantly different. Among the information treatments, crop loss was significantly lower when experimental subjects were provided with crop loss data from the SWAGMAN model after each period (T_3) rather than at the end of the session ($T_{1\text{-}2}$).

Additionally, results for player income indicate the positive influence of combined communication-information and market institutions on institutional durability. Player income was highest in the market-communication treatment (T_6) (see Fig. 4 and Table 4). Income, expected as the gains from trade, in the market only treatment was significantly higher than in the communication only treatment. The lowest incomes were in the information only treatments ($T_{1,2}$), but treatment three, which provided the most SWAGMAN information to participants, had significantly higher incomes than treatments one and two. The increased income is a result of reduced crop loss.

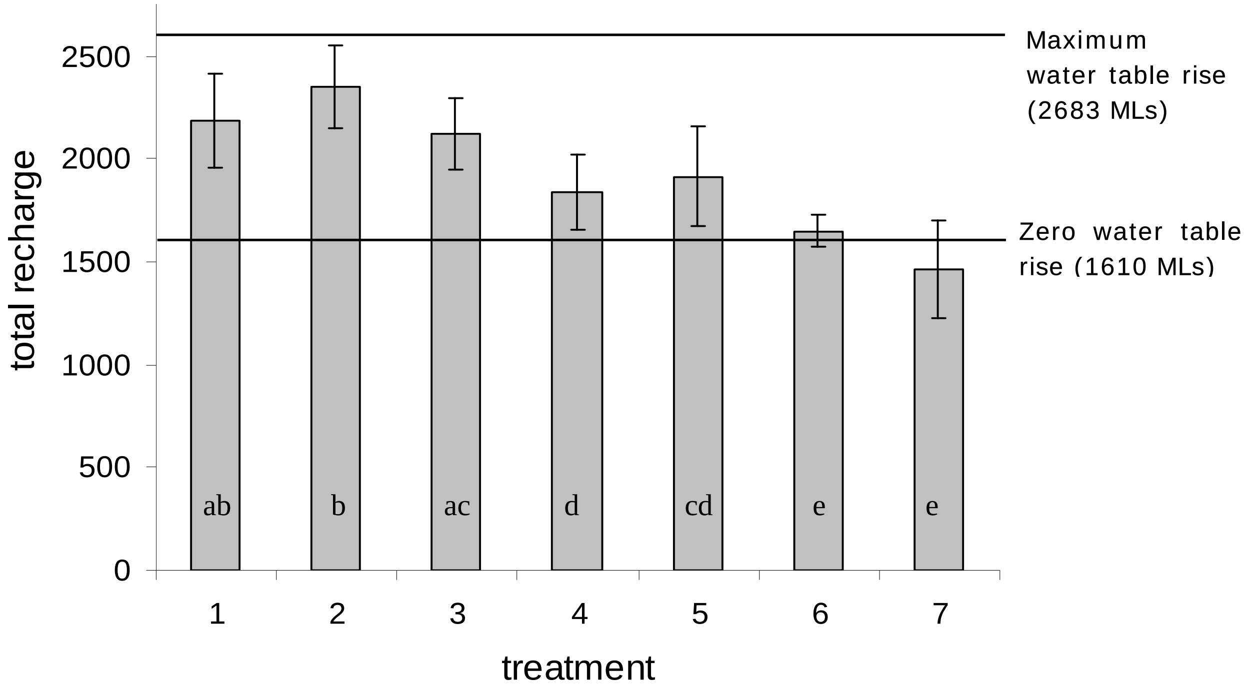

Figure 2: Total recharge (mean +/- 5%: 95% CI) by treatment[1].

Table 2: Table of descriptive statistics and ANOVA Total recharge

DESCRIPTIVES								
Total Recharge								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Min**	**Max**
control	20	2189.15	229.927	51.41335	2081.5406	2296.7594	1742.00	2440.00
swagman	20	2349.20	202.105	45.19214	2254.6118	2443.7882	1887.00	2658.00
Swagman+crop loss	20	2122.15	170.505	38.12626	2042.3508	2201.9492	1891.00	2492.00
communication	20	1839.15	183.209	40.96688	1753.4053	1924.8947	1610.00	2302.00
market	20	1914.30	244.400	54.64951	1799.9173	2028.6827	1091.00	2335.00
market+commun-ication	20	1650.30	81.0367	18.12037	1612.3736	1688.2264	1480.00	1769.00
Market+non-compliance	20	1464.55	235.791	52.72448	1354.1964	1574.9036	988.00	1928.00
model	10	1610.00	.00000	.00000	1610.0000	1610.0000	1610.00	1610.00
Total	150	1911.17	346.809	28.31686	1855.2188	1967.1278	988.00	2658.00

