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MEASURING PRICE ELASTICITIES OF DEMAND AND SUPPLY OF WATER ENTITLEMENTS BASED ON STATED AND REVEALED PREFERENCE DATA

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Estimates of price elasticities of water entitlements (known as permanent water or water rights in the United States) are complicated by data limitations and problems of endogeneity. To overcome these issues, we develop an approach to generate stated preference data and combine them with revealed preference data to estimate price elasticities from various types of water entitlement sales in the southern Murray-Darling Basin, Australia. Our results suggest that price elasticities of demand and supply of high security water entitlements are inelastic in the relevant market price range between AUD $1,700 to $2,100 per mega-liter, and that supply is relatively more inelastic than demand. For lower reliability water entitlements, the price elasticity of demand is estimated to be even more inelastic than high security water entitlements. The price elasticity of supply for general security water entitlements is similar to high security water entitlements, while the supply of low reliability water entitlements is extremely inelastic for our data set. The comparison between the stated and revealed preference data provides strong evidence of support for a data fusion approach; nevertheless, some differences in water sale preferences were found for irrigators choosing not to sell all of their water. The consistency of our results signals support for the use of this methodology in other water basins around the world.

Key words: Contingent behavior, irrigation, price elasticity, water entitlements, water markets.

JEL codes: Q21, Q25.

Irrigated agriculture is the largest water user in many countries in the world (World Water Assessment Programme 2012). Thus, understanding irrigators' responsiveness to changes in water prices is essential for evaluating various environmental and economic policy initiatives. Initiatives designed to address potential water shortages include: *a*) regulatory approaches such as restrictions and limits on water use, licenses, abstraction, and allocations; *b*) economic instruments such as water markets, charges, tariffs, and water pricing, as well as subsidization of water infrastructure or insurance schemes; and *c*) informational and other instruments such as education, meter water use, institutional changes, and cooperative/planning agreements (Griffin 2006). Information on price elasticities associated with some of the largest users of water is an important component for assessing these policy options.

Despite agricultural water markets being in existence for many years around the world, there is a lack of empirical studies on price elasticities (especially water entitlements) in water markets. This is mainly because of

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a paucity of water trade data, unavailability of price information, and a lack of water entitlement trade in general, in contrast to temporary or seasonal trade. Inherent in market transaction data are problems such as endogeneity between water prices and water supply/demand, variability in unobserved contextual characteristics, etc. To overcome having insufficient data and variation in observations of the same commodity at various price levels, we design a stated preference tool to elicit water demand and supply preferences, and administer it to irrigators in the southern Murray-Darling Basin (MDB) in Australia. This survey also collected irrigators' historical water market trade information, which allowed us to compare between hypothetical and actual trading information.

The MDB provides an excellent opportunity to experimentally examine water supply and demand elasticities because of its strong and well-established water institutions. Water markets were first established in Australia in the 1980s, with significant water reform, both urban and rural, introduced in the early 1990s (Council of Australian Governments 1994), and renewed with the introduction of the National Water Initiative (NWI 2004). Although water markets have been adopted in other countries around the world (e.g., Chile, the United States, Mexico, and China), Australian water markets are considered the most advanced and sophisticated, with official markets having been in operation for three decades (Grafton et al. 2011). In particular, our case study region—the MDB in Australia—comprised 94% of the volume of entitlements and allocations traded across Australia 2010–12 (NWC 2011b, 2013).[1]

This article describes a contingent behavior experiment where stated preferences for buying and selling different types of water entitlements at various price levels are elicited and compared with actual water market trading history. Our survey differs from contingent valuation studies, which typically seek to find *values* associated with a marginal change in an environmental good. Instead, we investigate contingent sale and purchase quantities of a private good that irrigators have considerable experience with in Australia, that is, the buying and selling of water. We are interested in examining how elasticity differs between buying and selling entitlements (by differing types of security) across regions and farm types. We also provide a comparison of stated and revealed preferences for water entitlement sales and offer valuable insights into the relationship between the two approaches and the validity of our experiment. The consistency of our results signals strong support for the use of this methodology in other water basins around the world.

