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Experiments with regulations & markets linking upstream tree plantations with downstream water users

by
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Abstract
Land-use change in upper catchments impact downstream water flows. As trees use large amounts of water the expansion of upstream plantations can substantially reduce water availability to downstream users. There can also be impacts on downstream salinity due to reduced dilution flows. In some jurisdictions afforestation requires the purchase of water rights from downstream holders, while in others it does not, effectively handing the water rights to the upstream landholders. We consider the economic efficiency and equity (profitability and distributional) consequences of upstream land use change in the presence of a water market under alternate property rights regimes and different salinity scenarios.

Key words: experimental-economics, tree-plantations, environmental-services, urban, irrigation, stock & domestic, water use, land use

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Introduction

Shortfalls in water supplies are perhaps the greatest practical NRM policy concern in Australia today, looming larger in many minds than the great international debates (Gore, 2006; Lomborg, 2007) on greenhouse gases, climate change and biodiversity. Because forestry uses more water per hectare than any other (Zhang *et al*. 2007; Gilfedder *et al*, 2009), expansion of upstream tree plantations can reduce water yields on which downstream urban, agricultural and wetlands depend.

Nordblom *et al*. (2009) consider the distributions of water use among various upstream and downstream landholders and water users within a catchment. The study considers the impact that land use decisions in the upper catchment have on downstream water users. If the demand for water among upstream users increases, for instance as greenhouse gas markets lead to an increase in the value of forestry, more water will be used upstream, and less water will be delivered to downstream water users. The analysis considers the potential for upstream and downstream water users to trade water entitlements. Such a market can ensure that water is allocated to its highest value use. A South Australian example deals with such an issue (DWLBC 2005; Schonfeldt 2005). Further benefits may be obtained by distinguishing between salty and fresh sub-catchments, enabling salt-sensitive water users to act via the market to secure reduced salinity in downstream flows.

Nordblom *et al.* (2009) showed that, by defining property rights both upstream and downstream, and facilitating trade between them may improve the welfare of both communities. There are strong theoretical grounds for advocating such a policy. While sound theory is necessary for economic policy, it is not always sufficient. Human behaviour often deviates from theoretical assumptions of rational, self-interested actions (Smith 1994; Kahneman 2002). This means the impact of a market or other policy intervention may be less than anticipated, and in some cases there may be unintended consequences (Whitten *et al.* 2004). Environmental policy therefore has much to gain from considering real human behaviour rather than stylised economic agents (Gintis 2000).

Experimental economics provides a method for incorporating human behaviour into policy design (see Smith 1994, 2002). Experimental participants are engaged in a simulated economic scenario and their decisions observed. To make the scenario incentive-compatible, participants are paid based on the outcomes of their decisions. Experiments can be used to test economic hypotheses and compare alternative economic institutions under controlled laboratory conditions.

This paper describes an experimental economics simulation of an upstream-downstream water market described in Nordblom *et al.* (2009). Our objective was to demonstrate how a market linking upstream and downstream water users adjusts from different initial water entitlements toward theoretical equilibrium holdings of entitlements, and to test how readily the theoretical equilibria would be reached. We also experimentally tested the effect of incorporating a very salty sub-catchment upstream from a salt-sensitive downstream user in the market. A key issue in the implementation of a market linking upstream and downstream water users is the initial allocation of property rights. For example, should upstream landholders, where most of the rain falls, have entitlement to the water? Alternately should they buy water from downstream users if they wish to use more, for example by expanding forestry?

While initial allocations of property rights clearly have massive financial implications for those concerned, it need not necessarily affect the subsequent functioning of the market. The Coase theorem states that, in the absence of transaction costs, markets will efficiently allocate resources regardless of their initial distribution (Coase 1960). However, this prediction may not hold with human traders, who do not always conform to ‘rational’ behaviour. In fact people often place a higher value on things they have than on things they do not – this is termed the ‘endowment effect’ (Thaler 1980). This is supported by experiments showing that people who are endowed with an item tend to be considerably less willing to sell it than others are to buy it, resulting in far less trade than anticipated (Knetsch and Sinden 1984; Kahneman *et al*. 1990).

The endowment effect means that the initial allocation of property rights may not only have equity implications, but could also impact on the subsequent functioning of the market. The same applies to any regulatory intervention which redistributes rights and entitlements. We explore this in our experiments by comparing two alternative property right allocations (downstream only; both upstream and downstream). According to Coase, the market should reach the same equilibrium in either case, but according to the endowment effect it may not. We also examine how the market responds to a sudden reversal of property rights. With perfectly rational economic agents the market equilibrium should be unaffected (though the distribution of profits will be altered), but human traders may respond differently.

Methods

Our experimental scenario included upstream and downstream water use sectors, based on data and modelling described in Nordblom *et al*. (2009). We took a $70/m^3 stumpage value for tree products, the top end of the range considered in the model. At this price, six sectors would be active in an extended water market. Two of these (UC10 and UC8, see Figure 1) are upper-catchment areas with 1000 and 800 mm annual rainfall, respectively; two (MCU and MCUS) are mid-catchment areas with 700 and 600 mm rainfalls, the latter being the saltiest sub-catchment; two downstream sectors (IRR and S&D) are the irrigation and the stock & domestic water users.

An additional sector UHS (urban and other high security) water users is assumed to require high quality water rather than additional water. This is an issue only in the hypothetical case that one of the sub-catchments (MCUS) yields very salty water, with 20 times the salt concentration of the actual area. This potentially becomes important if there are large reductions in dilution flows from the upper catchment that are due to new tree plantations. In this case UHS might subsidise tree planting in MCUS (toping up the marginal values of water use by trees in MCUS), rather than being directly represented in the experiment.

The lower-rainfall sectors (UC6 and MCD in Figure 1) were excluded from the experiment as high water prices precluded tree planting and consequently their engagement in a market if water rights had to be purchased. We excluded the Wetlands sector (WL) and effluent creeks and rivers (ECR) from the experiments and assumed the water use entitlements they hold will be respected by the six sectors named above. This assumption is not based on historical observation but is justified here as we seek to understand a possible means to sustain river flows by regulation and a water market extended to new tree plantations.

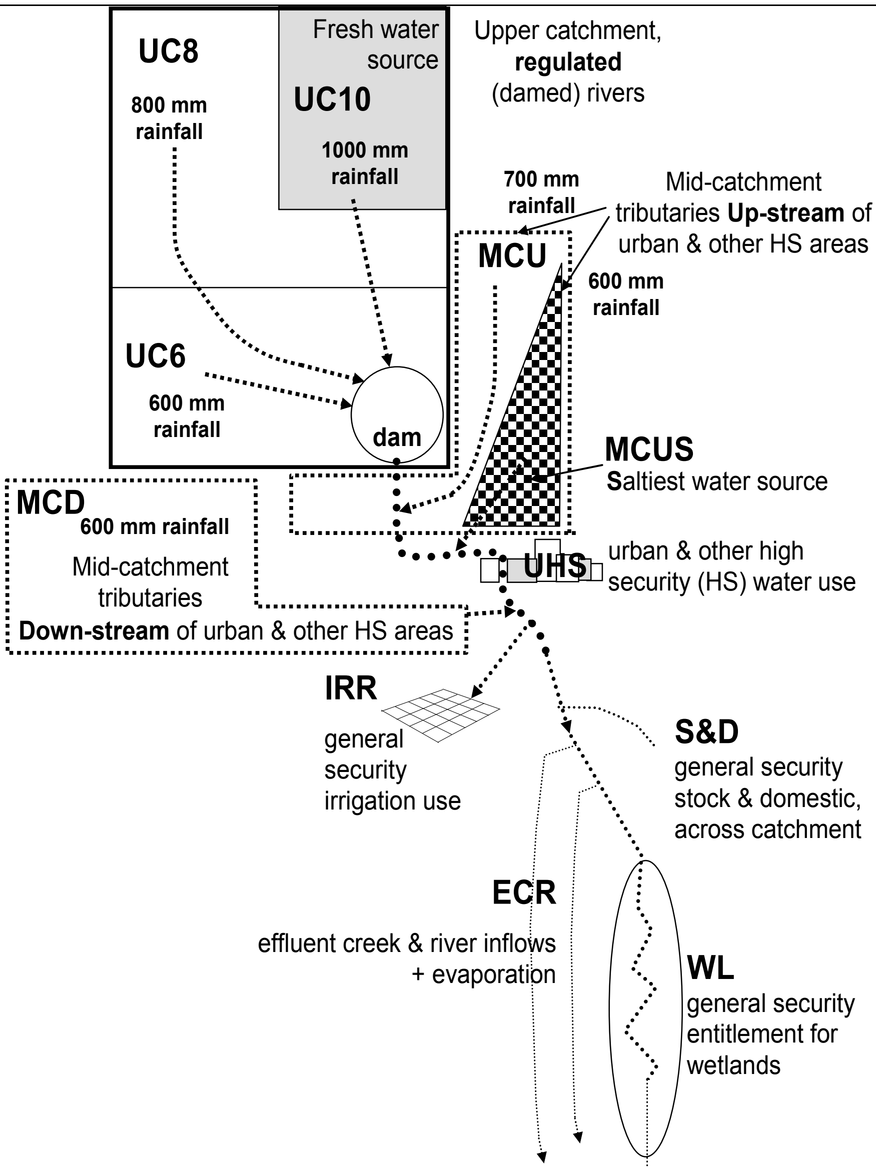


Figure 1. Schematic map of the Macquarie Catchment identifying key water sources by rainfall zone, salinity and location with respect to key sectors (from Nordblom *et al*. 2009).

A practical matter for our experiments was that the larger sectors would need to make a large number of trades to reach equilibrium and consequently time might become limiting. Our solution was to divide the largest sectors (UC8 and IRR) into two half-sectors. The horizontal sum of the water demand schedules of the half-sectors UC8a and UC8b equals the original demand schedule of UC8. The half-sectors IRRa and IRRb, similarly, add up to the original IRR sector's demand schedule.

Experiments were carried out with specially-developed software that features a real-time market interface. There were eight participants, each taking on the role of an upstream or downstream sector in the market. Table 1 lists the roles represented in the experiment. There were three downstream users – two representing irrigators and one for other users. The other five participants represented upstream sub-catchments. Experiments were context-free, as is usual practice in experimental economics. At the start of each trading period participants were allocated a number of units (see 'Initial units held' in Table 1). The human subjects did not deal with water or salt in our experiments, but simpler trading 'units'. Participants earned money relative to the units they held at the end of each trading period. The values of these units, which were derived from the marginal values of water for each sector (Appendix A and B), were displayed in a table on each person's screen. No participant could see any other's marginal values, but only the prices of offers to sell units and bids to buy units, which were posted for all to see.