[1] Bars with the same letter are not significantly different at the 5% level

Table 2: (cont'd) Table of descriptive statistics and ANOVA Total recharge

	T'ment t_1	**T'ment t_2**	**T'ment t_3**	**T'ment t_4**	**T'ment t_5**	**T'ment t_6**	**T'ment t_7**	**model**
Mean value	2189 [ab]	2349 [b]	2122 [ac]	1839 [d]	1914 [cd]	1650 [e]	1464 [e]	1610[e]
T'ment t_1								
T'ment t_2	0.455							
T'ment t_3	1.000	0.000 *						
T'ment t_4	0.000*	0.000*	0.000*					
T'ment t_5	0.020*	0.000*	0.091	0.999				
T'ment t_6	0.000*	0.000*	0.000*	0.007*	0.003*			
T'ment t_7	0.000*	0.000*	0.000*	0.000*	0.000*	0.069		
model	0.000*	0.000*	0.000*	0.001*	0.001*	0.555	0.244	

(*p* value, Dunnett's T3 post hoc test: Homogeneity of variance (Levine statistic) $p < 0.05$; ANOVA coefficients: $F_{(7, 142)} = 48.480$; $p < 0.05$; * indicates significantly different at $\alpha = 0.05$; Treatment means with the same letter were not statistically different at α=0.05.)

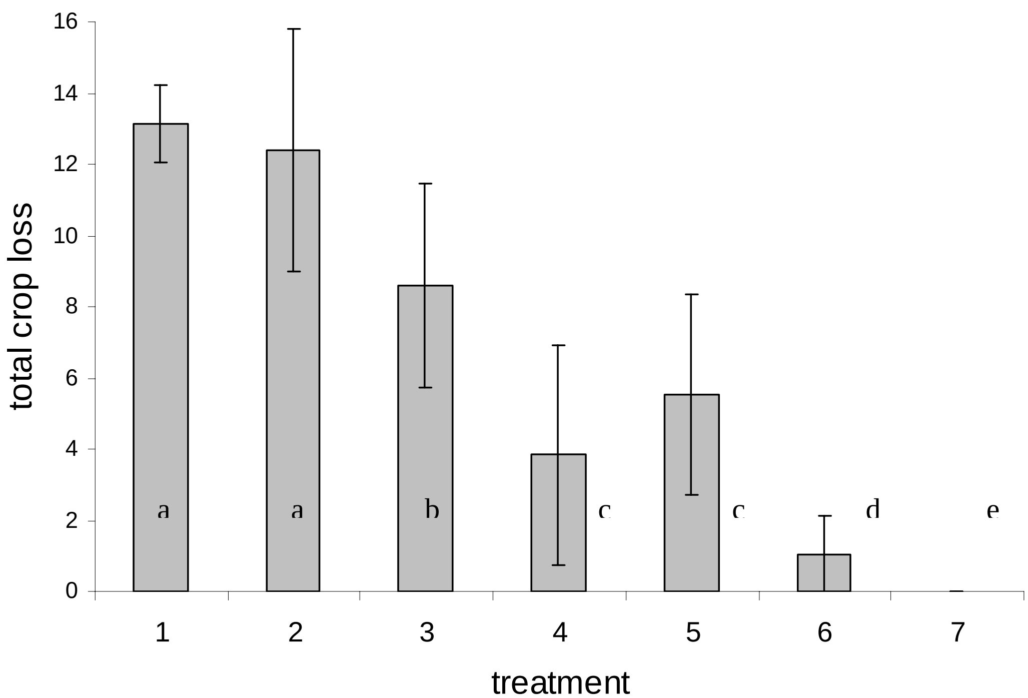

Figure 3: Total crop loss (mean +/- 5%: 95% CI) by treatment[2].

