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Experimental Economics and Water Policy

Charlotte Duke

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Experimental economics and water policy

Charlotte Duke

University College London

and

The University of Melbourne

Abstract

Experiments in economics and their application to policy design continue to gain increasing popular appeal. Australia is investing in training, capacity building and international partnerships to bring these skills to our policy makers. Economic experiments are used to test policy-related hypotheses: to examine the behavioural processes upon which the policy is built, identify policy bugs, confirm incentive mechanism performance, investigate new decision processes, and illustrate economic allocation systems to stakeholders. Experiments provide a new source of information to improve policy design.

This paper explores a set of experiments conducted for the National Action Plan for Salinity and Water Quality Market Based Instruments Pilots Program. The experiments test bed water and salt markets. The pilot region is the Sunraysia in northern Victoria, Australia. The paper looks at,

- How economic experiments can answer policy questions important for field implementation, using the questions posed by stakeholders in Sunraysia.
- How economic experiments complement economic theory, using examples from the salinity and water allocation problem in Sunraysia.
- Provide examples of other water policy experiments. These experiments address water allocation questions important to Australia.

The objective of the paper is to reveal both the strengths and limits of economic experiments for policy. The paper is based on my experiences using experiments for policy design in the role of a research economist for government and as a PhD researcher at University.

JEL Classification: Q25, Q28, C90.

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* Charlotte Duke is a Research Affiliate Student at University College London, 2005 - 06.

* Address for correspondence: <u>c.duke@ucl.ac.uk</u>, <u>c.duke2@pgrad.unimelb.edu.au</u>

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I. Introduction

This paper explores the use of *economic experiments* for *field policy* design. It forms part of a series of papers that investigate the performance of water markets and alternative corrective policies for negative water externalities using economic experiments: Specifically, salinity from irrigation. The learnings from salinity and water apply to other externalities such as nitrogen, phosphorous and suspended solids; when the relationships between water use and the externality can be measured (point-sources) or estimated (non-point sources). The research informs the *National Action Plan for Salinity and Water Quality, Market Based Instruments Pilots Program.*¹

The salinity experiments are calibrated to field conditions in the Sunraysia in northern Victoria, Australia. There is an operating water market in the Sunraysia. Irrigators can buy and sell water licenses (water property rights) in this market.²

The participants (also called subjects) in the economic experiments represent irrigators in the Sunraysia, and they must make decisions about water use, salt impact/cost and irrigation technology (abatement). Subjects can earn and lose money by making these production decisions.³ Any earnings made are paid to subjects in cash at the end of the experiment.

Irrigation externalities for the Sunraysia are estimated using hydrological modelling. This modelling allocates irrigators to one of five salinity impact zones located along the river reach.⁴ The salinity modelling allows regulators to attribute changes in river salinity concentration, measured at the end of system CAP located at the South Australian city of Morgan, to individual irrigators based on location and

¹ See <u>http://www.napswq.gov.au/mbi/round1</u>. Project reports can be found in MBI Pilot 10 Final Report, Cap and Trade for Salinity.

 $^{^{2}}$ For information on the water market see <u>http://www.watermove.com.au</u>. In this market 'traders may submit offers by mail, fax or online. Offers must define the trading zone volume for trade in megalitres, price per megalitre and the number of exchanges for which the offer is valid'.

³ Subjects are paid a non-salient (does not depend on their choices in the experiment) A\$5 turn-up fee. Salient earnings vary between A\$10 and A\$25 depending on the decisions the subject makes in the experiment. Each experiment lasted between one and half to two hours including time for instructions and two training periods to check subjects' understanding of the processes.

⁴ The impact zones are located on the Victorian side of the Murray River between the town of Nyah and the South Australian border. For details of the impact zones see

http://www.srwa.org.au/index2.htm the Lower Murray Water, Rural Water website.

water use.⁵ The impact zones allow environmental regulators to use point-source policies for a diffuse source externality. Figure 1 shows the Sunraysia, the salinity impact zones and the (estimated) location specific change in salinity from water trade. Water demand for Sunraysia is approximated using gross margin estimates for regional crops and irrigation technology published by the Victorian and NSW Departments of Primary Industries. Distribution of production across the region was gathered from aerial photos and land-use data held by local information brokers 'Sunrise 21'.

The experiments were conducted at the University of Melbourne Experimental Laboratory.⁶ Subjects traded in computerised environments.⁷ The trading programs were designed and developed at the University of Melbourne (see Duke and Gangadharan 2005, and Duke, Gangadharan and Cason, 2006, for the experiment instructions and the trading screens seen by subjects). The experimental environment included a water market where buyers and sellers could make and accept offers to buy and sell water: A unit of water is traded in the market if an offer to buy or sell is accepted.⁸

To manage the salinity externality, three alternative market based policies (MBI) were implemented with the water market.⁹

and performs the calculations. See Duke, Gangadharan and Cason, 2006.

⁵ The Impact Zone modelling estimates the change in river salinity concentration from an additional 1,000 mega litres traded into an impact zone from one of the four other impact zones. In the experiments we use these 'trade' generated external estimates as a proxy for 'use' generated estimates and assume all water bought and sold is used in production.

⁶ For information on economic experiments at the University of Melbourne see

http://www.economics.unimelb.edu.au/dept/EDN/EDNMain.htm, The Economic Design Network. The Tradable Permit experiments were implemented using hand-run double auctions for water and salt. We chose to not to use computers for the TEP experiments because hand-run experiments allow the experimenter to better observe the formation of prices in these markets. We were also learning how to run simultaneous double auctions with endogenous technology change. Choosing a hand-run environment allows the experimenter to identify, isolate and where possible correct misunderstandings and mistakes within a session. This is much more difficult when a computer organises the transactions

⁸ Water property rights in well designed markets reveal competing users' value for the shared resource. The market allows users to signal their willingness to pay for the resource and broadcasts the cost of supply to all users. Water rights can effectively reveal the cost of changing water quantities in different locations within a hydro-geographic region.