During the trading period participants could trade units with one another via a continuous double auction. Participants could increase their earnings by selling units in the market for more than their marginal value, or buying additional units for less than their marginal value. Bids and offers in the market could be seen by all participants, along with the last traded price. All trades were for single units. Each trading period lasted for five minutes, after which participants received an update of their total earning for that period. Units were reallocated at the start of the following period – units could not be carried over from one period to the next.

There were two variables in the experiment, the presence or absence of a very salty sub-catchment (following Nordblom *et al*. 2009) and the initial allocation of property rights. The absence or presence of very salty flows (FRESH/SALTY) from MCUS was reflected in different marginal values for water by that sub-catchment (Appendices A and B), as the downstream salt-sensitive user (UHS) was assumed to 'top-up' the benefits of a SALTY MCUS by \$200/unit (A\$2m/GL) used if for planting trees. Property rights were initially allocated either completely downstream

(D) or mostly to upstream users (U) in Table 1. These allocations were reversed midway through the experiment to test the impact of changing property rights. (see illustrations in Figures 2 and 3). Participants had no prior warning of this, other than being told in the initial instructions that 'allocations may change during the experiment'. Combining these two variables gave four treatments in total (Table 1).

Table 1. Experimental design and theoretical eqililbrium outcomes

Treatment	Salinity scenario	Order of Initial Endowments
T1-SUD	SALTY	U then D
T2-FUD	FRESH	U then D
T3-FDU	FRESH	D then U
T4-SDU	SALTY	D then U

Participant:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	Sum
Sector:	**UC10**	**UC8a**	**UC8b**	**MCU**	**MCUS**	**IRRa**	**S&D**	**IRRb**	units
Initial units held									
D	0	0	0	0	0	65	27	65	**157**
U	34	38	38	20	7	2	16	2	**157**
Market equilibrium in theory [A]									
FRESH ($188)	54	16	16	3	0	24	19	25	**157**
SALTY ($192)	52	14	14	2	15	21	18	21	**157**

[A] Theoretical equilibrium prices and units held were derived from Nordblom *et al.* (2009), Tables 7 & 8. Participants were not made aware of these theoretical expectations.

The experiments were carried out at the University of Sydney and Charles Sturt University in Orange, NSW. Prior to each experimental session participants read a set of instructions (Appendices C and D). They then had a practice trading period, which familiarised them with the interface. This practice period used a different set of marginal value tables to the subsequent experiment. Experiments ran for ten 5-minute trading periods (not including the practice periods). At the end of the experiment participants were paid in cash, based on their individual experimental 'earnings' over all ten periods. Average payments to individuals were A$33. All decisions made in the experiment were anonymous, with participants identified by ID numbers and interacting only via computer. There was no talking and no use of mobile phones.

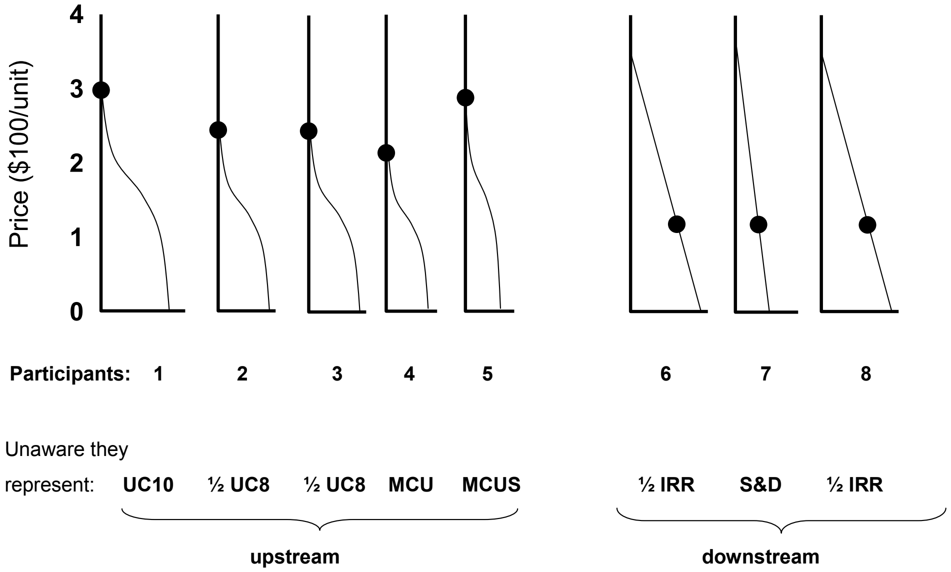


Figure 2. A market defined by marginal values of all participants, with initial endowments of units only in the hands of downstream users (**D**); not in equilibrium here

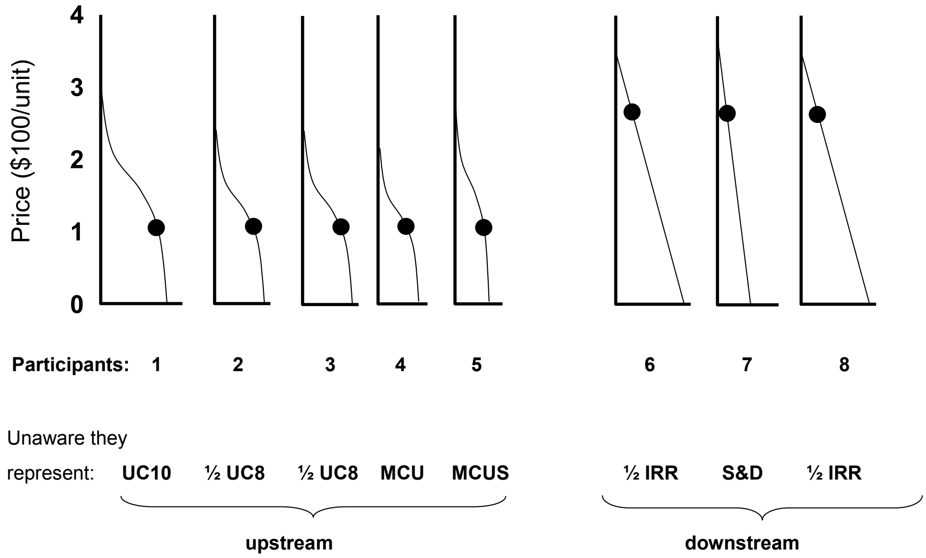


Figure 3. An imaginary market defined by marginal values of all participants and initial endowments of units in the hands of upstream as well as downstream users (**U**); not in equilibrium here

Results

Examples of experimental results from two trading periods, one starting with water rights scenario **U** and one starting with **D,** are given in the Figures 4 and 5, respectively. These were chosen for display because they were among those coming closest to the theoretically expected prices and final 'units held'. Summaries of all replicates of the experiment are given in the tables that follow.

Notice, in Fig. 4a and Fig. 5a the range of trade prices shown is between $130 and $270/unit as this nicely brackets the expected equilibrium price derived by Nordblom *et al.* (2009) shown in Table 1. However, a small number of the recorded trade prices were far outside this window, with one being $1/unit and one being $1750, both being well outside the ranges of marginal values with which the participants were working. We took the step of excluding any trades with prices greater than three digits or less than two as these were likely to represent typing mistakes.

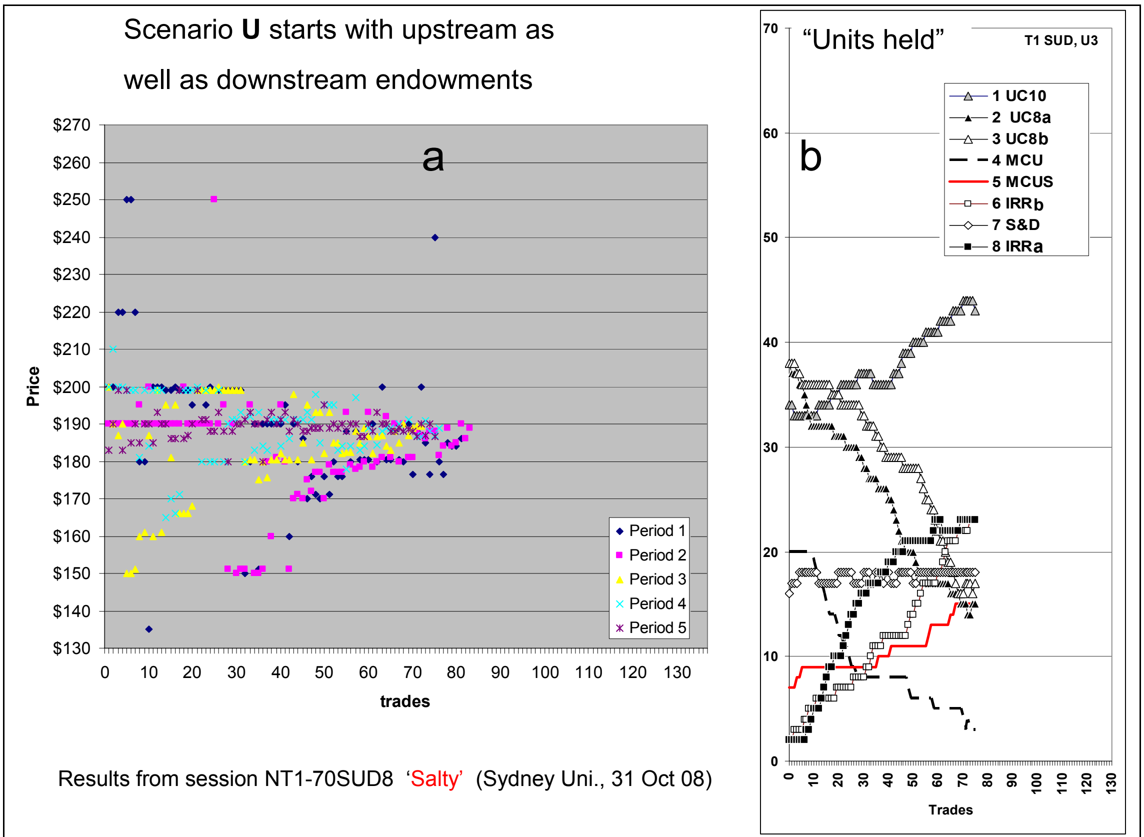


Figure 4. Prices of trades (**a**) made by participants in five 5-minute periods under scenario **U** where initial endowments are spread among upstream as well as downstream parties, and (**b**) running accounts of 'Units Held' in the final period (5)