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[2] Bars with different letters are significantly different at the 5% level

Table 3: Table of descriptive statistics and ANOVA Total crop loss

DESCRIPTIVES Total crop loss								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
control	20	13.1460	1.10427	.24692	12.6292	13.6628	11.16	15.36
swagman	20	12.4080	3.39018	.75807	10.8213	13.9947	4.68	17.64
Swagman+crop loss	20	8.5920	2.86136	.63982	7.2528	9.9312	4.68	14.76
communication	20	3.8400	3.08138	.68902	2.3979	5.2821	.00	11.64
market	20	5.5320	2.81368	.62916	4.2152	6.8488	.00	12.12
market+commun-ication	20	1.0200	1.10085	.24616	.5048	1.5352	.00	3.48
market+non-compliance	20	.0000	.00000	.00000	.0000	.0000	.00	.00
model	10	.0000	.00000	.00000	.0000	.0000	.00	.00
Total	150	5.9384	5.43479	.44375	5.0615	6.8153	.00	17.64

Table 3: (cont'd) Table of descriptive statistics and ANOVA Total crop loss

	T'ment t_1	**T'ment t_2**	**T'ment t_3**	**T'ment t_4**	**T'ment t_5**	**T'ment t_6**	**T'ment t_7**	**model**
Mean value	13.15 ^{a}	12.41 ^{a}	8.59 ^{b}	3.84 ^{c}	5.53 ^{c}	1.02 ^{d}		0.00^e
T'ment t_1								
T'ment t_2	1.000[1]							
T'ment t_3	0.000*	0.012 *						
T'ment t_4	0.000*	0.000*	0.00*					
T'ment t_5	0.000*	0.000*	0.041*	0.845				
T'ment t_6	0.000*	0.000*	0.000*	0.020*	0.000*			
T'ment t_7								
model	0.000*	0.000*	0.000*	0.001*	0.000*	0.014*		

(*p* value, Dunnett's T3 post hoc test: Homogeneity of variance (Levine statistic) $p < 0.05$; ANOVA coefficients: $F_{(7, 142)} = 48.480$; $p < 0.05$; * indicates significantly different at $\alpha = 0.05$; Treatment means with the same letter were not statistically different at α=0.05.)

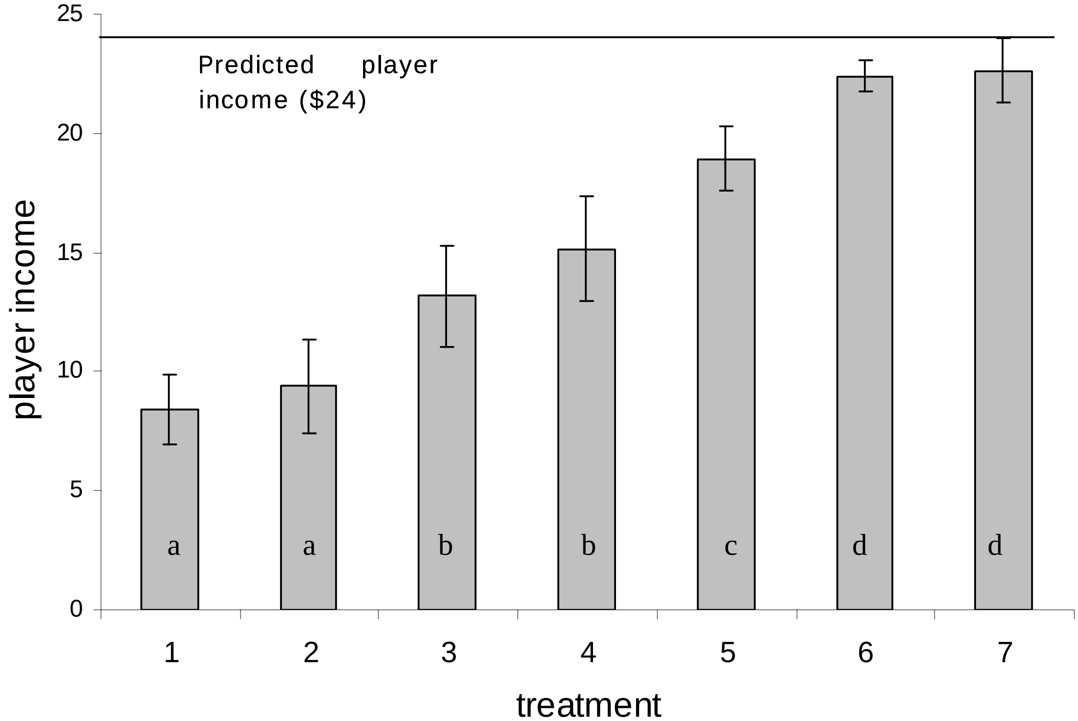

Figure 4: Player income (mean +/- 5%: 95% CI) by treatment[3].

