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Impact of environmental traders on water markets: An experimental analysis

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[1] This paper reports the results of a series of economic experiments in which an environmental agency with a stochastic demand function enters an existing water market to buy or sell water for instream use. Previous experimental studies have examined the use of tenders to reduce water extractions and social suasion to maintain aggregate flow levels and compared imposing minimum flow restrictions with subsidizing downstream water use and the allocation of tradeable minimum flow rights. The important contribution of this paper is that it explores the consequence of having an environmental agency enter an existing water market. In this paper we explore the consequences of (1) formally allocating tradeable water rights to the environmental agency, (2) allocating funding to purchase water as required, and (3) having the trading actions of the environmental agency a matter of public record. The research, while contextualized to water markets in this paper, addresses an important and timely issue that could have implication beyond water markets. In pollution permit markets, for example, there is the question of what the impact on the market would be if a government agency were to begin buying back permits, particularly if this represented a relatively large volume of trades and entered into such purchases on a needs basis.

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1. Introduction

[2] Environmental agencies are entering water markets to purchase extractive water rights for environmental use. Under the United States Central Valley Project Improvement Act, for example, the Department of the Interior is mandated to acquire water supplies to meet optimal waterfowl habitat management needs in California's Central Valley, certain State wildlife management areas and the Grassland Resource Conservation District. The Water Acquisition Process (WAP) goal is to acquire up to 163,000 acre-feet (1 acre-foot = 1234 m^3) annually to meet refuge requirements (Bureau of Reclamation, U.S. Department of the Interior Water Acquisition Program background information sheet, 2003, available at http://www.usbr.gov/mp/cvpia/3406b3_wap/info/background_info_sheet_11-2003.pdf). *Landry* [1998, p.457] estimates that: "[f]rom 1990 to 1997, more than US $37 million was spent to lease 2 million acre-feet of water and US$23.8 million was spent to purchase 132,000 acre-feet of water for environmental protection." The Australian Federal Government has set aside $A500 million over a 5 year period to redress the overallocation of water to extractive use in the Murray Darling Basin [*Goesch and Heaney*, 2003].

[3] The traditional school of thought, not just in the United States but in other countries such as Australia, is that the agency should be funded to purchase existing extractive water rights. An alternative is to establish tradeable environmental rights. To date, this option has not been fully explored. Should an environmental agency be endowed with a tradeable water right instead of funds to purchase (lease) existing extractive rights as required? Having a tradeable water right, rather than funds to purchase water, changes the dynamic role of the agency in the marketplace. Second, should the actions of the agency be a matter of common record? Whether the agency has a formal allocation of water or is simply a buyer of existing rights, it is dealing in significant state assets. It could be argued that such actions should be a matter of public record. Finally, what are the market and allocative efficiency consequences of these policy options?

[4] Some environmental agencies have taken advantage of the benefits of dry year and split year options in the leasing markets, whereby extractive and environmental users could coordinate their use of the entitlement during different periods of the year [*Colby*, 1990; *Goesch and Heaney*, 2003]. Most, however, have engaged in simple tenders to buy back water from extractive users [see, e.g., *Landry*, 1998; *Scoccimarro and Collins*, 2006] (see also Bureau of Reclamation, U.S. Department of the Interior Water Acquisition Program background information sheet). To sell/lease water when flow is not required or buy/lease water when demanded means that water is not withheld from productive use unnecessarily. Taking water away from productive use through tenders and holding it when it is not required for environmental flow is not necessarily the most efficient use of the available resource. This research adds to the growing body of literature exploring ways to optimize

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Table 1. Experimental Design

Knowledge of Environmental Trader	Environmental Trader	
	Buyer's Budget to Purchase Water	Seller's Allocation of Water
No information (unaware)	four sessions of 20 rounds each	four sessions of 20 rounds each
Information (aware)	four sessions of 20 rounds each	four sessions of 20 rounds each

the use of the available resource. This work evaluates strategies for agencies to hold water opportunistically for environmental use under controlled laboratory conditions. This is not a new notion. In fact it has been mooted as a benefit of alternative water management schemes ever since the 1980s [see *Dudley and Musgrave*, 1988; *Griffin and Hsu*, 1993; *Murphy et al.*, 2009]. This work contributes to the body of knowledge by exploring the impact of alternative funding, allocation and information options for environmental traders have on existing water markets.

[5] This paper explores, under experimental conditions, the consequences of having an environmental trader with a stochastic demand function enter a water market under each option. The paper begins by posing a number of research questions and associated hypotheses concerning the impact of alternative allocation, funding and information options. This is followed by an outline of the study design and procedures. The results of the experimentation are then discussed. Having evaluated the performance of the markets in terms of price and quantity market parameters to ensure they have performed as expected, the issue of allocating funds or water to an environmental agency and the associated supply of information is evaluated in terms of allocative efficiency.