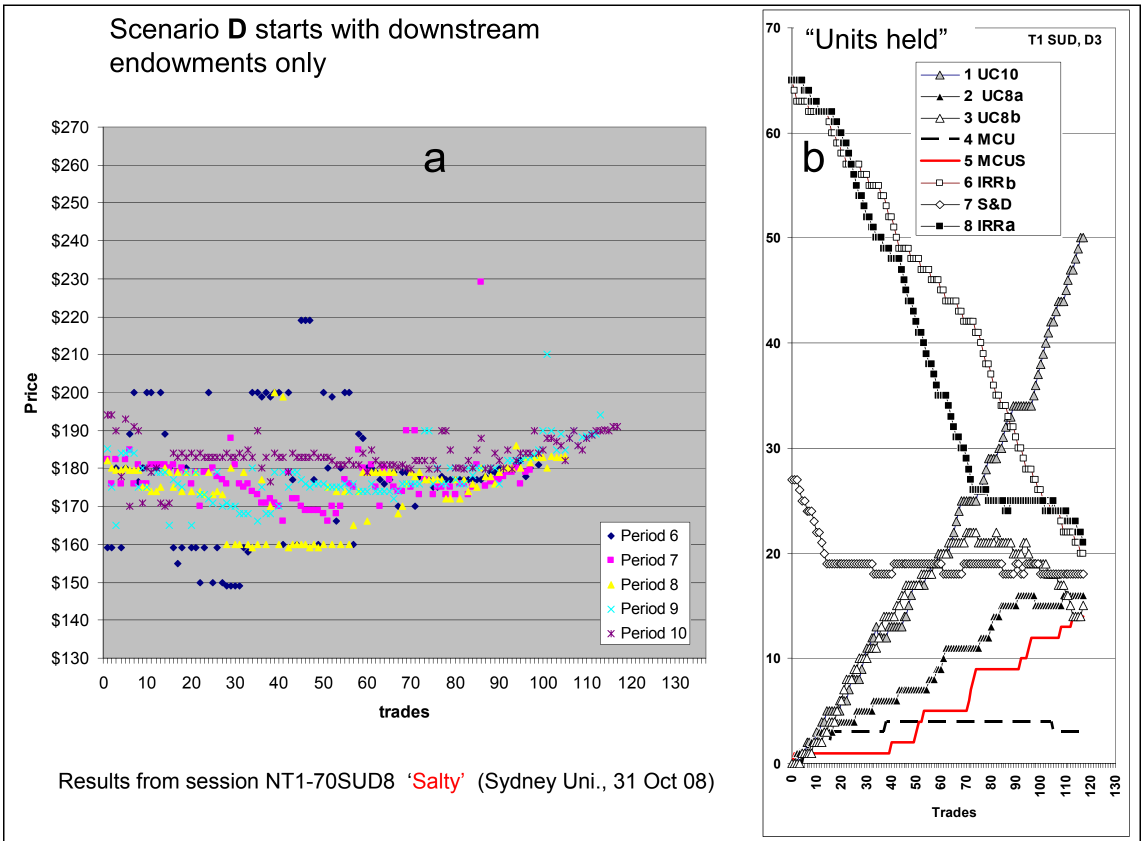


Figure 5. Prices of trades (**a**) made by participants in five 5-minute periods under scenario **D** where initial endowments are all in the hands of downstream parties, and (**b**) running accounts of 'Units Held' in the final period (10)

It is apparent in Fig. 5 above that three participants (UC10, IRRa and IRRb) had the most trading to do before being satisfied they could not do more.

In the tables below, the initial **U** and **D** 'Units Held' are indicated in the headings of each section and the 'Expected Final' holdings are indicated at the bottom, as given in Table 1 above. The observed final holdings of each sector (participant) are shown with the mean and standard deviation of prices of the final 20 trades. The aggregate units of water held by the upstream sectors (1–5) and downstream sectors (6–8) are also shown because these may be used in comparing the results of the **U** and **D** cases.

In both FRESH and SALTY treatments (Tables 2 – 4) the mean total upstream units held are greater than expected under scenario **U** and less than expected under scenario **D**. Whichever group holds the units at the beginning of the experiment tends to hold more than 'expected' at the experiment's end.

Table 2. Experimental results from the '**FRESH**' treatments, on initial and observed final numbers of units held by each participant (sectors 1 – 8), and the average price of the observed final 20 trades, compared with calculated expectations of the numbers of final units held and equilibrium price

FRESH		Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Sector 7	Sector 8		Units Held, Upstream & Downstream		Prices of last 20 trades	
Treatment, replicate	Units Held	UC10	UC8a (even)	UC8b (odd)	MCU	MCUS	IRRb (odd)	S&D	IRRa (even)	Sum Check	1 - 5 Units	6 – 8 Units	Mean	STDEV
Fresh U	Initial:	34	38	38	20	7	2	16	2	157	137	20		
T2 FUD														
U1	Final:	55	14	32	2	0	15	18	21	157	103	54	$190.25	$6.32
U2	Final:	54	17	17	3	2	23	18	23	157	93	64	$189.20	$2.21
U3	Final:	54	17	17	4	0	24	19	22	157	92	65	$184.00	$1.28
	UD mean U	**54.3**	**16.0**	**22.0**	**3.0**	**0.7**	**20.7**	**18.3**	**22.0**	**157**	**96**	**61**	**$187.82**	**$3.27**
T3 FDU														
U1	Final:	61	47	0	6	1	21	21	0	157	115	42	$166.30	$1.80
U2	Final:	49	21	17	3	0	24	22	21	157	90	67	$188.59	$1.16
U3	Final:	55	17	17	3	0	24	18	23	157	92	65	$185.50	$2.96
	DU mean U	**55.0**	**28.3**	**11.3**	**4.0**	**0.3**	**23.0**	**20.3**	**14.7**	**157**	**99**	**58**	**$180.13**	**$1.98**
	mean Fresh U (all)	**54.7**	**22.2**	**16.7**	**3.5**	**0.5**	**21.8**	**19.3**	**18.3**	**157**	**97.5**	**59.5**	**$183.97**	**$2.62**
Fresh D	Initial:	0	0	0	0	0	65	27	65	157	0	157		
T2 FUD														
D1	Final:	41	19	23	3	0	27	19	25	157	86	71	$182.40	$1.57
D2	Final:	50	12	9	2	0	19	18	47	157	73	84	$194.15	$9.66
D3	Final:	45	18	20	3	0	25	19	27	157	86	71	$182.96	$0.82
	UD mean D	**45.3**	**16.3**	**17.3**	**2.7**	**0.0**	**23.7**	**18.7**	**33.0**	**157**	**81.7**	**75.3**	**$186.50**	**$4.02**
T3 FDU														
D1	Final:	38	24	0	4	0	28	20	43	157	66	91	$175.98	$2.22
D2	Final:	33	11	14	2	2	18	23	54	157	62	95	$195.40	$1.88
D3	Final:	55	17	16	3	0	24	19	23	157	91	66	$186.85	$2.66
	DU mean D	**42.0**	**17.3**	**10.0**	**3.0**	**0.7**	**23.3**	**20.7**	**40.0**	**157**	**73**	**84**	**$186.08**	**$2.25**
	mean Fresh D (all)	**43.7**	**16.8**	**13.7**	**2.8**	**0.3**	**23.5**	**19.7**	**36.5**	**157**	**77.3**	**79.7**	**$186.29**	**$3.13**
	Grand mean	**49.2**	**19.5**	**15.2**	**3.2**	**0.4**	**22.7**	**19.5**	**27.4**	**157**	**87.4**	**69.6**	**$185.13**	**$2.88**
Expected Final holdings [A]		**54**	**16**	**16**	**3**	**0**	**25**	**19**	**24**	**157**	**90**	**67**	**$188**	

[A] *a priori* expectations for final 'Units Held' and equilibrium price from Table 1

Table 3. Experimental results from last of five periods with the 'SALTY' treatments, showing the initial and observed final numbers of units held by each participant, and the average price of the observed final 20 trades, compared with calculated expectations of numbers of final units held and equilibrium price

Salty Treatment, Replicate		Sector 1 UC10	Sector 2 UC8a even	Sector 3 UC8b odd	Sector 4 MCU	Sector 5 MCUS	Sector 6 IRRb odd	Sector 7 S&D	Sector 8 IRRa even	Sum Check	Prices of last 20 trades Mean	STDEV
T1 SUD	Initial Units:	34	38	38	20	7	2	16	2	157		
U1	Final:	53	14	15	2	15	20	18	20	157	$192.11	$2.97
U2	Final:[A]	0	40	37	7	15	21	20	17	157	$168.06	$3.34
U3	Final:	43	15	17	3	15	23	18	23	157	$188.69	$1.69
	UD mean U	**32.0**	**23.0**	**23.0**	**4.0**	**15.0**	**21.3**	**18.7**	**20.0**	157	**$182.95**	**$2.67**
T4 SDU												
U1	Final:[A]	0	2	56	11	16	5	22	45	157	$152.65	$3.65
U2	Final:	52	15	16	3	15	19	18	19	157	$190.38	$1.72
U3	Final:	55	16	17	3	15	8	19	24	157	$185.17	$3.23
	DU mean U	**35.7**	**11.0**	**29.7**	**5.7**	**15.3**	**10.7**	**19.7**	**29.3**	157	**$176.07**	**$2.87**
T1 SUD	Initial Units:	0	0	0	0	0	65	27	65	157		
D1	Final:	48	12	11	1	14	17	17	37	157	$199.10	$1.29
D2	Final:[A]	0	32	15	6	15	34	21	34	157	$170.15	$1.90
D3	Final:	50	16	15	3	14	20	18	21	157	$187.91	$2.51
	UD mean D	**32.7**	**20.0**	**13.7**	**3.3**	**14.3**	**23.7**	**18.7**	**30.7**	157	**$185.72**	**$1.90**
T4 SDU												
D1	Final:[A]	1	4	20	5	17	66	18	26	157	$169.84	$18.36
D2	Final:	51	0	19	2	15	33	18	19	157	$194.15	$2.91
D3	Final:	38	9	11	2	15	49	17	16	157	$197.75	$1.21
	DU mean D	**30.0**	**4.3**	**16.7**	**3.0**	**15.7**	**49.3**	**17.7**	**20.3**	157	**$243.99**	**$4.97**
	Grand mean	**32.6**	**14.6**	**20.8**	**4.0**	**15.1**	**26.3**	**18.7**	**25.1**	157	**$183.00**	**$3.73**
Expected Final holdings[B]		**52**	**14**	**14**	**2**	**15**	**21**	**18**	**21**	157	**$192**	