⁹ Water property rights alone do not reveal an important piece of missing information. Changing water allocations (also) impacts upon water quality. Water property rights do not effectively reveal the cost of salinity to different groups in the economy.

I. The Sunraysia Salinity Levy: This policy is a priced based MBI.¹⁰ The levy currently operates in the region and adds the cost of salinity to the price of water. The magnitude of the levy depends on how many impact zones the water is traded across: the further the buyer from the seller the larger the levy.¹¹ Buyers only pay the levy if they buy from a seller in a lower impact zone. There is no cost or benefit on water traded from a higher to a lower impact zone. The levy also introduces a trade barrier between the highest salinity impact zone and all other zones: No new water can be traded into the HIZ.

The Sunraysia Levy has been operating in the region since 2002. Empirical information on performance of the Levy, and its impact on water prices and salinity, is limited. The electronic water trade market, called *Watermove*, does report some price data. A lot of this information is however held by individual water brokers. Historical field data is therefore limited, and can be costly to collect. Further, when using field data it is difficult to isolate and control for different factors that can impact upon irrigator behaviour. Experiments can generate observations that can be used for empirical testing, and experiments can minimise noise in data allowing the policy designer to isolate the drivers of behaviour.

II. An alternative price based design, which we call a salinity tax, is tested. The salinity tax removes the Sunraysia Levy trade barrier and replaces it with a tax equal to the external cost of water traded into the HIZ from each of the four lower impact zones. This design more closely follow s recommendations from economic theory: If the impact of an additional concentration unit of salt generated by water trade into the HIZ is not 'catastrophic', then it may be more efficient to use an economic incentive as compared to a command and control instrument (the trade barrier). The economic incentive – the tax – will allow irrigators with high value use for water to use additional water in the HIZ and to pay for the additional salt they contribute. The irrigator is in a

¹⁰ See Weitzman, M.L. 1974, for a discussion of taxes/levies – price based market mechanisms – and tradable permits – quantity based market mechanisms.

better position to make this decision than the regulator (when the regulator uses a command and control directive). The tax minimises policy inefficiency caused by asymmetric information.

III. A tradable salinity permit market is implemented alongside the water market. In a TEP system irrigators must hold salinity permits if they want to use water in production.¹² For each unit of water used an irrigator will have to hold corresponding salt permits. Irrigators located in higher salt impact zones need to hold more permits per unit of water than irrigators located in lower salt impact zones. A market for salt can inform irrigators, government and society about the cost of salt in rivers. This is because the salt property right unbundles the salt right from the water right. The water price will reflect the scarcity of water quantity; the salt price will reflect the scarcity of water quality. This unbundling allows irrigators to focus management effort on both water and salt: Irrigators will choose to adopt salt abatement technology if the cost of change is less than the price of a salt permit in the salt market. This private investment provides an additional supply of salt abatement.

The salinity permit can minimise a second asymmetric information problem. The price of the salinity permit is determined in the salt market by three (main) features of the policy. First, the river CAP which limits the total supply of salt in the region (the total number of salt permits available). Second, the salinity impact zones that are used by the regulator to set the required number of salt permits for water use in each zone. Third, irrigators' individual demand for salt permits, which is based on irrigators' private production information and not known by regulators. These three design features interact to determine the cost of salt. The Tradable Permit system minimises a second asymmetric information problem because the permit market uses the irrigators' private production information to set the price for salt. Regulators in this system set framework and rules of the market — the aggregate number of salt permits

¹¹See <u>http://www.srwa.org.au/index2.htm</u> for the levies.

¹² Tradable permits can focus management effort on both water and salt. The water input is an essential factor in production. The user pays for the resource in the water market. Salt is an unavoidable output of the production process. The beneficiary – the user – can pay for using the resource – the river water – in the salt market. Both become essential factors of production and will be considered in all production decisions.

available in the region and the exchange rates set for salt permits. In a tax system the regulator sets both the price for salt and the exchange rates for salt (the different tax rates across zones). In a tax system there is no aggregate limit on salt; as the quantity of water use increases in the region, the tax paid will increase and the quantity of salt will increase. The price of salt can vary in a TEP system depending on agricultural market conditions; the regulator must vary the price in a tax system.¹³

II. Policy questions

The objective of this research is to use economic experiments to illustrate and test water and salt markets for field policy application. This section looks at the policy questions that were raised by the pilot stakeholders at the beginning of the pilot. The purpose is to illustrate how these policy questions are answered by the economic experiments.

The following questions come from field and policy officers from the regional water authorities and the state departments of Primary Industries and Environment, the Australian Government Department for Agriculture Forestry and Fisheries and the Murray Darling Basin Commission. At these stakeholder meetings the use of policy experiments and the three policies were explained - Salinity Levy, Salinity Tax and Tradable Permits for Salinity.

Three policy questions that could be addressed using experiments were identified as important to the region and other jurisdictions considering the use of markets for water quality.

I. The Sunraysia Salinity Levy adds a cost to the traded price for water in the water market. The levy can reveal to irrigators the cost of salinity from production. And the user pays for the resource. The levy paid is invested in local salt interception schemes. The magnitude of the levy is equal to the estimated cost of intercepting the salt using large scale regional interception. The cost of interception is increasing, both at the local and national level as

¹³ See Stavins 1996, for a discussion of permits and taxes when the regulator has uncertain information about external environmental impacts.

(effective) new sites become scarce. Additional suppliers of salinity abatement could reduce the cost of salinity management.

Question: 'Engineering solutions (local and joint interception schemes) for salinity are rising in cost, how can we engage alternative solutions and suppliers (of abatement) in salinity policy?'

A market mechanism for salt can account for multiple suppliers of salt abatement. The requirement is; Information sufficient to define the property that will be traded in the market, and an exchange institution that allows a property right created by interception and one created by, for example, suspending irrigation, to be substitutes.