2. Research Questions

[6] While there is a significant body of experimental economic literature on water markets [see, e.g., *Dinar et al.*, 1998; *Murphy et al.*, 2000, 2006; *Garrido*, 2007], there are but a few experimental economic studies that explore how environmental flow objectives can be achieved in a water market environment [*Cummings et al.*, 2004; *Tisdell et al.*, 2004; *Murphy et al.*, 2009].

[7] *Cummings et al.* [2004] reported on a series of experiments in which they tested an auction mechanism to compensate farmers for reducing extractive use of water during periods of low flows. They found that tendering for environmental water was a useful policy tool for acquiring water rights for environmental use.

[8] *Tisdell et al.* [2004] explored how social suasion and fines can be used in conjunction with water markets to achieve environmental outcomes. In their experiments the group faced a fine if aggregate extractions differed from the environmental flow objective. They found that aggregate rather than individual information led to greater accordance to environmental flow objectives.

[9] *Murphy et al.* [2009] tested a decentralized exchange mechanism that generated location-specific pricing in the presence of instream flow values. They compared minimum flow constraints, meeting instream flows by subsidizing downstream consumption, and having tradeable minimum flow rights. Markets with minimum flow constraints quickly converged to competitive equilibrium. Subsidizing downstream consumption yielded lower levels than having an environmental rights assigned. The market prices for the tradeable minimum flow rights and subsidizing downstream consumption were neither perfectly competitive nor rent seeking. The results were highly dependent on the decisions of the individual assigned the environmental agency role.

[10] What is different about this study to those of *Cummings et al.* [2004], *Tisdell et al.* [2004], and *Murphy et al.* [2009] is that the environmental trader enters and exits the market according to a stochastic demand for water. In the field, environmental traders may enter the market as buyers when weather is dry and as sellers when conditions are wet. At times traders can be quite large, as is the case with traders entering to buy or sell water for environmental use. Combining the relative size of such traders and the stochastic nature of their behavior, these traders have the potential to significantly destabilize water markets. This study attempts to answer the following questions: What are the consequences of having an environmental agency enter the market and purchase water as required? What are the consequences of allocating water to environmental use and allowing the agency to trade water not required in a given year? Finally, should the actions of the environmental trader be a matter of public record? These questions result in a number of testable hypotheses regarding (1) the operations of the markets (offers, quantities traded, and call prices) to ensure the market are operating as expected and (2) the relative allocative efficiency of the policy options.

2.1. Market Operations

[11] It is important at the start to ensure the markets are performing as expected. To do this we pose the following simple hypotheses concerning market prices and quantities. In hypothesis 1, having an environmental buyer stand in the market or an environmental seller exit a market will increase market prices. In hypothesis 2, information on the actions of the environmental trader will impact the offers made by the other traders.

2.2. Efficiency

[12] Provided the markets meet the simple operational conditions, the substantial concerns of efficiency can be addressed. In terms of market and allocative efficiency we pose the following two additional hypotheses. In hypothesis 3, whether the agency has a tradeable allocation of water or funds to buy water should produce equal market and allocative efficiency. In hypothesis 4, market and allocative efficiency improves with information about the actions of the environmental trader. This study is timely as government agencies focus more on voluntary trades, rather than takings through eminent domain, to meet environmental objectives.

3. Experimental Design

[13] Table 1 summarizes the experimental design. To answer the research questions the experiment design involved two main treatments in which an environmental trader entered the market either with a budget to buy water as required or a quantity of water to sell when not required. Players were either aware or unaware of the presence of the environmental trader in the market. Four experimental sessions of 20 rounds each

Table 2. Player Characteristics

Player	Allocation: Environmental Buyer	Allocation: Environmental Seller	Maximum Productive Use	Marginal Value
1	100	70	200	20
2	100	70	200	20
3	100	70	200	30
4	100	70	200	30
5	100	70	200	50
6	100	70	200	50
7	100	70	200	70
8	100	70	200	70
9	100	70	200	80
10	100	70	200	80

were conducted for each treatment/block combination. The following explains the nature of the existing water market and the strategy sets of the existing irrigators and the environmental trader.

3.1. Market

[14] Trade occurred through a closed call market. Each market involved players entering offers to buy or sell within a given time frame (call). Trade occurs automatically, clearing at a uniform price after the call closes (see *Smith et al.* [1982] and *Cason and Friedman* [1997] for a detailed explanation of the workings of a call market). Such call markets have been successfully used to trade water for many years (see, e.g., the Goulburn Murray Water Exchange, http://www.watermove.com.au). In this experiment an environmental agency enters such a market to trade water for environmental use.