[A] **Note: Unexpectedly, in the case of each sub-treatment, one participant in the role of UC10 either purchased no units or sold all endowments**

[B] *a priori* expectations for final 'units held' and equilibrium price given in Table 1

Table 4. Experimental results from the **'SALTY'** treatments, on initial and observed final numbers of units held by each participant (sectors 1 – 8), and the average price of the observed final 20 trades, compared with calculated expectations of the numbers of final units held and equilibrium price … excluding values from four aberrant sessions

Salty		Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Sector 7	Sector 8		Units Held, Upstream & Downstream		Prices of last 20 trades	
Treatment, replicate	**Units Held**	**UC10**	**UC8a even**	**UC8b odd**	**MCU**	**MCUS**	**IRRb odd**	**S&D**	**IRRa even**	**Sum Check**	**1 - 5 Units**	**6 – 8 Units**	**Mean**	**STDEV**
Salty U	**Initial:**	**34**	**38**	**38**	**20**	**7**	**2**	**16**	**2**	**157**	**137**	**20**		
T1 SUD														
U1	Final:	53	14	15	2	15	20	18	20	157	99	58	$192.11	$2.97
U3	Final:	43	15	17	3	15	23	18	23	157	93	64	$188.69	$1.69
	UD mean U	**48**	**14.5**	**16**	**2.5**	**15**	**21.5**	**18**	**21.5**	157	**96**	**61**	**$190.40**	**$2.33**
T4 SDU														
U2	Final:	52	15	16	3	15	19	18	19	157	101	56	$190.38	$1.72
U3	Final:	55	16	17	3	15	8	19	24	157	106	51	$185.17	$3.23
	DU mean U	**53.5**	**15.5**	**16.5**	**3**	**15**	**13.5**	**18.5**	**21.5**	157	**103.5**	**53.5**	**$187.78**	**$2.48**
	mean Salty U (all)	**50.8**	**15.0**	**16.3**	**2.8**	**15.0**	**17.5**	**18.3**	**21.5**	157	**99.7**	**57.3**	**$189.09**	**$2.40**
Salty D	**Initial:**	**0**	**0**	**0**	**0**	**0**	**65**	**27**	**65**	**157**	**0**	**157**		
T1 SUD														
D1	Final:	48	12	11	1	14	17	17	37	157	86	71	$199.10	$1.29
D3	Final:	50	16	15	3	14	20	18	21	157	98	59	$187.91	$2.51
	UD mean D	**49**	**14**	**13**	**2**	**14**	**18.5**	**17.5**	**29**	157	**92**	**65**	**$193.51**	**$1.90**
T4 SDU														
D2	Final:	51	0	19	2	15	33	18	19	157	87	70	$194.15	$2.91
D3	Final:	38	9	11	2	15	49	17	16	157	75	82	$197.75	$1.21
	DU mean D	**44.5**	**4.5**	**15**	**2**	**15**	**41**	**17.5**	**17.5**	157	**81**	**76**	**$195.95**	**$2.06**
	mean Salty D (all)	**46.8**	**9.3**	**14.0**	**2.0**	**14.5**	**29.8**	**17.5**	**23.3**	157	**86.5**	**70.5**	**$194.73**	**$1.98**
	Grand mean	**48.8**	**12.1**	**15.1**	**2.4**	**14.8**	**23.6**	**17.9**	**22.4**	**157**	**93.1**	**63.9**	**$191.91**	**$2.19**
Expected Final holdings[A]		**52**	**14**	**14**	**2**	**15**	**21**	**18**	**21**	**157**	**97**	**60**	**$192**	

[A] ***a priori*** **expectations for final 'units held' and equilibrium price given in Table 1**

Effects of trade on income

The laboratory experiments support the theory that a market can facilitate the efficient allocation of water between upstream and downstream users, resulting in higher overall incomes than without trade. Overall wealth among all sectors of the catchment in the absence of any market is compared with that given all potentially profitable trades in a market (Figure 6). Income levels observed during the experiments are greater than the 'no market' case but do not reach the levels expected in theory by the market.

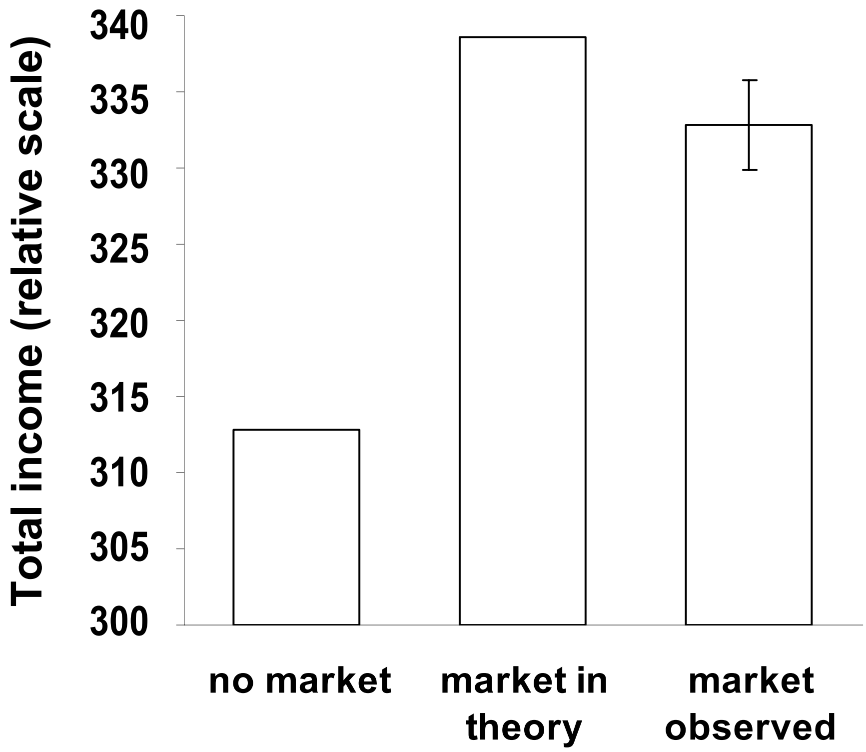


Figure 6. Total income across all sectors, with and without a market linking upstream and downstream users (over all ten periods, considering only the Fresh treatment, with initial distributions U and D combined).

In Figure 6 and the following charts, 'market observed' are the experimental results. 'Market in theory' values are those of the calculated optimal market distribution of water use from the viewpoint of maximising catchment NPV (Nordblom *et al*. 2009). 'No market' represents the outcome under the initial endowments of water rights, with no subsequent trade taking place.

It is clear that even with traders who had no prior experience in the market before coming to the experiments, most of the potential gains from trade were realised. The average price for trades in the fresh treatment was $185.13, a little below the theoretical equilibrium value of $188. (This suggests that the price was converging from below. Buyers have more market power in this scenario).

Considering salt values in addition to water increases the overall value of the system, both with and without trade (Figure 7). In the experimental sessions the market improved overall income, although it remained some way short of the theoretical maximum (Figure 7).

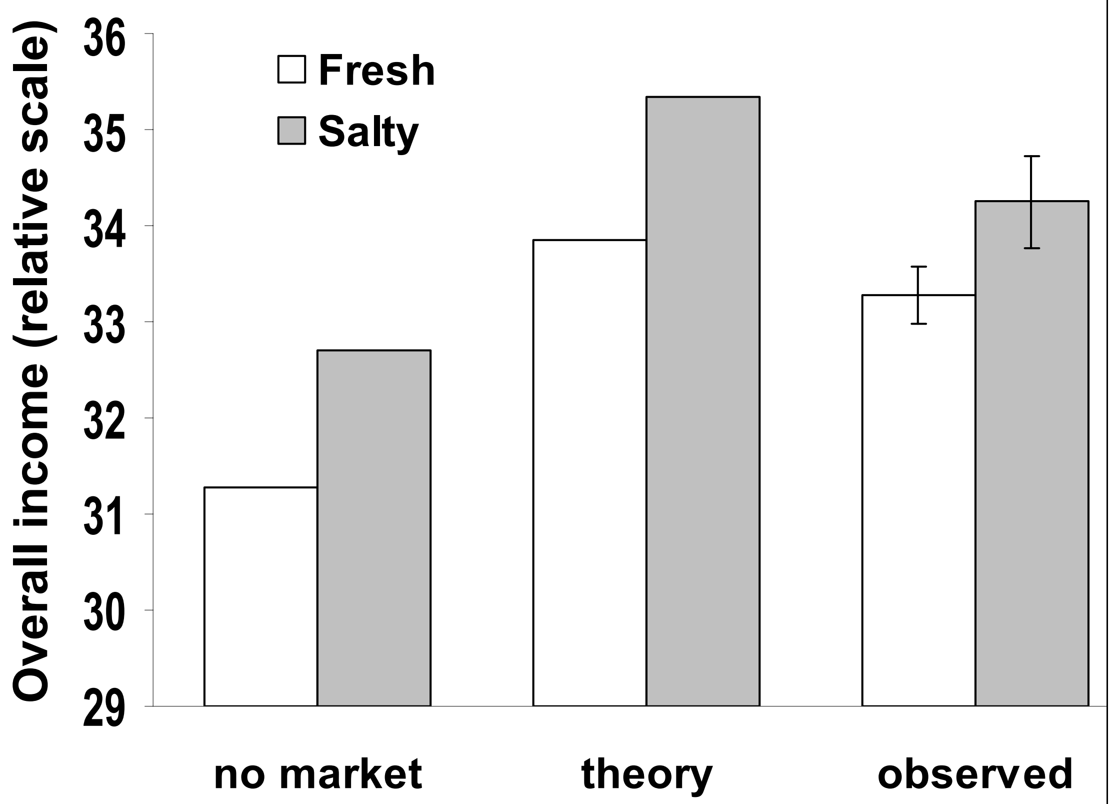


Figure 7. Overall, the observed market was able to capture most but not all the benefits of trade. Higher overall incomes in the case where a very salty sub-catchment (MCUS) exists are due to an external subsidy for tree planting there to mitigate river salinity.

Incorporating salt values particularly increased the value of the SALTY mid-catchment area (MCUS), but not because salinity is beneficial. Rather, in high concentrations, it is damaging to downstream urban water users (UHS). The benefit to MCUS is an artefact of our assumption that UHS would provide an external subsidy of $2m/GL to landowners using this water (and holding back salt from the river) through establishing new tree plantations in that sub-catchment, paid by UHS to reduce river salinity. The average experimental trade price was $187.46. This is higher than in the fresh treatments, reflecting the increased value of salt mitigation, but still below the theoretical equilibrium of $192.