This is a technical change question. Technology change in an economic framework changes the productivity of resources used in production and shifts the demand and supply schedules for the goods to which the technology relates. Private values and costs change, and this private information is known by the individual only. Therefore, when technology is adopted by traders in experimental markets the traders take time to learn about the new market conditions. Market performance measures should show this information transfer process happening in the experimental market, it can be seen in transaction prices and quantities moving from the pre-technology equilibrium to the new technology equilibrium. (See section IV.I for the experimental observations.)

II. A tradable permit market for salt creates salt property rights. The water market creates water property rights. These rights can be traded separately in the two markets. There was concern, particularly from regional water and extension officers, that the two markets are too complicated for irrigators to make profitable decisions about the quantity of water and salt permits that they should hold.

Question: 'Can irrigators trade in both water and salt markets; or are the markets too complicated and cumbersome?'

This question relates to one of the primary uses for experiments: Can the trading institution organise the exchange of water and salt between the economic agents? In other words, is the system doing what it is designed to do? This means, are resources being allocated to least opportunity cost players; and are prices, quantities and efficiencies moving towards the predicted theoretical equilibrium given the environment? Second, is the system working for understandable reasons? The policy should generate the observed outcomes (allocations) for reasons we understand, and these reasons should be supported by economic theory. These questions were first posed by Plott, 1994. (See section IV.II for how our experimental markets organise the exchange of water and salt between subjects.)

III. The Sunraysia Salinity Levy, which has operated in the region since April 2002, introduces a trade barrier between the Highest Salt Impact Zone and all other Impact Zones: No new water can be traded into the HIZ. This command and control instrument (the trade barrier) raised questions in the region surrounding equity; if the environmental impact of trading water into the HIZ is large but not 'catastrophic' then why not use a large levy (tax)? A tax can allow irrigators located in the HIZ who are high value users of water to buy water from other zones. This can support growth in the HIZ while maintaining environmental quality in the river.

Question: 'What is the impact in the region if the Sunraysia Salinity Levy trade barrier is removed and replaced with a tax equal to the external cost of salt if water is traded into the HIZ from other impact zones?'

This question prompted us to test the Salinity Tax treatment.¹⁴

Experiments are useful for comparing the performance of alternative policy designs. It is very expensive and almost impossible to compare alternative

¹⁴ Initially we planned to run three experimental treatments; (i) a water market, (ii) a water market with the Sunraysia Salinity Levy and, (iii) a water market with tradable salinity permits (the salt market). When we visited the region and looked at the design of the Sunraysia Levy more closely we decided it would be interesting to also investigate the salinity tax as an experimental treatment.

policy designs in controlled field conditions. Using field data generated from the same policy in different pilot regions or alternative policies in the same region but across different time periods, makes it difficult to control for features unimportant to the policy question but which can muddy performance comparisons. As explained in the introduction above; in the tax treatment the levy trade barrier was replaced with the externality tax between the HIZ and all other impact zones. The magnitude of this externality tax is set equal to the relative difference in cost from trading water between impact zones: The cost to regulators of intercepting additional concentration units of salt - called EC (electro conductivity) units. (See section IV.III for how this policy design change impacts upon water and salt in the experimental environment.)

A market design question was also important.

IV. The inter-relationship between the water licence and the salt permit: Namely, if an irrigator must hold both a water licence and a salt permit to irrigate her crop, and she needs to buy these licences in the water and salt markets. How can the irrigator decide how much to pay for her water licence if she does not know how much the salt permit is going to cost? The value of the water permit to her depends on the cost of the salt permits. This design question is relevant to many water externalities. For example, nitrogen, phosphorous and suspended solids.

Question: 'If water and salt are interrelated how should the water and salt markets interact?'

This question is about the design of markets for goods that are complements (are used or produced together) and substitutes (can be used or consumed in place of one another). Water and salinity are complements in production. Lessons from earlier markets designed for substitute goods provide the answer to this question. For example, the US Federal Communication auctions for radio spectrum. In this allocation problem the value of a radio licence depends on the geographical location of the other licenses the firm is successful at winning in the auction. If bidders must make bids for related goods in independent markets, then they do not have all the information they need to make a profitable bid on the bundle. The value of each good to them depends on the final bundle of goods they are successful in winning (Milgrom, 2004).

To minimise this information problem, and ensure the experiment subjects had all necessary information to make decisions about their water units and salt licenses, we implemented the water and salt markets simultaneously. Buyers and sellers could trade water and salt permits at anytime the two markets were open, and all necessary information – all offers and transaction prices, in both markets, was displayed publicly. (See section IV.IV for how these two markets interact in our experiments.)

III. Policy experiments and economic theory

This section looks at three ways that experiments complement the use of economic theory in policy design, and how using humans to make decisions under the rules suggested by theory can reveal knowledge and information questions we may not have asked before.

The strength of experiments is *control, treatment* and *replication*.¹⁵ It is important to *isolate* the policy features of most importance and then to *induce* incentives ¹⁶ that will reveal the performance of the policy in relation to the questions. ¹⁷ Designing and calibrating an experiment for policy requires the experimenter to make operational each feature of the mechanism. This process strengthens the application of economic theory to real world situations. Asking human subjects to make real decisions with real monetary pay-offs under the rules suggested by theory can,

¹⁵ These concepts are the same as control and treatment in physical experiments such as chemistry and biology. See Friedman and Sunder 1994, a good introduction to designing experiments. Chapter 2 in this book discusses the concepts of control and treatment.

¹⁶ This means, the earnings that subjects can make in the experiment are determined by the incentives they face in the experiment, and no information or preferences not controlled for in the experiment impact upon the subjects' decisions.

¹⁷ When reading an economic experiment paper, it is useful to read the experiment instruction in conjunction with the design section in the text. This recommendation is made by some of the leading researchers in the field (again see Friedman and Sunder 1994). The instructions will reveal how the policy incentives are induced in the laboratory and will help the user of the (experimental) results understand which policy features the experiment captures and which it does not.

(a) Identify our knowledge gaps about the characteristics of the environmental good.