Table 4: Table of descriptive statistics and ANOVA for player income

DESCRIPTIVES								
Player Income								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
control	20	8.3910	1.46815	.32829	7.7039	9.0781	6.63	10.92
swagman	20	9.3845	2.00641	.44865	8.4455	10.3235	6.38	13.87
Swagman+crop loss	20	13.1710	2.13244	.47683	12.1730	14.1690	8.24	16.29
communication	20	15.1475	2.18506	.48860	14.1249	16.1701	9.67	17.98
market	20	18.9265	1.36004	.30411	18.2900	19.5630	15.48	20.91
market+communication	20	22.3895	.66705	.14916	22.0773	22.7017	21.22	23.43
Market+non-compliance	20	22.6370	1.34919	.30169	22.0056	23.2684	19.32	24.59
model	10	24.0000	.00000	.00000	24.0000	24.0000	24.00	24.00
Total	150	16.2729	5.83797	.47667	15.3310	17.2148	6.38	24.59

3 Bars with different letters are significantly different at the 5% level

Table 4: (cont'd) Table of descriptive statistics and ANOVA for player income

	T'ment t_1	**T'ment t_2**	**T'ment t_3**	**T'ment t_4**	**T'ment t_5**	**T'ment t_6**	**T'ment t_7**	**model**
Mean value								
T'ment t_1								
T'ment t_2	0.859[1]							
T'ment t_3	0.000*	0.000 *						
T'ment t_4	0.000*	0.000*	0.148					
T'ment t_5	0.000*	0.000*	0.000*	0.000*				
T'ment t_6	0.000*	0.000*	0.000*	0.000*	0.000*			
T'ment t_7	0.000*	0.000*	0.000*	0.001*	0.000*	1.000		
model	0.000*	0.000*	0.000*	0.001*	0.000*	0.000*	0.006*	

(*p* value: Dunnett's T3 post hoc test; Homogeneity of variance (Levine statistic) $p < 0.05$; ANOVA coefficients: $F_{(7, 142)} = 256.086$; $p < 0.05$; * indicates significantly different at $\alpha = 0.05$; Treatment means with the same letter were not statistically different at $\alpha=0.05$)

In the baseline control treatment, in which experimental subjects were provided with no information about recharge or the aggregate penalty for incurred crop loss, overall recharge levels were high, resulting in significant crop loss. However it should be noted that recharge levels were still below the predicted maximum of 2683 MLs, suggesting that some participants may be voluntarily limiting their individual income in order to keep recharge down. Introducing additional information about individual contributions to recharge did not result in a significant reduction in total recharge when crop loss was not known until the end of the experiment. Crop loss also remained high in both these treatments. However, providing the monetary value of crop loss at the end of each period did result in a significant decrease in crop loss and a corresponding increase in player income. Therefore these experiments provide only limited support for hypothesis one, that providing information about recharge and crop loss will reduce recharge levels. As previous studies have found, information may be necessary for co-ordination and successful management, but it is seldom sufficient (eg Tisdell *et al.* 2004).

Providing the communication forum resulted in significant decreases in total recharge, crop loss and increased incomes. Hypothesis two is therefore supported by the experimental data. This suggests that face to face communication allows and reinforces the formation of an informal but robust social compact. The results are in accord with Ostrom *et al*. (1992), Tisdell *et al*. (2004) and Poe *et al*. (2004). Additionally, levels of observed voluntary adherence to the crafted contract were high and in contrast to game theoretic predictions (Ledyard 1995) did not decay through the experimental periods. Such institutions are attractive because they are entirely voluntary, and involve low transaction costs. This form of institution should be investigated further in the field trial to test whether the result holds among groups of irrigators characterised by potentially diverse social norms and competing demands. As a cautionary note, developing effective social norms is likely to be far more challenging among a large and diverse group of irrigators than among a dozen experimental participants.

While capping recharge clearly imposes a cost on landholders, allowing trade should compensate or reduce this burden. In a “frictionless” market setting where participants could quickly learn to understand the advantages of trade with “zero learning” cost, savings to landholders through market exchange between individuals with surplus recharge rights and those in deficit may be considerable. Information from frictionless market exchange would reveal any differences in returns to farm management options that reduce recharge and these would be immediately discovered and exploited.

The evaluation of the treatment testing behavioural responses to a clearance market mechanism indicated reduced crop loss and increased player incomes. In the presence of a cap, distributed according to a specified allocation limiting individual contributions to recharge, and enforced by a socialised penalty for breeching the cap, the ability to trade appeared to provide a statistically effective coordination mechanism. Combining the market with a communication forum significantly improved performance compared to the individual market and communication treatments. This suggests that people can achieve voluntary abatement targets and use the market mechanism to sufficiently compensate the loss of farm income with trade generated income. Hypothesis three and four, that markets and markets plus communication can facilitate a reduction in recharge, is therefore also supported.