Case Study Area: Murray-Darling Basin

The MDB is located in southeastern Australia (see figure 1), and includes parts of the states of Queensland, New South Wales (NSW), Victoria (VIC), South Australia (SA), and all of the Australian Capital Territory. The MDB has the largest amount of irrigated agricultural land in Australia and uses more than half of the irrigation water applied nationally. The primary uses of irrigation water in the MDB are the production of cotton, pasture for grazing, other cereals for grain or seed, and fruit (ABS 2013).

Most water trade occurs in the southern MDB water market, which is hydrologically linked across states (this means water can be transferred from one state to another) and constrained by a variety of defined trading rules, legislation, and water plans.[2] Irrigators in the MDB can trade two types of water: *a*)

[1] Land and water were initially unbundled in Australia, state by state between the early 1990s and early 2000s. Water rights were unbundled in the 2000s, which resulted in the water license being split into four categories: (i) an access right to receive seasonal allocations; (ii) a volumetric seasonal allocation credited to an allocation account; (iii) a water use right that allows the holder to extract the allocation and put it to a defined use; and (iv) a delivery capacity right which allows for the delivery of allocations. All of these (except the water use right) can be traded separately. There are two main water markets in Australia: a) trade of water entitlements (permanent water access right of (i) above); and b) trade of water allocations (known as temporary seasonal trade in Australia or as lease trade in other country jurisdictions, and is the (ii) above) (NWC 2013). To irrigate, a farmer needs an allocation (from own water access right or bought from the allocation market), a water use right to extract the allocation, and a delivery capacity right, but does not need any access rights because they can buy temporary allocation water (ACCC 2010). Many irrigators who choose to sell all their water access rights keep their right to have water delivered (Wheeler and Cheesman 2013). Irrigators who operate within an irrigation district are known as district irrigators, as compared to a private irrigator, who are responsible for all their own infrastructure and pumping surface water direct from a river (or a groundwater bore).

[2] For more history of water reform in Australia, see NWC (2011a).

Figure 1. Murray-Darling Basin in Australia

Source: http://www.abc.net.au/site-archive/rural/murraydarling/map-large.png.

water entitlements that can be high security (HS, in NSW, Victoria, and SA), general security (GS, mainly in NSW), or low security (LS, mainly in Victoria); and *b*) water allocations for seasonal temporary water. Trading on the water market is now fairly common: over 30% of seasonal water and 10% of water entitlements are traded in the southern MDB (NWC 2011b). Wheeler et al. (2014) estimated that at least 55% of irrigators have traded temporary water and 25% permanent water since official southern MDB water trades began. Trade is also growing in other non-MDB areas and in alternative water market products such as groundwater, unregulated seasonal water, options, and forward contracts.

At the beginning of each growing season (usually July or August), the local water authority announces an initial opening allocation of water supply. The initial allocation is a percentage of an irrigator's full entitlement and is based on water availability in storage areas and predicted rainfall in catchment areas. Allocations are progressively revised during the season as, or if, more water becomes available until final allocations are known, normally by February.[3]

[3] Table A.1 in the supplementary online appendix illustrates how end-of-season allocation levels have differed across securities, regions, and years. Table A.1 shows that prior to the 2000s, it was common for HS entitlement owners to receive their full allocations. This situation changed in the drought years of the mid 2000s. The last row of Table A.1 specifies the long-term average annual yield (LTAAY) attached to a particular water entitlement security in a particular region. These figures show that on average, LS entitlement owners are only expected to receive 100% of their water entitlements in 24–35 out of 100 years, GS entitlement owners can expect full entitlements in 64–81 years, and HS owners in 90–95 out of 100 years.