Overall income was higher where property rights were initially allocated upstream. In this treatment reversing the distribution of initial water rights after period five made little impact on overall welfare (Figure 8), although it will, of course, have had massive distributional impacts among the various participants. The reduction in overall income in the downstream-only treatment was only partially offset when allocations were reversed (Figure 8).

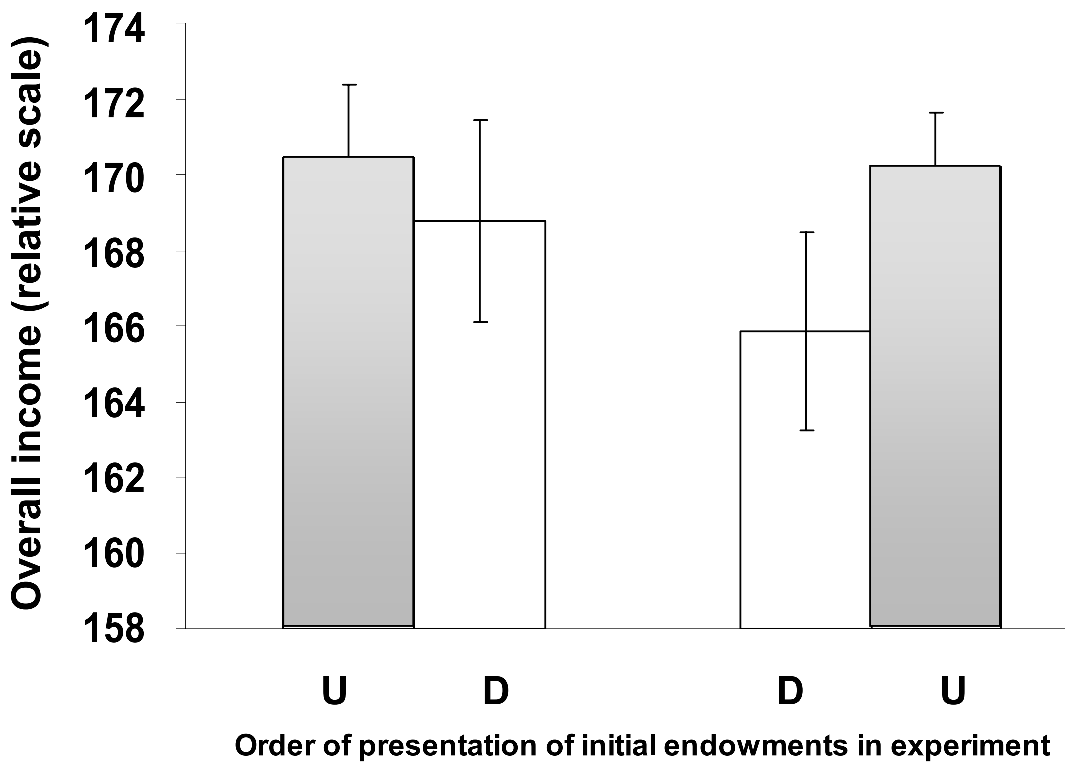


Figure 8. Effects of presentation order of initial endowments (UD or DU) on overall income observed in experiments (means +/- standard errors). With U, regardless of order, observed overall catchment income was only slightly greater than with D; the difference was greatest (approx. 2.7%) where the order was DU. See Table 1 for definitions of D and U.

Effects of trade on the distribution of final units held

Experimentally observed performance was variable among the sector incomes and final numbers of units held (Figures 9 and 10). Over the six replicates of the SALTY treatment, for example, UC10 on average performed worse than in the absence of a market. This is a result of "irrational" trades made by individuals representing UC10 in two of the SALTY replicates. In contrast the irrigation sector did better than predicted by theory – these participants may have been exploiting market power to pay below the equilibrium price for water, and with the others, benefited from 'irrational' trades made by UC10.

Considering individual sectors, all are in theory made better off by the introduction of the market, provided initial rights allocations are not changed. Figure 9 shows very large differences in observed incomes among sectors with the two scenarios of initial endowments of units held. In scenario U, which assumes large upstream endowments, all upstream sectors (except UC10) retain more units than theoretically expected given the opportunity to profitably sell units to the downstream IRR sector. In scenario D, where all units are initially held by the downstream S&D and IRR sectors, they retain more units than theoretically expected. The market has theoretical benefits for all sectors (although for the S&D sector it is very small). Most of these benefits were realised in the experiments. In the experimental sessions the actual distributions of gains from trade varied with individual trading performance.

In the FRESH case with U initial endowments (Figure 9), MCUS shows income only from the sale of its endowments since it cannot gain as much from using the units. In the SALTY case, MCUS is able to gain from using its endowments with U or purchasing units when it has none of its own, as with D.

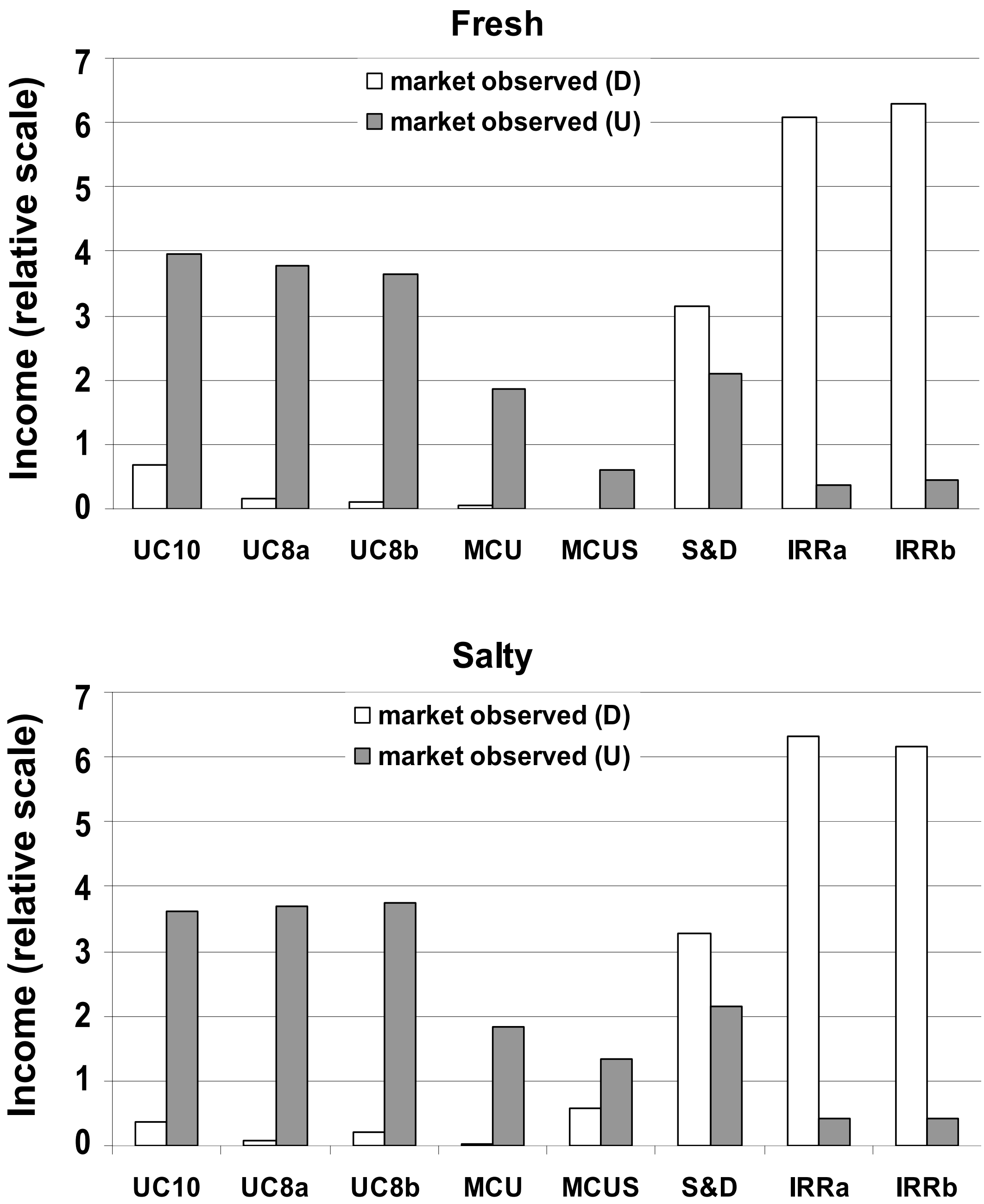


Figure 9. Observed incomes of different sectors are strongly affected by the distributions of initial endowments (D and U) in both the FRESH and SALTY cases. Where the downstream sectors (S&D and IRR) hold all initial endowments (D), they are able to gain considerably by selling to the upstream sectors who have high incentives to buy units. When endowments are mainly in the hands of the upstream sectors, they gain income from using the units and selling to the downstream users.

Examining average unit holdings at the end of each period(Figure 10) shows that these differ from the theoretically expected equilibrium holdings listed in Table 1.