4.3 Other hypotheses

Modelling of social networks and assessment of strength of opinion were beyond the scope of this study, however, these insights and hypotheses show the direction in which one could extend this research to gain greater understanding of the qualitative factors impacting on the durability of institutional arrangements.

5. Discussion and conclusions

The combination of a market with processes for communication and information sharing improve environmental outcomes and player payments greater than a market alone. We assert that a MBI is thus more durable when combined with appropriate community-based structures that best mimic local, informal rules about resource use and conflict resolution. The fact that the combination of a market institution with communication processes leads to the desired environmental benefits will contribute to the acceptance and durability of the institutional arrangement, in other words, the fact that it is achieving its stated goal sends a positive signal to resource extractors. Acceptance and durability is also boosted by the increase in player payments, which act as an additional incentive to participating in the market.

Theoretical insights from the literature on institutional analysis, network theory and deliberative and participatory methods about successful adaptive governance of common pool resources reveal that there are many factors that can impact on the acceptance and durability of an institutional arrangement. This is based broadly on the enduring compatibility of formal and informal rules and the capacity of communities to adapt to changing circumstances through their structures and processes.

The analysis of competitive markets is premised by a set of articulated predicates: that exchange outcomes are highly excludable, divisible, transferable and fully internalised by those engaged in the exchange process. In an idealised market, agents acting as profit maximisers responding optimally to coherent, accurate and reliable price signals can reach collective decisions resulting in an ordered, predictable outcome which is superior to other possibilities and dispositions. The reality is that the full set of conditions necessary to ensure frictionless and efficient markets and to comply with cap and trade prerequisites are rarely if ever present. In many market settings there are numerous impediments to the satisfaction of these conditions. A number of potential impediments which potentially violate those necessary conditions were identified across an array of market structures. An overview of the practical consequences to market outcomes is specified in Ward (2004).

Unaccounted for market impediments and the common pool nature of groundwater recharge are likely to compromise *a priori* theoretical prediction reducing its capacity as an analytical tool or a reliable precursor for recharge policy decision making in the CIA. In addition the recent advances of MBIs as policy tools for managing diffuse source environmental problems, has also meant limited opportunities for policy makers to gain experience and expertise in their design, testing and implementation. Appraisals of their relative importance in policy portfolios have also been informal and *ad hoc*. Although the analysis of market based instrument performance has improved, simple rules and evaluation protocols to identify *ex ante* the relative advantages over other instruments to resolve specific environmental problems have not yet emerged. The use of institutional analysis, network theory and deliberative and participatory methods can offer additional insight into these issues.

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Appendix A

Table A1 Table showing relationship of water table (WT) rise, gross margin (GM), recharge and crop mix

Max WT rise (m)	Surplus water (MLs)	GM ($)[1]	Recharge(MLs)	Crop type (Ha)								TOTAL (ha)	Irrigation MLs
				rice	maize	lucerne hay	wheat	canola	dryland wheat	dryland pasture	fallow		
max		103965	228	69	20	3	48		40		20	200	1154
0.6		103548	211	69	20	8	23	0	40	20	20	200	1152
0.5	0	102737	191	66	20	13	14	0	40	27	20	200	1153
0.4	0	101180	160	56	20	13	66	0	25		20	200	1163
0.3	0	98790	132	57	9	12	100	2			20	200	1161
0.2	33	95333	104	57		11	52	60			20	200	1126
0.1	128	90687	74	48		11	61	60			20	200	1041
0[2]	223	86041	44	39		10	71	60			20	200	946
-0.1	318	81395	14	30		10	80	60			20	200	860
-0.15	366	79071	0	25		10	85	60			20	200	813

Table A2 Table showing relationship of water table rise, experimental decision set, farm income and recharge

Max WT rise (m)	Experimental decision	GM ($)	Recharge (MLs)	Marginal change[3] in GM ($)	Marginal change in recharge (MLs)
max	1	$103,965	228	17924	184
0.4	2	$101,180	160	15139	116
0.2	3	$95,333	104	9292	60
0	4	$86,041	44	0	0
-0.15	5	$79,071	0	6970	44

[1] Gross margins include the sale of surplus water a$30/ML
[2] zero water table rise: recharge allocation for experimental farm is set at 44 MLs
[3] marginal change is calculated as the difference in decision value ($ or MLs) and zero water table rise (viz. $86,041 or 44 MLs)

Appendix B

Development of the experimental CIA catchment

Experimentally testing the management of salinity reduction requires simplified yet realistic simulations of farm decision-making that include the most important aspects of the system and yet are simple enough to be implemented as an experimental treatment. The objective of the simulation was to represent the economic decision-making and trading environment with the salient biophysical, economic and hydrological characteristics estimated for the Central sub-catchment of the CIA.