For example, in the case of environmental externalities such as salinity, nitrogen and phosphorous, the location of the emission matters. In many regions knowledge about the aggregate quantity of emissions is available but information that reveals the relative magnitude of the externality across locations in a water MBIs require information on the relative magnitude of the basin is not. externality. Price based MBIs - taxes (levies) and subsidies - need information on the difference between the private cost of production, which includes the cost of buying irrigation water in the water market. And the social cost of production, which is the cost of water plus the cost of salt. Regulators can estimate the cost of salt using impact zoning, but regulators cannot know the private cost of production. This is an asymmetric information problem; irrigators are in the best position to know their private costs. In the Sunraysia the levies are set equal to the cost of local interception using engineering schemes. The impact zoning multiplies the cost of intercepting an EC unit (a concentration unit of salt) by a 'dilution' factor. This multiplier takes account of discharge distance from the CAP at Morgan and soil attributes in the zone where the water is used, and the salt is therefore discharged. For example, in the Sunraysia, an additional 1,000 megalitres of water traded into the HIZ increases salinity concentration at the end of system CAP by thirty times as compared to 1,000 megalitres in LIZ 1 (see Figure 1). Therefore, the emission tax on water traded into the HIZ should be thirty times the magnitude for LIZ 1. Quantity based MBIs, tradable permits for salt, require information on the aggregate sustainable limit of pollution – the CAP, and the relative impact at the CAP from another unit of emission at different locations. For example, if the relative difference in emission between the HIZ and LIZ 1 is thirty, then irrigators in the HIZ should hold thirty times the number of permits for each unit of water as compared to irrigators in LIZ 1.¹⁸

¹⁸ Trading a large number of permits in a market period takes time and incurs cost; this may prevent the market finding the efficient outcome because there are too many permits to trade. EC units can be bundled, so that fewer permits need to be traded in equilibrium. In the Salt permit experiments reported here we simplified the experimental environment. Our objective is to understand how these markets operate. In Sunraysia there are 5 salinity impact zones (see Figure 1). In this pilot test bed experiment we use 2 impact zones and a multiple of 4 for salt concentration between the two zones. This simplified environment provides some understanding without introducing additional complexity. In future

(b) Raise questions about how the incentives created by a field policy 'map' to economic theory ;

For example, the experimental design for the Sunraysia Levy and salinity tax experiments required careful consideration of the trading institution rules.¹⁹ The differential levies paid by buyers of water require, we think, a multiple market design.²⁰ Sellers are different markets from the point of view of buyers and sellers' offers are displayed separately to the buyers.²¹ We chose a multiple market design for the following reason. Transaction price for water is an amalgamation of private marginal cost (marginal value) plus (minus) the location specific levy (tax). The magnitude of the levy (tax) differs depending on the trade pair. If we used a single market, some profitable trades would be prevented because of the institutional design. This is because sellers make their sell offers based on private marginal cost, but the price the buyer must pay includes marginal cost plus levy_i (tax_i) where *i* is one of five impact zones. In addition, buyers' willingness to pay differs depending on the trade pair; therefore the price a single seller can possibly receive from a buyer depends on the buyer's location relative to each seller. In single market environments subjects are different in marginal value (cost) but this value (cost) does not differ depending on trade pairs.²² The salinity levy (tax) is similar to markets with differential transport costs. Buyers will prefer to buy from sellers located closer to the buyer along the river. Therefore, a buyer may be willing to purchase water from a seller with a higher marginal cost but a lower levy (tax) than a seller with a lower marginal cost but higher levy (tax).

experiments, we plan to increase the number of subjects and impact zones to more closely model the field.

¹⁹ See Duke and Gangadharan, 2005.

²⁰ Goodfellow and Plott, 1990, investigate the determination of input and output prices in two markets. Lian and Plott, 1993, also investigate multiple markets for inputs and outputs. Noussair, Plott and Reizman, 1995, investigate international trade using a multiple market environment.

²¹ The multiple markets mean that sellers' offers are displayed separately to buyers, and buyers can choose to accept each seller's best offer to sell. In single markets, only the one best sell offer across all sellers, at a point in time, is displayed and can be accepted by the buyers.

²² We initially ran some sessions with a single market design. Subjects quickly identified that they were missing out on trades because sellers with whom they could profitably trade with were not necessarily the lowest cost sellers. The overall improvement rule meant these (higher cost but lower levy) sellers' offers were not the active bid in the market.

(c) Provide empirical measures that can be used to describe the performance of a given policy or to compare the performance of competing policies.

Given the parameters used in an experiment the outcomes – the allocation of resources between experiment participants measured by transaction prices and quantities, and economics surplus – can be predicted using economic principles. The observed outcomes generated under controlled experimental conditions can then be compared to the theory predictions. How well a policy performs compared to the best feasible outcome can tell us if a policy works as the economic model predicted. By comparing two alternative policy designs under identical controlled conditions we can provide estimates of the differences in outcomes.

For example, given the field parameters used in our experiments we expect the price for water in the water market to be between 1009 – 978.²³ This price range is similar to that reported by *Watermove* in the historical price data for the region.²⁴ And, is the price range we expect to observe for water if economic surplus is maximised across experimental subjects. Economic surplus is maximised when market demand equals market supply and the price for water is equal to the last profitable trade. We use the water market with no salinity policy as a baseline treatment. The baseline is used as a benchmark from which we compare the performance of the three salinity policies – Sunraysia Levy, Salinity Tax and Tradable Permits for Salinity. If we consider the performance of the levy and the tax: We expect, given the field parameters used, the price of water to lie between 1029 – 930 in both of these treatments.

Figure 2 shows the observed transaction price for water from the experimental sessions for the three treatments.