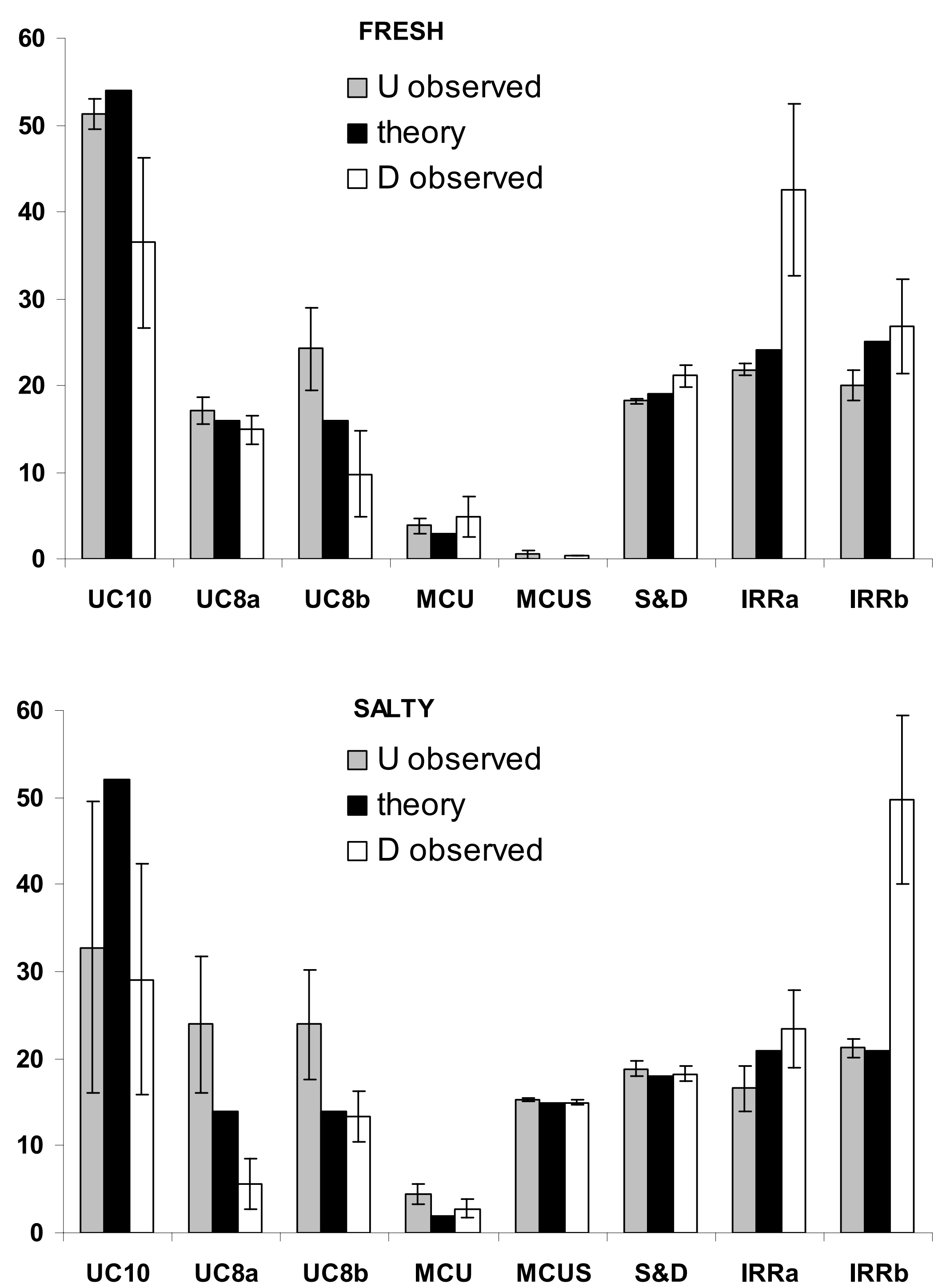


Figure 10. Expected and observed unit holdings at the end of the trading period, over the first five periods of the experimental sessions (means +/- standard errors), given initial endowments (D) downstream only and (U) upstream/downstream

Discussion

These experiments demonstrate how the introduction of a market linking upstream and downstream water users can more efficiently allocate water and hence increase overall welfare. Experimental participants were able to secure most of the potential gains from trade in this system. However, while trading in these experiments is free of risk, financial constraints and transaction costs, observed performance still fell short of the theoretical equilibrium. In the real-world, with all these obstacles present and with many more players in the market, we may be assured that a lower share of the potential gains from trade will be captured.

It is also clear that with human subjects there is greater variability in outcomes. Not all participants will be equally adept at realising potential gains from trade offered through a market-based policy intervention. While in theory no one should be worse off with access to a market, even in our simple experimental scenario some participants managed to 'lose' money overall.

Our results also suggest that the initial endowments of property rights can have a significant impact on market performance, contrary to the Coase theorem. In the real world, with transaction costs and barriers to entering the market (such as knowledge and experience of the trading process), endowment effects may be greater still. Our results also show that sudden shifts in property rights, as occurred midway through the experimental sessions, can impact the functioning of the market, with participants less willing than expected to purchase what they had previously owned.

To be fair, some of the discrepancies observed in the experimental sessions may be an artefact of the limited time available for trading. All trades were for single units, so participants may have run out of time (even though the five minute trading periods in theory allowed more than enough time for all profitable trades to take place). Experimental participants often appeared to be more concerned about 'getting a good price' for individual trades than in maximising their overall income. They focus on price at the expense of volume, resulting in sub-optimal trading performance. This is also observed in real-world markets, in which people will walk away from profitable trades if they feel they are not getting the best possible price (e.g. Ariely 2008).

These effects may have been exacerbated by the structure of our experiment, in which there were three downstream participants and five upstream. The downstream participants may have been able to exert market power, withholding supply (or demand) in order to get more favourable prices. This would be less likely in the real world, where each sector would consist of many smaller players.

Conclusions

Without the regulation that water entitlements be purchased to offset the extra water use by tree plantations the implications are clear. Where profitability of tree plantations increase (due to markets for wood products and/or carbon sequestration, possibly combined with other incentives), we should expect expansion of tree enterprises and subsequent reductions in river flows (see Nordblom *et al*. 2009).

These negative consequences of expanded tree plantations may be avoided by introduction of policy and regulations that water entitlements be purchased to offset the extra water use by non-holders of entitlements. As in South Australia the amount of offset water required for a given area of plantation is a function of the rainfall zone and other factors that affect the expected reduction in water yield (DWLBC 2005). The result is not a prohibition on new plantations but a balance in water use; where entitlements for water to be used by the trees are purchased from those downstream entitlement holders who are willing to permanently give up their entitlements.

However, policy makers need to consider that not all expected gains from trade will be realised, and some individuals may make costly mistakes in a market. This is particularly important where new markets are introduced and participants don't have experience of similar markets. If landholders are to be engaged in trading new forms of water or salinity rights, some form of training program may prove beneficial, both for the individuals concerned and for the efficient functioning of the overall market.

References

Ariely, D. 2008. *Predictably Irrational: The Hidden Forces That Shape Our Decisions*. HarperCollins Publishers, New York

Coase, R.H., 1960. The problem of social cost. *The Journal of Law & Economics*. 3: 1-44.

DWLBC (Department of Water, Land and Biodiversity Conservation). 2005. *Approval process for plantation forestry under the Natural Resources Management Act 2004*. DWLBC, Mount Gambier, South Australia. URL accessed 21 Nov 2008. http://www.dwlbc.sa.gov.au/assets/files/ForestryfactsheetFINAL10-05.pdf

Gilfedder, M., Walker, G.R. Dawes, W.R. Stenson, M.P., 2009. Prioritisation approach for estimating the biophysical impacts of land-use change on stream flow and salt export at a catchment scale. *Environmental Modelling & Software* 24: 262–269

Gintis, H. 2000 Beyond Homo economicus: Evidence from experimental economics. *Ecological Economics* 35: 311-22.

Gore, A., Melcher Media. 2006. *An inconvenient truth: the planetary emergency of global warming and what we can do about it*. Rodale Press, Emmaus, Pennsylvania.

Kahneman, D. 2002. *Maps of bounded rationality: a perspective on intuitive judgment and choice*. Nobel Prize Lecture, Dec. 8, 2002. (On line, accessed 21 Nov 2008): http://nobelprize.org/nobel_prizes/economics/laureates/2002/kahnemann-lecture.pdf

Kahneman, D., Knetsch, J.L., Thaler, R.L., 1990. Experimental tests of the endowment effect and the Coase theorem. *Journal of Political Economy*. 98 (8): 1325-1348.

Kahneman, D., Tversky, A. 1979. Prospect theory: An analysis of decision under risk. *Econometrica* 47, 263-291.

Knetsch, J.L. and Sinden, J.A. 1984. Willingness to pay and compensation demanded: Experimental evidence of an unexpected disparity in measures of value. *Quarterly Journal of Economics*. 99, 507-521.

Lomborg, B. 2007. *Cool it: the sceptical environmentalist's guide to global warming*. Alfred A. Knopf, New York.

Nordblom, T., Finlayson, J., Hume, I., Kelly, J, (2009). Matching water-yield and salinity benefits / damages with costs of land use change. Chapter 2 in Nordblom, T.L. (ed.). *Developing environmental service policy for salinity & water.* Final project report to the Rural Industry Research and Development Corporation and partners on completion of the project. The present paper will be the basis of "Chapter 3" in the same RIRDC report.

Schonfeldt, C. 2005. Managing the impacts of plantation forestry on regional water resources in the south east of South Australia. Paper presented at the 8th Annual AARES Symposium, Markets for Water: Prospects for WA. 23 Sept. 2005, Duxton Hotel, Perth, Western Australia.

Smith, V.L. 1994 Economics in the laboratory. *Journal of Economic Perspectives* 8: 113-131.

Smith, V.L. 2002. *Constructivist and ecological rationality in economics*. Nobel Prize Lecture, Dec 8, 2002. Interdisciplinary Center for Economic Science, George Mason University, Fairfax, Virginia. (accessed on line 21 Nov 2008) http://www.nobel.se/economics/laureates/2002/smith-lecture.html

Thaler, R. 1980 Toward a positive theory of consumer choice. *Journal of Economic Behavior and Organization* 1: 39-60.