Previous research employing the SWAGMAN model has established and enumerated the relationship between an established and proposed crop mix, water application, groundwater depth, soil type and subsequent management with farm income and recharge volumes spatially located to specific landscape positions in the CIA (Khan *et al*. 2003). A simulated catchment was constructed comprising twelve model farms based on a representative sample of farms from the CIA, with sizes ranging from 200 to 335 hectares. The SWAGMAN model was used to estimate levels of income and recharge under alternative crop mix and management options. For each model farm there were five alternative management options, representing different mixes of crops. Each of the five crop mix decisions are characterised by a specific farm income associated with a recharge level. Higher incomes are associated with higher recharge levels. SWAGMAN was used to estimate the threshold level of recharge below which the water table would not rise – this was the policy target in this simulation. The set of selected farm enterprises represent the main relationships between landscape positions, farm management regimes, farm income and groundwater recharge.

Additional context was iteratively introduced into the experimental domain, where participants are informed they are hypothetically farmers, are located in a closed catchment and produce recharge, which in turn potentially affects other farmers. Using the experimental setting, we sought to elicit and measure behavioural responses to hypothetical decision environments simulating policies and diverse institutional structures across an array of market conditions in an analogue specific to the CIA.

Contextualisation is not usual experimental protocol, however this research follows the practical and theoretical lead of Cardenas (2000), Krause *et al*. (2003), Poe *et al*. (2004) and Tisdell *et al*. (2004). As an important insight from cognitive psychology, Lowenstein (1999) and Loomes (1999) advocate that decision-making is highly context dependent. This has lead some experimentalists to conclude that to inform policy meaningfully, experiments may need to be designed to include salient features of the policy setting of interest (Krause *et al.*, 2003; Loomes, 1999; Lowenstein, 1999; Tisdell *et al.*, 2004). Adherents conclude that while experiments designed to eliminate any confounding effects are useful for isolating influence of single treatment factors, they may not tell us much about how people are likely to react in real world contexts where confounding factors exist. There is now a growing body of experiments conducted in context rich environments. Results demonstrate that differences in context lead to differences in bargaining behaviour, risk-taking and sharing (see Camerer & Lowenstein, 2004; Gintis, 2000; see Krause *et al.*, 2003).

While experiments from context rich settings may allow only limited inference about behaviour in other contexts, according to proponents they represent the most appropriate way to draw inferences about behaviour that are valid for specific contexts where policy design is being investigated (Lowenstein, 1999; Plott & Porter, 1996). Context also makes the simulation more readily transferable from the laboratory to field trials, and can provide a tool to facilitate learning and engagement by the catchment community. Figure B1 illustrates the predicted outcome of trade in recharge units, assuming traders were profit maximisers who completely understood and acted upon optimal trade strategies. The values are derived by computing the demand and supply relationships underlying the range of management decisions that subjects faced in the experiments. The predicted equilibrium is 407 ML traded at a price of $43 per ML and aggregate gain from trade in the recharge market is $17,501. The estimated aggregate gain from trade, relative to the estimated maximum income ($1,272,484), is 1.38%.

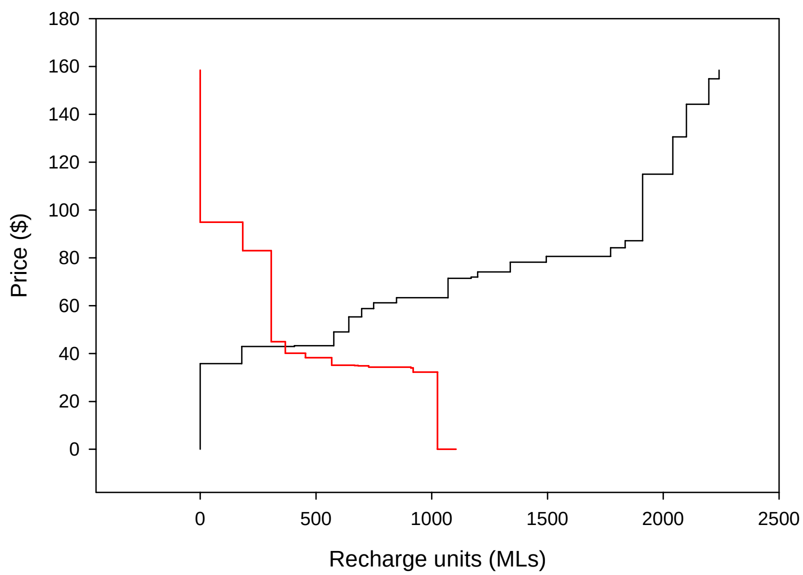

Figure B1: Estimated supply and demand for recharge in the experimental simulation of CIA