In Treatment 1, the water market baseline treatment, we can observe transaction price adjusting from above to within the treatment prediction of 1009 – 978. It does not take the market long, only 3 to 4 trading periods, to transfer the private cost and value information between subjects, and for subjects to organise

²³Duke and Gangadharan, 2005, 'Salinity in water markets', describes these experiments in detail and provides results from econometric tests for these comparisons.

the allocation of water efficiently between themselves using the rules of the market. We can say this because the efficient equilibrium price is found.

Treatment 3 is the Sunraysia Salinity Levy. In this treatment we expect the equilibrium price range to change to 1029 - 930. The expected equilibrium widens as compared to the baseline treatment because the levies and the trade barrier make some trades that were profitable in the free trade water market unprofitable or disallowed when the salinity policy is added. Theory cannot tell us where we expect equilibrium price to lie within this range. Exactly where the observed equilibrium price lies depends on the relative bargaining power of the marginal buyers and sellers, and this bargaining power can be influenced by the rules of the market. In figure 2, we observe that transaction price for water in Treatment 3is within the predicted range for the treatment and is almost equal to the observed transaction price in Treatment 1. When we conduct econometric tests for these outcomes, we find the (null) hypothesis that the transaction price for water is the same in Treatment 1 (water market baseline) and Treatment 3 (Sunraysia Levy) cannot be rejected. Further, the transaction price in Treatment 2 (the salinity tax) is significantly lower transaction price in Treatment 3 (in the early market trading periods). We believe the observed transaction price in the Salinity Levy Treatment is influenced by market power conferred to sellers located in the HIZ by the water trade barrier, and this market power is removed when the trade barrier is removed (see Duke and Gangadharan, 2005).

IV. The policy questions and the experiments

In this section we explore how the policy experiments address the questions posed by the project stakeholders.

IV.I Technology Change

New interception sites, engineering solutions that minimise salty water entering the river by pumping this excess irrigation water away from the river to evaporation basins, are becoming scarce and more expensive. Landholders and other salt users, for example salt harvesting, could provide additional salt abatement. If

²⁴ www.watermove.com.au Permanent Used Water Right/Diversion License is reported to trade at \$950

farmers and private firms can supply salt abatement at a lower cost than government engineering solutions, then there is a potential gain if we can include these management options in policy.

To include additional sources of salt abatement in both experiments and future field policies we need to know what options are available, how effective these options are at reducing salt in the river and how these options impact upon the irrigators' production systems. Some abatement options can increase productivity and reduce salt, for example upgrading irrigation systems. Other options can reduce productivity and reduce salt, for example suspending irrigation. Knowledge about water use and salt impact is advanced in the Sunraysia region. The salinity impact zones provide this information. Knowledge about private abatement options is however scarce.

Recommendation: Scientific knowledge on the effectiveness of alternative abatement options is not available. If we want to include private abatement in policy we need improved information. Information on abatement options needs to be at (least) the same scale as the impact zones.

The Tradable Salt Permit experiments: We include private abatement in the tradable permit experiment. We include a limited number of options – upgrading irrigation technology and groundwater pumping. To include these options we constructed a simple hydrological model linked to the impact zone modelling. This allowed us to estimate the decrease in salt if the option was adopted, for different crop type and impact zone (see Final Report for MBI Pilot no. 10 for a discussion of the abatement estimates).

When salt reducing technology is included in the salt permit market the technology will impact upon both the water and the salt market. We expect to observe an increase in the price of water in the water market given the environment we use. The price of water is expected to increase because salt reducing technology increases water efficiency in these sessions.²⁵ When water efficiency increases, buyers' demand

^{- \$1,500} per ML over the 2005 and 2006 seasons.

²⁵ It would be interesting to include technology that is salt saving but reduces water productivity as would also be the case in the field. For example suspending irrigation.

for water will increase and sellers' supply of water will increase. ²⁶ Given the parameters used in these experiments, expected transaction price for water increases from 900 - 997 with the 'old' technology, to 963 - 997 if the salt abatement technology is chosen (see figure 3 for these model predictions). We expect the quantity of water traded to increase if technology is chosen; from 7 units with the 'old' technology (see figure 4).

Salt abatement is (also) salt saving and therefore reduces the number of salt permits required by an irrigator for each unit of water she holds. We expect the quantity of salt permits in the salt market to decrease from 7 to 20 - 16 permits (see figure 5).²⁷ For a complete discussion of these experiments see Duke et. al. 2006.

Figure 3 presents the observed transaction price in the water market for the salt abatement treatment. Subjects can make a decision to change technology or to stay with their starting technology after period four ends and before period five begins. This is an endogenous change choice. ²⁸ We think our experiments are the first to introduce endogenous change in a simultaneous double auction trading institution. In Treatment 3 session 1, as shown in Figure 3, shows the market is responding to the technology change. ²⁹ Although in period 5 average prices in both sessions fall, perhaps because subjects are unsure about the impact of the change on market equilibrium, information about the new (private) costs and values is quickly reflected in the market. Subjects first realise they can profitably trade more units of water and transaction quantity increases in period 5, as seen in Figure 4. Then in periods 6 to 8 prices begin to rise towards the new equilibrium, seen in Figure 3.

Observation: Markets for water and salt, implemented simultaneously and designed using double auction trading rules, can engage alternative sources of salt abatement: The markets do transfer the technology change information and traders can find the new efficient outcome.

²⁶ This is shift upwards of the market demand curve and a shift out of the market supply curve.

²⁷ See Duke, Gangadharan and Cason for how transaction price for salt is determined in these markets.

²⁸ Experiments that include exogenous determined technology change include, Buckley, Mestelman and Muller, 2004; and Gangadharan, Farrell and Croson, 2005.

IV.II Organising exchanges

Experiments in economics are a good illustration and communication tool. Engaging policymakers in a controlled environment, and asking them to make real decisions when faced with the incentives created by a proposed policy, can be a suasive method. There is considerable knowledge about the trading institution we used to implement the water and salt markets: A double auction. The double auction exchange was chosen as it most closely matches the way the water market is organised in the field.³⁰

But, do these markets actually operate as expected? And, do they operate for reasons that are understandable and supported by economic theory? Can irrigators efficiently trade in both water and salt markets? To gain insights we can look at the formation of prices and quantities in the experimental markets.