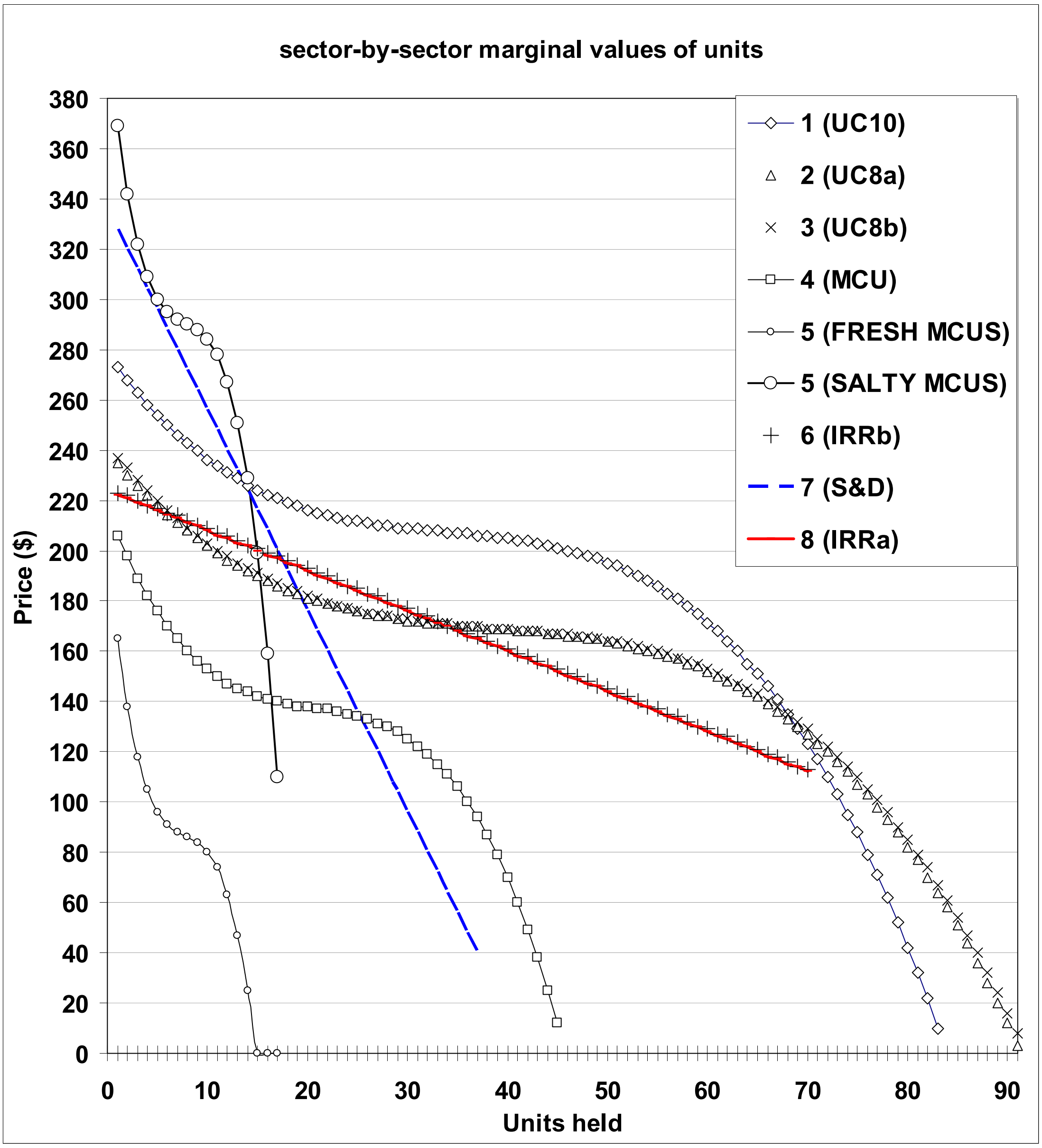
Whitten, S., Carter, M., Stoneham, G. (eds). (2004). Market-based tools for environmental management, Proceedings of the 6th annual AARES National Symposium 2003, A report for the RIRDC / Land & Water Australia / FWPRDC / MDBC Joint Venture Agroforestry Program, Publication No. 04/142. Available from URL: http://www.rirdc.gov.au/reports/AFT/04-142.pdf (accessed 21 Nov 2008)

Zhang, L., Vertessy, R., Walker, G., Gilfedder, M., Hairsine, P., 2007. *Afforestation in a catchment context: Understanding the impacts on water yield and salinity.* Industry Report 01/07. CSIRO. Land and Water Science Report Number 01/07. eWater Cooperative Research Centre, Canberra. Online (accessed 21 Nov 2008): http://www.ewatercrc.com.au/documents/Afforestation%20in%20catchments.pdf

Appendix A. Sector-by-sector marginal values of units used in experiments

					5 (MCUS)	5 (MCUS)			
Unit Held	**1 (UC10)**	**2 (UC8a)**	**3 (UC8b)**	**4 (MCU)**	**5 FRESH**	**5 SALTY**	**6 (IRRb)**	**7 (S&D)**	**8 (IRRa)**
0									
1	273	235	237	206	**165**	**369**	223	328	222
2	268	230	233	198	**138**	**342**	222	320	221
3	263	226	228	189	**118**	**322**	220	312	219
4	258	222	224	182	**105**	**309**	218	304	218
5	254	218	220	176	**96**	**300**	217	296	216
6	250	214	216	170	**91**	**295**	215	288	214
7	246	211	213	165	**88**	**292**	214	280	213
8	243	208	209	160	**86**	**290**	212	272	211
9	240	205	206	156	**84**	**288**	210	264	210
10	236	202	203	153	**80**	**284**	209	256	208
11	234	199	200	150	**74**	**278**	207	248	206
12	231	196	198	147	**63**	**267**	206	240	205
13	229	194	195	145	**47**	**251**	204	232	203
14	226	192	193	144	**25**	**229**	202	224	202
15	224	190	191	142	**0**	**199**	201	216	200
16	222	188	189	141	**0**	**159**	199	208	198
17	221	186	187	140	**0**	**110**	198	200	197
18	219	184	185	139			196	192	195
19	218	183	184	138			194	184	194
20	216	181	182	138			193	176	192
21	215	180	181	137			191	168	190
22	214	179	179	137			190	160	189
23	213	178	178	136			188	152	187
24	212	177	177	135			186	144	186
25	212	176	176	134			185	136	184
26	211	175	175	133			183	128	182
27	210	174	175	131			182	120	181
28	210	174	174	130			180	112	179
29	209	173	173	128			178	104	178
30	209	172	173	125			177	96	176
31	209	172	172	122			175	88	174
32	208	171	172	119			174	80	173
33	208	171	171	115			172	72	171
34	207	171	171	111			170	64	170
35	207	170	170	106			169	56	168
36	207	170	170	100			167	48	166
37	206	170	170	94			166	40	165
38	206	169	169	87			164		163
39	205	169	169	79			162		162
40	205	169	169	70			161		160
41	204	168	168	60			159		158
42	204	168	168	49			158		157
43	203	168	168	38			156		155
44	202	167	167	25			154		154
45	201	167	167	12			153		152
46	200	166	167				151		150
47	199	166	166				150		149
48	198	165	166				148		147
49	197	165	165				146		146
50	195	164	164				145		144
51	194	163	164				143		142
52	192	162	163				142		141
53	190	161	162				140		139
54	188	160	161				138		138
55	186	159	160				137		136
56	183	158	159				135		134
57	181	157	157				134		133
58	178	155	156				132		131
59	175	154	155				130		130
60	171	152	153				129		128
61	168	150	151				127		126
62	164	148	149				126		125
63	160	146	147				124		123
64	155	144	145				122		122
65	151	142	143				121		120
66	146	139	140				119		118
67	141	136	138				118		117
68	135	133	135				116		115
69	129	130	132				114		114
70	123	127	129				113		112
71	117	123	125						
72	110	120	122						
73	103	116	118						
74	95	112	114						
75	88	107	110						
76	79	103	105						
77	71	98	101						
78	62	93	96						
79	52	88	90						
80	42	82	85						
81	32	77	79						
82	22	70	74						
83	10	64	67						
84		58	61						
85		51	54						
86		44	47						
87		36	40						
88		28	32						
89		20	24						
90		12	16						
91		3	8						

Appendix B. Plots of marginal values facing participants in experiments. These are values given in Appendix A.



Note: Correspondence with values in Nordblom *et al*. (2009) is simple: 1 unit here = entitlement to 1 GL of water /year there, and $1 here = $0.01m there, the numeraire for permanent water trades and expected NPV. In Table 8 there, 89 GL was the most water sold by IRR, starting from an initial level of 333 GL. To allow greater scope for change in the experiments it was assumed that IRR could choose to sell up to 130 GL. Splitting IRR into IRRa and IRRb sectors meant each could trade away up to 65 GL from the initial levels, where zero for IRR in the experiment corresponds to 333 GL in the 'real world' depicted there. Working 'up' the marginal value curves, giving up 'units held', effectively provided the supply curves of IRRa and IRRb in the case of **D** initial endowments. Likewise for S&D. In the cases of **U** initial endowments, IRRa and IRRb each are assumed to start with only 2 units held, which combine to depict IRR with just 207 GL (=333- (130 – 4)).

APPENDIX C.

EH GRAHAM CENTRE for Agricultural Innovation

an alliance between Charles Sturt University & NSW Department of Primary Industries

CHARLES STURT UNIVERSITY

NSW DEPARTMENT OF PRIMARY INDUSTRIES

8 Oct 2008

Economic Experiments at CSU INFORMATION SHEET

You are invited to participate in an economic experiment. Please make sure you read and understand the information below before deciding whether to participate. Participation is entirely voluntary, and will not confer any academic advantage or disadvantage. Participation is open to any student at Charles Sturt University. You are free to leave if you do not wish to participate. The experiment will last no more than two hours.

Economic experiments investigate how people make economic decisions. They are used to help design economic policies, through a better understanding of how people respond to different policies and incentives. By taking part in an experiment you will have the opportunity to earn money. The amount you earn will depend on the outcomes of decisions made during the experiment. You will be paid a minimum of $20, up to a maximum of $50 (rounded to the nearest dollar).

During the experiment you will be presented with a scenario, and asked to make various decisions relating to that scenario. You will be provided with a full set of instructions explaining the scenario and the decisions you are required to make.

The decisions you make during the experiment will be recorded and used to compare the effects of alternative policies. All decisions you make will be completely **confidential**. Your name will not be stored with the data from the experiment. Results will not be published or reported in any way which may identify the individuals involved.

You will receive your payment at the end of the experiment. You will be asked to sign a receipt for the money we pay you – this is for accounting purposes only. The amount of money you earn in the experiment will be confidential.

If you require any further information, please contact:-

Dr Tom Nordblom tom.nordblom@dpi.nsw.gov.au
E H Graham Centre for Agricultural Innovation
WaggaWagga, NSW 2650
tel: (02) 69 38 16 27 fax: (02) 69 38 18 09

NOTE: Charles Sturt University's Ethics in Human Research Committee has approved this project. If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer:

The Executive Officer
Ethics in Human Research Committee
Academic Secretariat
Charles Sturt University
Private Mail Bag 29
Bathurst NSW 2795

Tel: (02) 6338 4628
Fax: (02) 6338 4194

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.