Player payments and penalties

Experimental economics tests and measures real rather than hypothetical economic behaviour by paying participants based upon the outcomes of their decisions. The comparison and analysis of experimental treatments is statistically more robust when participant decisions are responses to equivalent payment options. Therefore in these experiments, payments for each period were relative to the optimal decision responses for each farm. It was also necessary to ensure that payment functions are equivalent *between* experimental treatments. Player payments were therefore calculated as a function of actual and optimum aggregate farm management and trading outcomes, specific to each experimental treatment.

In addition to a $10 attendance payment, player payments are calibrated using a single variable OLS regression, relating a $2.00 per period for achieving the derived optimum farm income and $0.40 for decisions predicted to produce minimum farm incomes. Theoretical optima assume players are profit maximises acting optimally to available levels of information and strategies. To ensure salience of player behaviour and response to income variance in the simulated catchment, the player payments are therefore a scaled representation of the income decisions confronting farmers in the CIA. To ensure the integrity of future experimental sessions, the payment functions have not been reported here. They are available upon request from a co-author (j.ward@csiro.au).

If aggregate recharge exceeds the threshold for a zero water table rise (1610 MLs), farms incur crop loss, resulting in a reduced income. Nett player income is calculated by subtracting the crop loss penalty from the gross player payment for each period. The crop loss penalty represents a socialised cost (except in the individual penalty treatment), equally imposed on all players, as rising groundwater increases salinity for the whole of the Coleambally catchment. The maximum crop loss penalty is $1.50 or 75% of the optimum player payment, corresponding to estimates of actual crop loss due to maximum water table rise and subsequent soil salinity (Khan, 2004). The crop loss penalty is calculated as a linear function of the rise in water table. Khan (2004) proposes the function is likely to be non-linear, but an accurate estimation was not available at the time. In the individual penalty treatment, participants who exceeded their recharge allocation had their income reduced to that of the nearest option that did meet their allocation.

The experimental simulation and recharge credit trading environment was field demonstrated at Yanco Agricultural College with CIA based irrigators. In the experimental field simulations, observed market prices for recharge units generally reflected modelled outcomes, although the level of trade was limited and the incentive to trade was small, i.e. the proportion of trading income relative to farm income was very low. The data for the simulated catchment were refined and re-framed for the laboratory sessions in accord with irrigator comments. Suggestions were made for a larger penalty for non-compliance with recharge targets. In accord with farmer consultation, current experimental penalties reflect a reduction in farm income corresponding to an income level associated with a complied recharge target. The market costs of recharge purchases that partially fulfil targets were also deducted from farm income.

Characteristics of the experimental setting

Experiments were carried out at the Griffith University experimental economics laboratory in Brisbane, using the MWATER experimental software platform developed and administered by Dr. John Tisdell. The software provides a standardised decision-making environment and allows for the inclusion of complex biophysical data in the experimental decision set. Participants were drawn from a pool of approximately 200 Griffith students who had taken part in a number of previous experiments. The use of students as experimental participants is in accord with standard experimental economics practice (Friedman & Sunder, 1994; Kagel & Roth, 1995; Smith, 2002).

At the beginning of each session, participants accessed a set of power point instructions through their computer terminal. The instructions explain the rules, protocols of the experimental setting and the characteristics of the experimental farm. They are specific to the treatment being tested in that session. Staff supervising the experimental sessions do not verbally present the instruction sets to avoid personality or behavioural biases and delivery nuances. Talking, unless in a formal treatment, is forbidden throughout the sessions, except to clarify questions regarding the experimental setting. To ensure consistent understanding participants were asked to complete a quiz comprising 10-12 questions specific to the experimental treatment. All questions must be completed successfully before participants can access the experimental software.

Participants are randomly assigned to the 12 model farms. Upon accessing the experimental software they are presented with a table listing the farm income associated with each of the five management options available to them. They are also told their farm's initial recharge allocation (R_a), nominally set as the crop mix option corresponding to a zero water table rise. In treatments two onwards they are also told how much each decision would contribute to total recharge. Recharge information is provided to participants as the number of recharge units, rather than as ML. Participants only have access to their own farm information, updated throughout the experiment. All information is derived from the SWAGMAN model.