3.2. Agency Strategy Set

[15] There seems no simple definition of environmental flows. Knowledge of the water requirements of environmental ecosystems is still evolving. Ultimately, the total water requirement of a river is very site specific and defined in terms of monthly flow variability, floods of given timing and duration, and flushing flows [*Arthington et al.*, 1991]. Methods for estimating environmental flows have been grouped into hydrological rules, hydraulic ratings and habitat simulation methods [see, e.g., *Dyson et al.*, 2003; *Tharme*, 2003].

[16] For the purposes of evaluating the policy options under controlled conditions it was necessary to formulate a simple flow objective that could be applied across the various sessions. It is well recognized that the strategies of environmental agencies are catchment specific and likely to be spatially complex, consisting of a combination of stochastic flow events. In a controlled experimental setting, as with a glass house, the aim is to capture the most salient features of an environmental flow regime. At the core of environmental flows are events which occur stochastically in a cyclical pattern of unequal lengths. A number of simplified patterns were considered. The stochastic demand for environmental water could include a simple probability each year, say, a 1-in-4 chance that this year will be "dry" and therefore the environmental trader needs to acquire water. A second form may be that the agency cannot allow more than a certain amount of time (say, 4 years, for example) to elapse between market entry rounds. A final form may be that the agency must enter the market at least once in every 4 year block.

[17] This paper explored the consequences of having the environmental trader enter the market randomly once in every 4 round cycle to buy water or randomly 3 in every 4 rounds to sell water, according to the endowment of the environmental agency. This pattern was chosen for a number of reasons. The pattern means that the likelihood of market entry increases each year. This form is significant because it allows specific study of the consequences of environmental trader activity on player expectations given a systemic pattern of entry. It is similar in nature to the second form but also has the interesting characteristic that more than 4 years can elapse without the environmental trader entering the market. The environmental trader may enter in two consecutive rounds (the forth in one round and the first the following round) or as far apart as seven rounds (the first round and the last round of the following set of four). While this may appear to be a very special case it is likely that an environmental trader will have some form of increasing likelihood of watering requirement through time. This strategy set may be still considered to be too deterministic and so quite at odds with the more complex field environment. If, however, the players are not adversely affected by an environmental agency with such a deterministic strategy, then it is unlikely that they will react to one with a less deterministic and so predictable strategy set. Conversely, if the players react to the actions of the agency then a more complex setting may be worth exploring in future studies.

[18] At its core, the environmental demand for water is highly stochastic, driven by rainfall events which are highly catchment specific. In order to draw broader policy recommendations it is important not to focus on specific regions, rather to capture the essential underlying stochastic nature of environmental demand common to all.

[19] As players traded in a uniform price closed call market, it was relatively straightforward to automate the environmental trader. Automating the entry of environmental offers avoids the frailties of having a player represent the environmental agency. Robot environmental traders are commonly used in economic experiments of this nature [see, e.g., *Murphy et al.*, 2000]. There is some question whether robot traders represent the actions of real traders in the field. In the field such traders would adopt actions specific to their catchment. What is important in the controlled environment of the laboratory is to the capture the general principle that such a trader would trade according to stochastic triggers.

3.3. Existing Traders in the Market

[20] The experimentation involved an environmental agency entering an existing water market. The market involved 10 players each having 100 units of water, a maximum water usage of 200 units, and marginal values of water as shown in Table 2. Trade without an environmental trader demanding or selling water represented the existing water market status quo. The existing water market is symmetric with an equilibrium price of $50. The market price is expected to vary between $50/ML and $70/ML depending on whether the environmental trader (player 11) is active in the market.

[21] The environmental target was to acquire 300 ML of water at $A70/ML. While this paper reports the results of a set of noncalibrated experiments, *Stone* [1992] conducted a contingent valuation study of the Barmah Wetlands