From 2000–2009, the MDB experienced a period of lower than average rainfall (known as the Millennium drought), followed by rainfall well above the long-term average in 2009–10. A large number of environmental water assets were under threat during this period of drought, which prompted a significant change in water policy, with the main objective being to reallocate water from consumptive to environmental use. The Basin Plan set a limit of 2,750 giga-liter (GL) for water recovery by 2019, representing 20% in current diversion limits for surface water at the Basin scale. One of the policies put in place was the Restoring the Balance (RtB) program that was implemented under the Australian Government's national *Water for the Future* program (DoE 2014). The Australian Commonwealth initially committed AUD $3.1 billion to the RtB program between 2007-08 and 2016-17, to buy back water entitlements from willing water holders. Additional funding of up to AUD $310 million per annum from 2014–15 was pledged to bridge any remaining gap of required water to be returned to the environment under the final MDB Plan.

Willing water sellers offer non-binding expressions of interest to the federal government, with offers assessed on the basis of "value for money" (e.g., taking into consideration the securing of a license, area, price, and volume offered). The buy-back of water entitlements from irrigators is generally accepted as being the most effective and efficient way to recover water for the environment in comparison to other strategies such as upgrading irrigation on- and off-farm infrastructure (Crase, O'Keefe, and Kinoshota 2012). Considerable research explores the implications of selling water entitlements in the Australian irrigation sector. Wheeler and Cheesman (2013) estimated that by the start of 2012, 20% of the irrigator population in the MDB had sold permanent water to the Australian Commonwealth. Of the irrigators who had sold water, 60% had sold part of their water entitlements and were still farming, 30% had sold all of their water and had exited farming, and 10% had sold all of their water and were still farming. It was also found that 94% of the irrigators who stayed farming after selling water kept their water delivery entitlements (Wheeler and Cheesman 2013).

Price Elasticity Literature Review

To estimate the demand for irrigation water, it is necessary to obtain an estimate of the marginal value (such as estimating price elasticities) that farmers place on irrigation water. Elasticity estimates are sensitive to the method used to estimate them, depending on if they are econometric studies, mathematical programming, or field studies. Irrigation water demand elasticities are more elastic than residential water demand elasticities, as shown by econometric and mathematical modeling (Scheierling, Loomis, and Young 2006). Most of the literature on irrigator water values tends to be derived from programming models (e.g., Appels, Douglas, and Dwyer 2004; Howitt, Watson, and Adams 1980), and has concentrated upon temporary water demand price elasticity rather than water entitlement demand price elasticity. In addition, the lack of information on individuals' explicit demand for water has meant that most estimates of elasticity have only considered average prices paid (e.g., Schoengold, Sunding, and Moreno 2006). Scheierling, Loomis, and Young (2006) reviewed 24 studies of price elasticity of demand for temporary irrigation water and report estimates ranging from –0.001 to –1.97, with a mean of –0.48. Schoengold, Sunding, and Moreno (2006) decomposed price elasticity into the direct effect of water management and the indirect effect of water price on choice of output and irrigation technology, and reported an elasticity estimate of –0.79.

Consistent with international findings, estimates of Australian price elasticities based on mathematical programming find the demand for seasonal irrigation water to be very inelastic at low prices (Jayasuriya, Crean, and Hannah 2001). From an analysis of large-scale farm survey information for a variety of agricultural industries, Bell et al. (2007) report water demand elasticities from –0.8 to –1.9. Broadacre (larger scale crop) industries were more responsive to water prices than horticultural industries. Using water market trade data for the Goulburn Murray Irrigated District in Australia, Wheeler et al. (2008b) estimated price elasticities using *a*) bid demand and supply data (offers for water, not actual prices paid or received) for seasonal water from 2001 to 2007, and *b*) actual prices paid from 1997 to 2007. These authors found a bid price elasticity of demand of –1.51, and a bid price elasticity of supply of 0.89 for the period 2001 to 2007; while using actual prices paid, the study found a short-run demand elasticity of −0.52, which was very similar to that found in Scheierling, Loomis, and Young (2006).