At the beginning of each period, participants are asked to select one of the five discrete farm management options by entering a number into a box, which appears on screen for 90 seconds. After entering the chosen management option, screens are updated with the option-specific income. In treatments one and two subjects are provided gross income for each round, and are told that there is likely to be a crop loss penalty, which will not be known until the end of the session. In subsequent treatments, subjects learn their income nett of any crop loss in each period. If all experimental players choose the crop mix that maximises income, recharge is also maximised to a level of 2683 MLs. A crop mix decision set that corresponds to a zero water table rise represents a recharge value of 1610 MLs.

In the market treatments participants are also told the required recharge balance for the selected option and the marginal value of recharge units. The recharge balance (R_b) is calculated as the initial recharge allocation less the amount needed for the farm management option the participant selects. R_b can represent a surplus or deficit of recharge units depending on the farm allocation and management option selected. For example if $R_a = 100$, $R_{\text{option 1}} = 200$, $R_b = -100$. If $R_a = 100$, $R_{\text{option 5}} = 0$, $R_b = 100$. Option one has a recharge shortfall of 100 units, requiring purchase in a recharge market; option five has a surplus of 100 units, allowing a sale in the market. The marginal value of a recharge unit is calculated as the difference in income between that of the target recharge option and the selected management option, divided by the cumulative difference in recharge between the target recharge and the selected management options.

Players voluntarily enter the market to meet recharge shortfalls and sell surplus recharge units. Market trading options are contingent on player behaviour and conditioned by farm characteristics. Participants can either buy or sell (subject to having surplus recharge units), but may only enter a single bid in each period. Market entrants enter bid quantities (based on R_b) and their price (based on the marginal value of recharge). Players are prevented from offering surplus recharge units for sale in excess of their calculated R_b. A closed call market institution is used in the trading session. Bids are accepted over a 90 second period, and the market clearing price calculated. The market price is announced (in the event that there are no matching buy and sell offers, it is announced that no trades occurred), but individual bids are not revealed. Participants' screens are then updated to reveal the outcome of their bids, the market price and their total income from the period.

In the communication treatments, participants are asked to move into a separate room and encouraged to discuss coordinating their recharge decisions. The initial forum, lasting five minutes, is prior to selecting management options in the first experimental period. Before each subsequent round participants are again asked to move into a side room for a further three minute discussion forum. Players cannot reveal their farm characteristics, intended or historical market strategies or the value of their recharge units. Making threats, or arranging side payments outside the laboratory, are forbidden. Players who contravene these experimental protocols are excluded from future sessions. Consensus is achieved by majority vote if required. Communication between players is not permitted between the discussion forums. Supervising staff are able to facilitate the discussion forum by answering technical questions and calculating aggregate recharge reduction and social payment estimates only. They cannot engage in any strategic discourse with the players. Participation in the treatment is voluntary, subsequent decisions remain anonymous, and there is no individual penalty for non-adherence to the group consensus.

Each session involved approximately ten periods (the exact number was randomly varied so the participants could not be sure when the experiment would end) and varied from 1.5 to 2 hours depending on treatment design. Participants were paid their total earnings for all periods in cash at the end of each session. All decisions and payments were anonymous. A complete set of the experimental instructions can be obtained from the author (j.ward@csiro.au).

The experimental rules and player information in the treatments are summarised as:

- ***Treatment $_1$ (control):*** farm income (converted to gross player income) only associated with 5 crop mix decisions, no recharge information. The total crop loss penalty (equally shared amongst all players) is announced at the end of the 10 period experimental *session* (i.e. the penalty is announced once).
- ***Treatment $_2$:*** farm income corresponding to 5 crop mix decisions plus associated recharge rate and the farm income/crop mix associated with zero water table rise (called SWAGMAN information). The crop mix decision associated with the zero water table rise specific to each farm corresponds to the recharge entitlement. The total crop loss penalty is announced at the end of the 10 period *session*.
- ***Treatment $_3$:*** SWAGMAN information, zero recharge rate and player income net of crop loss penalty plus crop loss penalty is publicly announced at the end of each *period* (i.e. the penalty is announced 10 times).
- ***Treatment $_4$:*** SWAGMAN information, zero recharge rate, period announcement of crop loss penalty plus communication forum.
- ***Treatment $_5$:*** SWAGMAN information, zero recharge rate, period announcement of crop loss penalty plus cap and trade market.
- ***Treatment $_6$:*** SWAGMAN information, zero recharge rate, period announcement of crop loss penalty plus market and communication.
- ***Treatment $_7$:*** SWAGMAN information, zero recharge rate, plus market plus individualised penalty for non-compliance with the specific individual recharge entitlement.