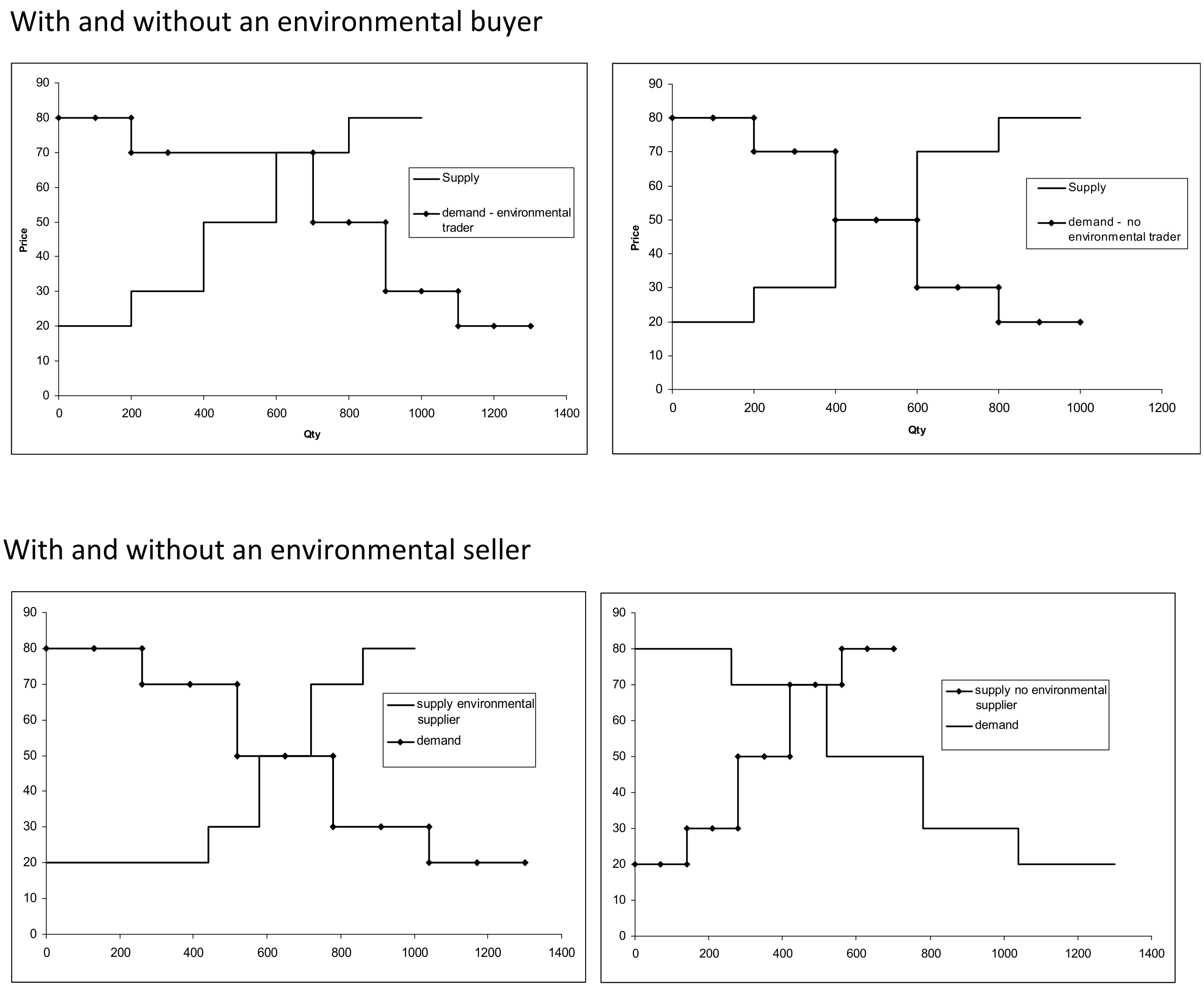

Figure 1. Supply and demand with and without an environmental trader.

in Victoria and found the value of the wetlands to lie between \$76.9 million and \$97.5 million. Given that the Barmah-Millewa wetlands has an environmental allocation of 1000GL, this equates to a average value of \$872/ML. Atomized over 20 years the current value of the wetland is $R = S/A_{ni} = 975/s20.0.05 = 872/12.462210 = \$70/ML$.

[22] In the case where the environmental trader has an allocation of 300 ML each player receives a reduced allocation of 70 ML, leaving 300 ML from the sum for the environmental trader. Based on these player characteristics, Figure 1 shows expected demand with and without an environmental trader. Looking at the charts, we can see that at least in theory, players 9 and10 are always buyers, and players 1 and 2 should always be selling regardless of environmental demand. The role of the other players depends upon the environmental demand. When there is environmental demand, players 4 and 5 (MV = 50) are always sellers. Without environmental demand, players 7 and 8 (MV = 70) are buyers. The other players have more a difficult decision. They must decide whether to be a buyer or a seller at the competitive equilibrium price.

[23] In essence, the study is based on two forms of assets available to the environmental trader: having funds available to buy water when required and having a formal allocation of water which can be sold when not required. If the environmental trader has a volume of water, they will sell it three in every 4 year cycle when it is not required. Alternatively, if the environmental trader has funding to purchase water on a needs basis, then they only enter the market once in every 4 year cycle.