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APPENDIX D. Participants' instructions (next four pages)

Experimental Scenario

- In this experiment you have the opportunity to trade experimental "units"
- Each unit has a value to you
- You may keep your units, or trade with other participants

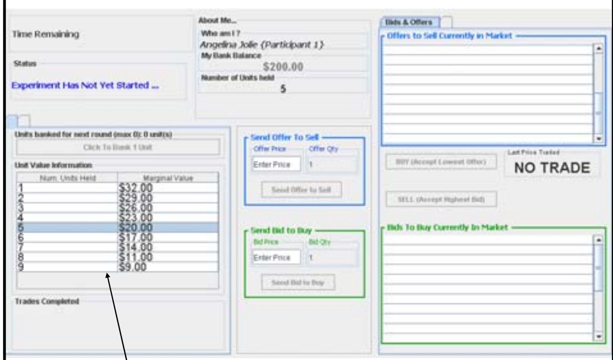
Experimental Scenario

- The experiment consists of a number of rounds
- Each round lasts for five minutes
- You will earn money, based on the value of the units you hold at the end of each round, and your trading activity

Units

- At the beginning of each round you will be assigned a number of units
- During each round you may buy and sell units in the market
- Units are 'cashed in' at the end of each round - the value of each unit you hold will be added to your bank balance
- The unit value table shows how much each unit is worth to you

At the start of the experiment you will see a screen like this:



This is your unit value table

Unit Value table

Num. Units Held	Marginal Value
5	20
6	19
7	18
8	17
9	16
10	15
11	14
12	13
13	12

- The table shows the *marginal value* for each unit
- For example, here unit number nine is worth $16 to you; unit number ten is worth $15
- Therefore if you currently have nine units, the value of an additional unit is $15
- The greyed out row in the middle of the table shows the number of units you currently hold
- As you buy and sell units the values in the table will adjust to reflect your current position

Unit Value table

Num. Units Held	Marginal Value
5	20
6	19
7	18
8	17
9	16
10	15
11	14
12	13
13	12

- It is important that you understand the values in the table in order to trade effectively
- Remember the table shows the *marginal value* for each unit
- In this example, each unit has a different value
- If you hold nine units and you buy an additional unit, that unit is worth $15 at the end of the round
- If you hold nine units and sell one unit, that unit would have been worth $16 at the end of the round

Unit Value table

Num. Units Held	Marginal Value
6	19
7	18
8	17
9	16
10	15
11	14
12	13
13	12
14	11

↓ If you buy an extra unit the table scrolls down

Unit Value table

Num. Units Held	Marginal Value
4	20
5	20
6	19
7	18
8	17
9	16
10	15
11	14
12	13

↑ If you sell a unit the table will scroll up

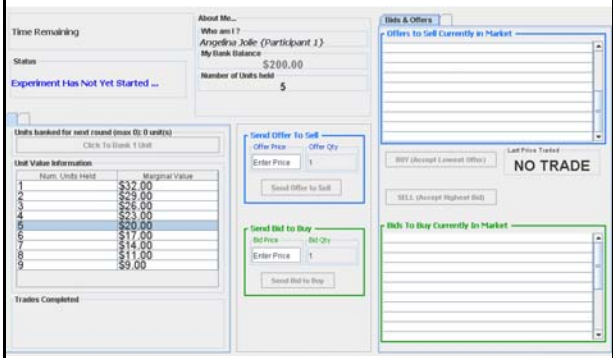
Trading Hints

- When thinking about buying or selling units, make sure you consider your current marginal values
- You don't want to buy a unit for more than it is worth to you
- Nor would you want to sell one for less than it is worth

How to Trade

- Units can be bought or sold one at a time
- You can buy and sell as many units as you like each round, time permitting

At the start of the experiment you will see a screen like this:



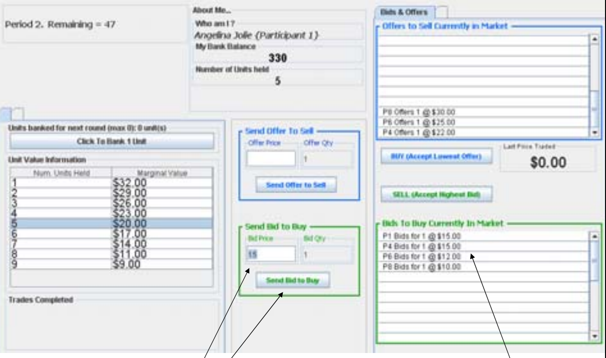
How to Buy

- First, decide how much you are willing to pay for an additional unit
- You can then make a 'bid to buy' – enter your price in the 'bid to buy' box

OR

- You can accept an 'offer to sell' made by another participant

How to Buy

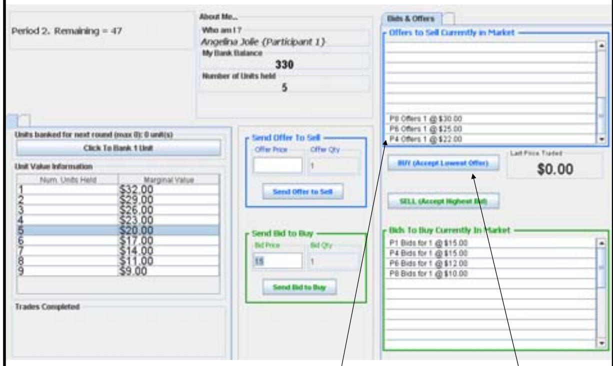


To make a bid to buy, enter your price here and click here

Your bid will appear in the market here

13

How to Buy



Offers to sell already in the market appear here

To accept an offer to sell, click here

14

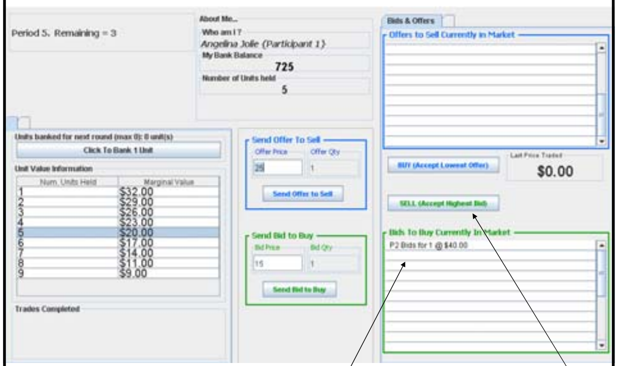
How to Sell

To make an offer to sell, enter your price here and click here

Your offer will appear in the market here

15

How to Sell



Bids to buy already in the market appear here

To accept a bid, click here

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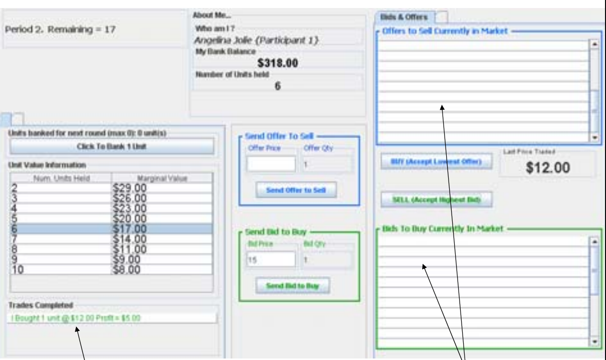

When you make a trade, your profit appears here in green (or your loss in red!)

Bids in the market flash green when you accept them, or red when someone else does

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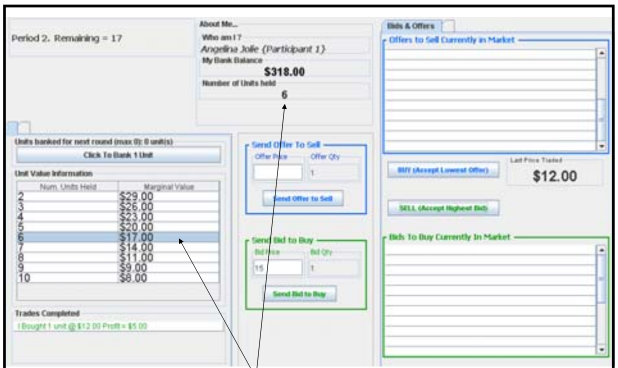

After you make a trade, your ‘number of units held’ and unit value table are updated

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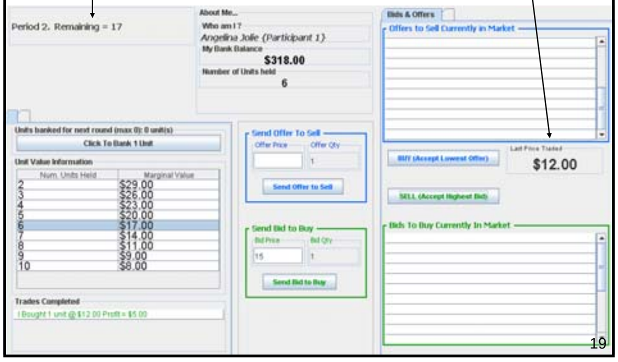
The ‘clock’ ticks down to the end of each round

The most recent price at which anyone traded appears here



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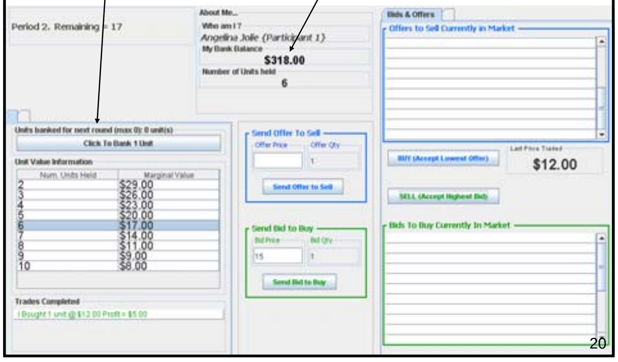
Please ignore the ‘Bank Units’ feature (it is for a different experiment)

Your ‘experimental bank balance’ updates throughout the experiment



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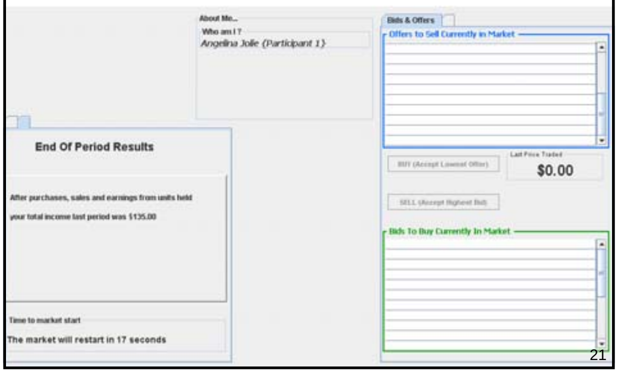
At the end of each round you see a summary of your results. At the start of the next round you will be given a fresh allocation of units. The only thing carried forward is your bank balance!



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Bids and Offers

- Bids and offers expire after two minutes
- You can only have one bid and one offer in the market at a time
- Submitting a new bid or offer automatically replaces any existing bid or offer
- Keep an eye on your value table – this will change as your unit holdings change

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Be Aware…

- There are a limited number of units available
- Initially they are allocated to certain participants
- These allocations may change during the experiment

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Finally…

- There will be a 15 minute practice period, which doesn’t count towards your earnings
- All decisions made during the experiment are confidential
- Please don’t talk or look at others’ screens during the experiment
- You will be paid in cash based on your bank balance at the end of the experiment
- Any questions at any time, please ask…

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