Duke.C. et. al. 2006, observe that transaction prices and quantities for water (in the water market) and transaction price and quantity for salt (in the salt market) do adjust towards the expected equilibriums. Figures 3 and 4 show these outcomes for the water market. Figure 5 shows the quantity of salt permits traded in the salt market. In figure 5, market traders find the efficient quantity of salt trade, equal to 20 permits, within the first four market trading periods. In period five, after the technology choice has occurred, traders quickly realise they now require fewer salt permits for each unit of water. Transaction quantity for salt permits quickly adjusts to the new equilibrium, equal to 16 salt permits. Information transfer takes a bit longer in the water market. First traders realise they need fewer salt permits, and then they realise this reduces the cost to them of irrigation water, irrigators (then) demand more water and water price begins to rise to the expected new equilibrium prediction.

When technology change occurs, the markets take time to re-adjust. This is expected as it takes time for the market to transfer new value and cost information.

²⁹ The transaction price in session 1, is, we think, influenced by subject misunderstand about how the salt market operates. We adjusted the instructions in s ession 2, and understanding improves. This is a technical learning issue about how to implement simultaneous markets. See Duke et. al. 2006.

This information is, however, successfully transferred (within approx. two trading periods) and the new efficient equilibrium price and quantities are found in both markets.

Observation: Market participants can organise transactions in markets for water and salt.

IV.III Changing the features of policy

Experiments in economics allow policy designers to focus on a particular feature of a policy, and to observe how policy performance changes if the one feature is changed holding all else constant. This is very difficult to do with field data. Duke and Gangadharan, 2005, investigate the impact on market performance of removing the Sunraysia Salinity Trade Barrier between the High Impact Zone and all other zones and replacing the barrier with a tax equal to the magnitude of the salinity externality.

Duke and Gangadharan, 2005, find that the trade barrier can create market power in the High Impact Zone. This is because sellers of water in the HIZ are monopoly suppliers to buyers of water also located in the HIZ: HIZ sellers will attempt to force HIZ buyers to pay monopoly prices. If the trade barrier is removed and replaced with an externality tax, then HIZ sellers lose some of their monopoly supply power and HIZ buyers can participate in bargaining in the market. Water prices are lower when an externality tax is used instead of the trade barrier and environmental quality does not decline.

Recommendation: If a price based MBI is used (ie. a tax or levy on water) then externality taxes between impact zones may be more efficient then using a trade barrier.

³⁰ In the double auction both buyers and sellers make offers to buy and sell units of the good at any time the market is open. Buyers can accept the sellers' best offer and sellers' can accept the buyers' best offer at any time the market is open.

IV.IV Trading institutions and complementary goods

There is a considerable amount of economic theory published about tradable permit markets. How the institution maps to different field environments is, however, often not known. Implementing field pilots to test how the policy behaves under different conditions is costly. Experiments allow us to observe the performance of policy given specific characteristics at much lower cost than field pilots.

The water and salt markets are implemented simultaneously. Initially we considered implementing the markets sequentially. If implemented sequentially, subjects would first trade in the water market. Once the water market had closed, they would then trade in the salt market buying and selling salt permits to account for their water trades. Learnings by earlier researchers show, however, that sequential markets for water and salt could generate inefficiencies in these markets. Water and salt must be used together; a water user cannot use his water right if he does not hold enough salt property rights. If an irrigator must buy(sell) water and then salt, she does not have all the information needed to make profitable offers and acceptances in the water market. The total cost of production includes the cost of water and the cost of salt, but in a sequential design the price for salt is only known after all trades in the water market have been completed. The simultaneous design becomes even more important when abatement is included in the salt market. Abatement changes the relationship between water use and salt generation. For example, abatement could halve the amount of salt generated by each megalitre of water used in irrigation. The change in the proportions of salt and water shift the expected equilibrium outcomes in both the salt and water markets.

Recommendation: Water markets and salinity markets should be modelled as simultaneous markets because water permits and salt permits are joint inputs to production. Salinity abatement introduces additional complications into the market design, as technology change shifts market parameters. This design recommendation also applies to markets for N, P and SS.

V. Ideas and suggestions for future research

Abatement Information: When we designed these water experiments available information on the external benefit of salt abating technology was scarce. Water pollution externalities are difficult to estimate. The issues we may need to consider for all water externalities include,

- Water externalities exhibit temporal variations such that actions taken today to mitigate the externality may take many years to manifest benefits. In the experiments discussed in this paper we use estimates that assume a 30 year impact window (MDBC 2003), but the irrigator pays for the cost today by buying salt permits. Does this temporal variation and uncertainty impact upon the definition and security of the salt property right? (Temporal characteristics are also important for N, P and SS in water.)
- The nature of the externality may impact upon the required scale of abatement. In the case of salinity, actions taken by individual irrigators may generate a small external benefit. It may be necessary to co-ordinate actions between 'neighbouring' landholders: Agglomeration of benefits. The problem is similar to the co-ordination of individual properties forming landscape corridors. If agglomeration is necessary how does this impact upon the salt property right? If we use group property rights, how can we manage free riding in the group, and how will these group rights align with individual water property rights? (Agglomeration may also be important for N, P and SS in water.)

Parallelism: The strength of experiments is control. Control allows the experimenter to isolate the drivers of behavioural change. In some cases it may be desirable to give-up (some) control in policy experiments to increase parallelism with the field. For example,

In situations where the trading institution is well understood: If the rules of exchange are well understood it may be possible to systematically introduce additional field conditions to more closely represent the complexity of the real world. The experimenter can then observe if behaviour persists as complexity is

increased in a systematic and controlled way. Friedman and Sunder 1994 discuss this point.