3.4. Experimental Procedures

[24] Participants were recruited from the student population at Griffith University, Brisbane, Queensland, Australia. Subjects were paid \$A10 as a turn up fee and then given an opportunity to earn extra money throughout the experiment by trading. The average earnings was \$A36 (A \$1 = U.S.\$0.8) including the turn up fee. The students were paid in cash at the end of the experiment.

[25] Each experimental session lasted approximately 2 h. On arrival, the students were directed to a set of online instructions that included an interactive quiz to ensure understanding before being allowed to log into the experiment. A unique logon password was displayed once a player successfully answered all the quiz questions.

Table 3. Random Effects Regression Model of Market Prices[a]

	Buyer's Budget to Purchase Water[b]		Seller's Tradeable Allocation of Water[c]	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Constant	48.85***	1.783	57.26***	1.216
Information	2.54	2.500	−2.16	1.488
Trader	9.20***	0.880	−8.66***	0.814

[a]Significance: ***, significant at $\alpha = 0.01$.
[b]Likelihood ratio $\chi^2 = 110.48$, p = 0.000.
[c]Likelihood ratio $\chi^2 = 115.25$, p = 0.000.

[26] The experiments were run in a computer laboratory using the experimental software system (TESS), specialized experimental software developed at Griffith University, Brisbane, Queensland, Australia. Once logged in, players could view their allocation, maximum usage and marginal value. Each round consisted of a uniform price, closed call market in which the subjects had 90 s to enter an ask or bid. As appropriate, the software automatically entered an ask or bid on behalf of the environmental agency as required. Once the call closed, the software ordered the asks and bids, determined the pool price and successful trades and updated the players' screens. As the experiment involved a closed call auction, the players could only view the history of pool prices and their own offers. In the information treatments when the environmental trader had entered the market, that fact was announced once the call had closed. The research assistant also announced that the environmental trader would not be entering the market again until the beginning of the next 4 round cycle. For example, if the experimental session was a buyer in experimental session 2, after round 3 the assistant would announce: The environmental trader entered the market that round and will not be entering the market again until after round 4.

4. Results

[27] The study asked whether it is better to give an environmental agency a tradeable water allocation or a budget to buy water when needed. What are the consequences of having an environmental agency enter the market and purchase water as required? Alternatively, what are the consequences of allocating water to environmental use and allowing the agency to trade water not required in a given year? Finally, should the actions of the environmental trader be a matter of public record? In answering these questions we analyzed the consequences of having an environmental agency enter the market either as a seller or buyer on (1) market prices and quantities traded, (2) average and total ask and bid quantities, (3) average ask and bid prices, and (4) market and allocative efficiency. Random effects regression models assuming AR1 covariance error structures were used to analyze the experimental data. Interactions are only reported when significant. The analysis was conducted using STATA V10.

4.1. Market Prices and Quantities Traded

[28] The analysis of results begins with an examination of the market price consequences of having an environmental trader enter and exit a water market. It is important to first ensure that markets are behaving as expected before drawing any conclusions on their relative performance in the laboratory. It is expected that when the environmental trader enters the market or when the environmental seller exits the market, the market price will increase.

[29] Table 3 presents a random effects regression model of market prices assuming AR1 covariance structures. In both models the presence of an environmental trader influenced the market price. In the case of the environmental buyer, having them stand in the market significantly increased the market prices by $9.20 on average. Similarly, having the environmental seller exit the market significantly increased the market price by $8.66 on average. Information on whether the environmental trader was active in the market was not found to be a significant determinant of average market prices. Table 4 presents a random effects model of market quantities traded. Information on the actions of the stochastic environmental trader did not influence the overall quantity of water traded.

[30] The first result is that the environmental trader actions influenced the market price and quantity traded. Information on whether the environmental trader was active in the market, however, was not found to be a significant determinant of market prices or aggregate quantities traded.

4.2. Average and Total Ask and Bid Quantities

[31] Evidence of strategic interaction between the timing of the environmental trader entering or exiting the market and the actions of the other traders in the markets is likely to be found in the offers made. The effect of information on the actions of the environmental trader is explored in terms of the prices and quantities of offers made to the market.

[32] Table 5 presents the random effects regression model of offer quantities. Information on the environmental buyer actions significantly increased the average bid quantity ($p < 0.01$). Information on the actions of the environmental seller in a market reduced the average bid quantity ($p < 0.10$). It was further reduced in those rounds when the trader was in the market ($p < 0.10$). When the environmental buyer was in the market the average bid quantity did not change significantly ($p > 0.10$). Information on, or the existence of, the environmental trader (either as a buyer or seller) in the market did not impact on the total bid quantities.

[33] The second result is that information on the actions of the environmental buyer in the market significantly increased the average bid quantity. Information on the actions of the environmental trader in the market had little impact on the average ask quantities. The total ask quantities were significantly influenced by information on the activities of the environmental trader with an allocation of water (p <

Table 4. Random Effects Regression Model of Market Quantities[a]

	Buyer's Budget to Purchase Water[b]		Seller's Tradeable Allocation of Water[c]	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Constant	368.14***	15.984	265.67***	55.197
Information	5.52	22.075	−31.07	76.990
Trader	84.96***	13.691	113.85***	13.924

[a]Significance: ***, significant at $\alpha = 0.01$.
[b]Likelihood ratio $\chi^2 = 67.03$, p = 0.000.
[c]Likelihood ratio $\chi^2 = 38.57$, p = 0.000.

Table 5. Random Effects Regression Model of Offer Quantities[a]

	Buyer's Budget to Purchase Water		Seller's Tradeable Allocation of Water	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
	Average Bid Quantities[b]			
Constant	92.27***	1.441	127.40***	11.116
Information	6.63***	2.011	−29.96*	15.685
Trader	−0.81	0.885	−1.907*	0.9881
	Total Bid Quantities[c]			
Constant	423.09***	13.490	648.98***	70.180
Information	4.87	18.530	−154.06	97.938
Trader	−17.16	12.798	−21.76	15.185
	Average Ask Quantities[d]			
Constant	96.16***	1.687	69.65**	1.159
Information	3.45	2.355	−1.09	1.505
Trader	−0.35	1.058	−1.06*	0.629
	Total Ask Quantities[e]			
Constant	503.64***	20.888	336.58***	11.727
Information	45.11	29.195	−47.58***	13.228
Trader	2.99	12.557	4.94	9.447

[a]Significance: ***, significant at $\alpha = 0.01$; **, significant at $\alpha = 0.05$; * significant at $\alpha = 0.10$.
[b]Buyer's likelihood ratio $\chi^2 = 11.72$, p = 0.008; seller's likelihood ratio $\chi^2 = 7.37$, p = 0.0609.
[c]Buyer's likelihood ratio $\chi^2 = 1.87$, p = 0.599; seller's likelihood ratio $\chi^2 = 4.53$, p = 0.209.
[d]Buyer's likelihood ratio $\chi^2 = 2.26$, p = 0.520; seller's likelihood ratio $\chi^2 = 3.41$, p = 0.3326.
[e]Buyer's likelihood ratio $\chi^2 = 2.44$, p = 0.4854; seller's likelihood ratio $\chi^2 = 13.21$, p = 0.004.

0.000). Information on the actions of the trader significantly reduced the total ask quantity compared to no information.

[34] The third result is that information on the actions of an environmental seller significantly reduced the total ask quantity and increased average bid prices compared to no information.

4.3. Average Ask and Bid Prices

[35] The fourth result is that information on the environmental seller activities led to a significant increase in average bid prices. Table 6 presents the random effects regression models of offer prices. Average ask prices were not affected by information on or the existence of the environmental trader in the market. In contrast, the average bid price was significantly influenced by information when the environmental trader was given a tradeable allocation of water ($p < 0.05$). Information on the environmental seller activities led to a significant increase in the average bid prices.

4.4. Market and Allocative Efficiency

[36] The fifth result is that market efficiency was maximized when the environmental agency holds a tradeable water allocation. Table 7 summaries the market and allocative efficiency of having the environmental agency in the market as a buyer or as a seller, with and without information. The efficiency measures were estimated using weighted average of periods with and without the environmental agency standing in the market. Overall, market efficiency was maximized when the environmental agency holds a tradeable water allocation (86.6% compared to 80.3% with information; 93.3% compared to 74.1% without information; and 89.9% compared to 77.2% overall). Market efficiency was maximized when the presence of the environmental seller was not known.

[37] This superiority did not translate into allocative efficiency. Overall, there was no discernable difference in allocative efficiency between the two options (95.9% compared to 95.4%). Within the options allocative efficiency was maximized by having information and an environmental agency demand water (96.4%). No information resulted in significantly lower allocative efficiency (78.0% and 75.5%, respectively). The sixth result is that allocative efficiency was maximized by having information and an environmental agency demand water.

5. Conclusion

[38] This paper reports on a series of economic experiments in which an environmental trader enters a water market to meet a stochastic demand for water. How the environmental trader is defined is seen as important. Options included giving an allocation of water to the environment, which they can lease out in all but 1 in 4 years, or allowing the trader to acquire the water through buying on demand from the water market.