For example, in the experiments reported here, the generic term unit and licence was used instead of water and salt permit. This is usual in experiments to remove unobservable values and preferences held by subjects about the good in question. The term tax was used. The choice to use tax may or may not impact upon behaviour in these experiments. If it does, the effect is not expected to be large enough to change behaviour significantly. An alternative non-value based term could be 'cost'. To increase parallelism in future experiments we plan to use the terms water and salt, and to give subjects information about the nature of the farm (business) they are making decisions about. Given we have information from the (more) tightly controlled experiments, we are now more confident about relaxing some 'rules' of experimental control in the future.

When subject pool is a control variable: Related to the above, sometimes the experimenter is specifically interested in the how different subject pools behave under the same rules of exchange. Student subject pools minimise unobservable and uncontrollable private information and preferences that may influence behaviour. Minimising these human 'unobservables' can help the experimenter isolate drivers. However, these 'unobservables' may in some cases be important, and we may need to understand how the exchange mechanism operates when they are included in traders' private information.

The next experiment planned in this series will use market players (if possible irrigators, or other representatives from agricultural groups, research and policy organisations). An important consideration when using market participants is how to ensure their choices are induced by the incentives in the policy experiment (*Saliency*). Student subjects respond to potential payments between 15 and 30 dollars, but irrigators' opportunity costs are probably much higher than this. The use of non-salient payments such as bottles of wine or lunch, does not link their behaviour in the experiments to the incentives posed by the experiments. A thought for consideration; The impact of this non-salience may not be that great,

as seen in some preliminary experiments conducted with policy officers from the Victorian Department of Primary Industries for this project.

Experiments can be used as a training tool. In some cases experiments have been used prior to field implementation as part of the information and marketing process (see for example, Cummings et. al. 2004). In these situations earlier controlled experiments are usually employed to test the design features of the mechanism.

VI. Other water policy experiments

This section looks at two water policy experiments conducted by European and US researchers. The policy design issues these experiments address are also important for water policy in Australia. The first experiment conducted by researchers at Emory University, looks at field experiments for drought auctions. In these drought auctions irrigators offer to suspend irrigation on acres of their land for one growing season. The second conducted by researchers at the University of Nottingham, looks at water rights when different users have peak demand requirements at different times of the year.

In 2000, the state of Georgia in the USA passed The Flint River Drought Protection Act. The Act required the state to use an auction in declared drought years to buy water licences from irrigators. It is interesting to note as an aside, the use of legislative mandates is an important driver of policy change and has (perhaps) been the motivation for wider use of economic incentives for environmental management in the US than other countries. For example, Sulphur Dioxide Trading and the Clean Air Act, and the RECLAIM program in Los Angles.

The experiments for the Georgia Irrigation Reduction Auction (Cummings et. al. 2004) used both student subjects for more controlled testing of the incentives; and irrigators from the region to test the incentives when unobservable private information influences decisions in the experiment, and to communicate and train irrigators for the actual auction. The controlled experimental treatments were designed to answer questions about how the choice of auction design, and an organisation rule – 'whether irrigators can revise offers within an auction', affect average price paid by the regulator to the irrigators, the number of acres taken out of irrigation and auction efficiency.

Efficiency in these auctions is the opportunity cost of the accepted offers *minus* the minimum opportunity cost that could have been incurred if the auction had secured the most productive irrigation licences to suspend from irrigation the same number acres (as that secured by the winning offers). In other words, the opportunity cost of the bundle of accepted irrigation licences is the cost of an alternative bundle of licences which was not accepted. If this alternative bundle would have secured for the state of Georgia the same number of acres suspended from irrigation but at a lower financial cost, then this alternative bundle is the better, more efficient, bundle. If the state of Georgia had complete information about irrigator costs then they could have solved for this most efficient bundle. Because the regulator has asymmetric information an auction can help to reveal this private information.

Cummings et. al. 2004 use the tightly controlled experiments to investigate the performance of a sealed auction design with offer(bid) revision and different tie breaking rules. The tie breaking rule was important in these drought auctions because the regulator has a fixed budget and it is possible that more than one bid at the highest accepted price could be made by irrigators in the auction. If the budget constraint binds then how can the regulator choose which one of the multiple but identical bids should be accepted? This is important for policy acceptance in the region and equity.

A second technical design question was the pricing rule used in the auction. Cummings et. al. 2004, focus on the choice between uniform and discriminative price rules. In these uniform price auctions all successful bidders(irrigators) are paid the highest accepted offer price. This is the market clearing price. A uniform price auction creates incentives for bidders to truthfully offer their private value(cost) in the auction because only the last accepted offer affects price received. An individual irrigator never knows if their offer is the market clearing offer, and if they offer 'too high' in a cost(price) minimisation auction then they run the risk of not having their bid accepted. This is called incentive compatibility. In a discriminative price auction successful bidders are paid their own offer price. In the experimental drought auctions implemented by Cummings et. al., bidders in the discriminative price auction raised their bids as revision rounds increased. The authors conjecture that this is probably because the information feedback rule, which revealed the maximum offer price accepted, signalled to bidders in the discriminative price auction the maximum price the regulator was willing to pay for suspension, and eroded any efficiency advantages of the discriminative price auction when bidders can make offers for multiple units (this was a multiple unit auction because irrigators could offer to suspend irrigation on one or many acres of land in their offer).³¹ The pricing rule also is important for political acceptance. An irrigator who was paid a low price in a discriminative price auction will know the highest price paid (to last successful bidder) due to the revision rule. This low price irrigator will more than likely be disgruntled by his lower payment.

The experimental sessions using irrigators were conducted to test the incentives in a less controlled environment. These sessions were implemented at the request of the regulator. These field sessions confirmed the performance of the auction design; the field observations were similar to the controlled environment observations. The field sessions also allowed irrigators to raise questions about the auctions, which when combined with a pre-auction registration day when the policy was rolled out to the field, improved understanding, acceptance and success of the auction.