[39] The environmental trader actions influenced the market price and quantity traded as expected. Information on whether the environmental trader was active in the market, however, was not found to be a significant determinant of market prices or aggregate quantities traded. Importantly having the trading actions of the environmental agency a matter of public record impacted on average bid quantities rather than bid prices. When the environmental buyer was in the market, players increased their average bid quantities in response. Similarly, when the environmental seller was not in the market, the average bid quantity declined. Total bid quantities did not significantly change implying that players opted fewer, larger (or more, smaller when in decline) bid offers. Knowing that the environmental agency is selling reduced the total ask quantity suggesting

Table 6. Random Effects Regression Model of Offer Prices[a]

	Buyer's Budget to Purchase Water		Seller's Tradeable Allocation of Water	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
	Average Ask Price[b]			
Constant	43.89***	2.177	41.80***	2.698
Information	2.98	3.069	−4.17	3.693
Trader	−0.30	0.697	0.51	0.906
	Average Bid Price[c]			
Constant	58.16***	2.099	58.59***	4.546
Information	2.78	2.957	−15.64**	6.405
Trader	−0.71	0.705	0.19	0.536

[a]Significance: ***, significant at $\alpha = 0.01$; **, significant at $\alpha = 0.05$; * significant at $\alpha = 0.10$.
[b]Buyer's likelihood ratio $\chi^2 = 0.95$, p = 0.813; seller's likelihood ratio $\chi^2 = 1.60$, p = 0.659.
[c]Buyer's likelihood ratio $\chi^2 = 1.91$, p = 0.591; seller's likelihood ratio $\chi^2 = 6.09$, p = 0.107.

Table 7. Allocative and Market Efficiency

	Allocative Efficiency (%)		Market Efficiency (%)	
	Environmental Supply	Environmental Demand	Environmental Supply	Environmental Demand
Information	94.3	96.4	86.6	80.3
No information	78.0	75.5	93.3	74.1
Overall	95.9	95.4	89.9	77.2

that having a large environmental seller in the market may crowd out other potential sellers.

[40] The experiments involved a uniform price, closed call market. Without information on the actions of the environmental trader, players' only information was the pool price and the success or not of their offers. No significant interaction between information and trader actions was found, suggesting that the price signal that an environmental trader was active in the market was not sufficient to change player behavior.

[41] In summary, these results suggest that (1) quantity offered, rather than offer prices, are affected by environmental agencies standing in the market, (2) an environmental seller may crowd out other sellers in the market, and (3) whether the activities of the environmental agency is a matter of public record or not is a significant factor in determining the impact the environmental trader will have on an existing water market. When the actions of the environmental seller are a matter of public record, allocating a budget to buy water has a lower impact on market activity. Given a tradeable allocation of water, knowledge of environmental trader activity impacted on the average bid price and total ask quantities.

[42] What then of the question of whether the environmental agency should be given a tradeable allocation of water or a budget to buy water? Both influenced the experimental market prices and quantities of water traded. In terms of trader activity impacts, the environmental seller impacted on average bid quantities and average ask quantities, where the environmental buyer did not.

[43] While allocating tradeable water to an agency maximized market efficiency it did not maximize allocative efficiency. Allocative efficiency was maximized in the laboratory by providing information on the actions of the environmental buyer. In both cases no information reduced allocative efficiency. An important area for further research is the distributive consequences that result from the different agency allocation and funding options. Further, this study was based on one form of environmental flow. A comprehensive sensitivity study of alterative flow uncertainty may commend quantity mechanisms over incentives systems.

[44] The notion of arbitraging water to meet environmental demand has been muted in this journal since the 1980s [*Dudley and Musgrave*, 1988]. To date, most real environmental trades have involved simple one off purchases from extractive users [see, e.g., *Landry*, 1998] (see also Bureau of Reclamation, U.S. Department of the Interior Water Acquisition Program background information sheet). As strategies for effectively trading water for environmental use evolve, agencies will need to consider notions of trading opportunistically, if for no other reason than to be cost effective. This research may at least encourage agencies to consider leasing out water when not required to support environmental flows or leasing water when required.

[45] In conclusion, the environment is now a formally recognized player in water markets in many countries and support for pro-market solutions to environmental flow problems is significant [*Landry*, 1998]. Determining the resource mix and role of environmental traders is important. This paper provides some important insights, within an experimental setting, to the nature and consequences of having an environmental trader stand in a water market, and how players in such markets may react to their presence. The experimental results suggest to policy makers that both options are worthy of further consideration. Allocative efficiency, an important objective of any resource policy, was maximized by providing funds for an environmental trader to lease water as required and to make their actions a matter of public record. The next step in the development of a well crafted policy is to consider small field trials of these alternatives.

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References

Arthington, A. H., J. M. King, J. H. O'Keeffe, S. E. Bunn, J. A. Day, B. J. Pusey, D. R. Bluhdorn, and R. Tharme (1991), Development of an holistic approach for assessing environmental flow requirements of riverine ecosystems, paper presented at International Seminar and Workshop on Water Allocation for the Environment, Cent. for Water Policy Res., Armidale, N. S. W., Australia.

Cason, T. N., and D. Friedman (1997), Price formation in single call markets, *Econometrica*, *65*(2), 311–345, doi:10.2307/2171895.

Colby, B. G. (1990), Enhancing instream flow benefits in an era of water marketing, *Water Resour. Res.*, *26*(6), 1113–1120.

Cummings, R. G., C. A. Holt, and S. K. Laury (2004), Using experimental experiments for policymaking: An example from the Georgia irrigation auction, *J. Policy Anal. Manage.*, *23*(2), 341–363, doi:10.1002/pam.20007.

Dinar, A., R. E. Howett, S. L. Rassenti, and V. L. Smith (1998), Development of water markets using experimental economic, in *Markets for Water Potential and Performance*, edited by K. W. Easter, M. Rosegrant, and A. Dinar, pp. 259–275, Kluwer Acad., Boston, Mass.

Dudley, N. J., and W. F. Musgrave (1988), Capacity sharing of water reservoirs, *Water Resour. Res.*, *24*(5), 649–658, doi:10.1029/WR024i005p00649.

Dyson, M., G. Berkamp, and J. Scanlon (Eds.) (2003), *Flow: The Essentials of Environmental Flows*, Int. Union for Conserv. of Nat., Gland, Switzerland.

Garrido, A. (2007), Water markets design and evidence from experimental economics, *Environ. Resour. Econ.*, *38*, 311–330, doi:10.1007/s10640-006-9077-0.

Goesch, T., and A. Heaney (2003), Government purchase of water for environmental outcomes, *Rep. 03.22*, Nat. Resour. Manage. Bus. Unit, Dep. of Agric., Fish. and For., Canberra.

Griffin, R. C., and S. H. Hsu (1993), The potential for water market efficiency when instream flows have value, *Am. J. Agric. Econ.*, *75*, 292–303, doi:10.2307/1242913.

Landry, C. (1998), Market transfers of water for environmental protection in the western United States, *Water Policy*, *1*(5), 457–469, doi:10.1016/S1366-7017(99)00011-2.

Murphy, J. J., A. Dinar, R. E. Howitt, S. J. Rassenti, and V. L. Smith (2000), The design of 'smart' water market institutions using laboratory experiments, *Environ. Resour. Econ.*, *17*(4), 375–394, doi:10.1023/A:1026598014870.

Murphy, J. J., A. Dinar, R. E. Howitt, E. Mastrangelo, S. J. Rassenti, and V. L. Smith (2006), Mechanisms for addressing third-party impacts resulting from voluntary water transfers, in *Using Experimental Methods in Environmental and Resource Economics*, edited by J. A. List, pp. 91–112, Edward Elgar, Northampton, Mass.

Murphy, J. J., A. Dinar, R. E. Howitt, S. J. Rassenti, V. L. Smith, and M. Weinberg (2009), The design of water markets when instream flows have value, *J. Environ. Manage.*, *90*, 1089–1096, doi:10.1016/j.jenvman.2008.04.001.

Scoccimarro, M., and D. Collins (2006), Natural resource 'buy-backs' and their use to secure environmental flows, Land and Water Aust., Canberra. (Available at http://lwa.gov.au/projects/3222)

Smith, V. L., A. W. Williams, W. K. Bratton, and M. G. Vannoni (1982), Competitive market institutions: Double auctions vs. sealed bid-offer auctions, *Am. Econ. Rev.*, *72*(1), 58–77.

Stone, A. (1992), Contingent valuation of the Barmah Wetlands, Victoria, in *Valuing Natural Areas: Applications and Problems of the Contingent Valuation Method*, edited by M. Lockwood and T. DeLacy, pp. 47–70, Johnstone Cent. of Parks, Recreation and Heritage, Albury, N. S. W., Australia.

Tharme, R. E. (2003), A global perspective on environmental flow assessment: Emerging trends in the development of environmental flow methodologies for rivers, *River Res. Appl.*, *19*, 397–442, doi:10.1002/rra.736.

Tisdell, J. G., J. R. Ward, and T. Capon (2004), Impact of communication and information on a complex heterogeneous closed water catchment environment, *Water Resour. Res.*, *40*, W09S03, doi:10.1029/2003WR002868.

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