The field auction was implemented in March 2001. The auction design chosen was discriminative pricing, with offer revisions, no maximum accepted offer price announcement and random-tie breaking rules (Cummings et. al. 2004). The experiments are an excellent example of how economists and policymakers can work together. The experiments helped the regulator to narrow down a large number of policy design options quickly; to identify the best design and to be able to explain why they chose the design against the policy objects. The field experiments helped to

³¹ The different number of acres contained within each offer makes irrigators' offers heterogeneous. Discriminative price auctions can be more incentive compatible than uniform price auctions when traders are heterogeneous in the goods they are offering for sale. See Milgrom, 2004, and Klemperer, 2002 for discussion of discriminative price auctions. See Cason, Gangadharan and D uke, 2003, for another example of a discriminative price auction for land-use change for nitrogen reduction in rivers in Port Phillip Bay Victoria Australia.

roll out the policy, to train field participants and to improve understanding and performance of the auction.

In the second policy experiment summarised here, the policy question was how to organise the demand for water in the Syr Darya River which passes through the Central Asian Republics of Kyrgyzstan, Uzbekistan and Kazakhstan (Abbink et. al. 2005). Upstream Kyrgyzstan demands water during winter for electricity generation: The summer flow is stored in dams and released during the winter months. Downstream Uzbekistan and Kazakhstan demand the water for irrigation in summer. Prior to the collapse of the Soviet Union in 1991, the flow was regulated by central planners in Moscow. The river was regulated for irrigation: Kyrgyzstan was ordered to release summer flows, and electricity during winter was supplement by exports of fossil fuels from Uzbekistan and Kazakhstan. This exchange is now organised through voluntary co-operative agreements negotiated between the three parties. Abbink et. al. 2004, show in their model that these agreements are economically beneficial for all three. In the field, however, the agreement for the upstream party to release water in summer and for the downstream parties to supply energy during winter has been breached repeatedly. This allocation problem is important to the Central Asian Republic region, and downstream republics have plans to build expensive reservoirs inside their borders to improve security of water supply.

Abbink et. al. 2004 implement experiments calibrated to the field conditions of the Syr Darya River to test these voluntary agreements. They ask the question; is noncooperation an outcome of the exchange institution or is it an idiosyncratic outcome that could change if new players are brought into the negotiation: Relevant to these regions because of recent domestic political change.

The enforceability of agreements for temporal water demand problems is also relevant to other regions. For example, environmental flows in Australian rivers may need to be high during winter and spring to mirror the natural cycles, while agricultural production has peak demand for water during summer. Storage of winter inflow for increased water security in summer can impact upon river function in winter. Another example is the investment in alternative energy in Britain which driven by the UK Energy White Paper and the Government's commitment to a large reduction in greenhouse emissions within the next decade. Alternative sources of energy including hydro-pow er are being considered. In a country that has a reputation for being rather damp, the UK is experiencing a drought and water restrictions for the first time since the mid 20th century. The distribution of rainfall across land and across time is changing. Water transfers are being discussed in the media. An increase in demand from traditional users as summer temperatures rise and a new market for alternative energy will create a need for improved water allocation institutions. Agreement enforceability is an important policy consideration.

The Abbink experiments use student subjects to play the role of the Republic decision makers. Three subjects represent each republic and the (three) 'republics' interact repeatedly to mirror the repeated relationships in the real world. The experiments investigate how much water the upstream republic releases to downstream users. The cooperation game problem is basically that the upstream user is a first mover and must decide how much water to release. The optimum outcome for all republics is for the upstream user to release more water than is privately optimal for him. The downstream republics should compensate the upstream republic, but this compensation is not made until a later time period. The incentive, particularly during low river flow years, is for the upstream player to release too little water. In high flow years, the private equilibrium is closer to the socially optimal equilibrium for all players.

The dams proposed by the downstream players to reduce dependency on upstream decisions during low flow years, does improve cooperation, but the improvement is not significant in the experiments. The Abbink et. al. model and experiments show that local storage options still require regional co-operation to maximise basin wide benefits.

The Abbink experiments for temporal water allocations are a good example of how economic theory and controlled experiments can provide answers to why some exchange organisations fail. The allocation question was a high stakes question, and the experiments helped to reduce investments in both policy design and physical capital that would have had low returns.

VII. Conclusion

Experiments in economics are real decision making processes. The pay-offs in the experiments can approximate field conditions to improve parallelism between the field and the experiments. The use of field participants in the experiments further improves parallelism. Experiments in economics do simplify the field environment. Simplification is necessary for control. Control is essential in experimentation to identify and isolate the drivers of behaviour of lesser and most importance. Control allows experiments to answer specific design questions that may have large impacts on policy outcomes. Control and treatment is difficult with field data.

The interpretation of experimental results is limited to the incentives induced in the experiment; the experiment can answer questions that were induced and controlled for but not others. While the scope of the experiment is limited by the design, the precision and discipline in designing experiments allows policymakers to understand the fundamental drivers of the policy and how these drivers interact with each other. Well designed policy experiments can complement other empirical methods and can help economists, scientists and policymakers work together more effectively. Economic experiments are a quick and cheap method for testing policy alternatives. Experiments rely on economic theory, and good economic theory can save significant resources. Experiments are cheaper than field pilots, and can be used prior to field pilots to answer difficult design questions and to educate users of the policy. Information and knowledge transfer in policy trials using experiments can help policy acceptance. U nderstanding of the exchange rules improves policy performance.

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IX. Appendix





Figure 2: Transaction price for water in the water market*



*Treatment 1 is the water market with no salinity policy operating. We ran three sessions of for treatment 1. Treatment 2 is the water market with the salinity tax (no trade barrier). We ran four sessions for treatment 2. Treatment 3 is the water market with the Sunraysia Salinity Levy (including the trade barrier between the HIZ and all other zones). We ran four sessions for treatment 3.



Figure 3: Transaction price in the water market when there is a salt market and salt abatement technology choice.

Figure 4: Transaction quantity in the water market when there is a salt market and salt abatement technology choice.





Figure 5: Transaction quantity in the salt market when there is salt abatement technology choice.