In addition, using demand and supply bids and offer curves for water allocations, Brooks and Harris (2008) estimated an average demand elasticity at −3.20, and an average supply elasticity at 3.50 for the Greater Goulburn trading area. Wheeler et al. (2008a) is the only identified study that has attempted to estimate the price elasticity of permanent water entitlements, and found that the lack of available trading information resulted in a statistically insignificant price coefficient. One of the issues these authors encountered is the endogenous nature of prices and quantity demanded, especially in time-series models (e.g., Wheeler et al. 2008b) that need to be controlled for and corrected.

In terms of using other methods to value water, there is a growing number of stated preference studies: Bakopoulou, Polyzos, and Kungolos (2010) in Greece; Chandrasekaran, Devarajulu, and Kuppannan (2009) in southern India; Calatrava and Sayadi (2005) in Spain; and Salman and Al-Karablieh (2004) in Jordan. Although a wide variety of choice experiment studies indirectly feature irrigation, they do not derive marginal values of irrigation water (e.g., Barkmann et al. 2008; Hope 2006). Exceptions to this include Rigby, Alcon, and Burton (2010) in southern Spain; Kunimitsu (2006) in Japan; and Crase, Dollery, and Lockwood (2002) in Australia.

In summary, although there has been considerable research on temporary water demand, there have been no studies that we are aware of that have sought to estimate the price elasticity of permanent water demand *and* supply. Our study was designed to overcome these statistical issues by designing an experiment to collect a range of offer and supply bids for water entitlements by all surveyed farmers across the MDB. This allows us to: *a*) collect a significant number of water entitlement bid and offer observations and link these to other farm and farmer information; and *b*) avoid endogeneity problems that characterize aggregate time-series modeling on water prices with prices and quantities traded simultaneously determined in the water market.

Methodology

A survey was designed to collect how much water entitlements individual irrigators would buy and sell in response to different prices. A variety of methods to collect these stated preferences were first tried in exploratory research (e.g., using a choice experiment framework) before settling on directly eliciting responses as a form of contingent behavior. Data for the empirical analysis were collected using a mailed survey to irrigators in 2011, which was augmented through links to individual irrigator information in an existing 2010 dataset, reported in Wheeler et al. (2012). The irrigators participated in a telephone survey the previous year, with the information collected that year supplementing the mail-out survey results. The mail-out survey consisted of a variety of questions on water trading, farm production, and general water and rural issues in the MDB.[4] The design was informed by focus groups with randomly sampled irrigators in SA and Victoria, and from in-depth pre-test interviews with individual irrigators across the MDB. After two mail reminders and personal phone calls to those who did not respond to the final mail-out, the response rate was 63% (after removing those who had left farming), resulting in a sample size of 535 irrigators.[5]

Contingent Behavior Approach

We chose a contingent behavior approach that employed a matching exercise between price demanded/offered and volume offered/demanded for different types of water entitlements. The contingent behavior approach is frequently used in studies valuing environmental or recreational goods (e.g., Adamowicz et. al. 1997; Alberini, Zanatta, and Rosato 2007; Haener, Boxall, and Adamowicz 2001). Krueger and Kuziemko (2013) recently used a similar approach

[4] A copy of the survey is included in the supplementary online appendix for interested readers.

[5] Although a response rate of 63% compares very favorably to other mail-out surveys in the published literature, non-response is a serious issue that undermines statistical results if non-response is not random. A comparison was made between all respondents (e.g., the telephone survey dataset and the mail-out survey dataset) and other measures of the irrigator population in terms of state distribution, age, irrigated area, and water entitlement ownership. The comparison reveals that the main characteristics of the respondents are very similar to the irrigator population; hence, the chances of non-response bias are reduced. Please refer to the supplementary online appendix for further details.

to study the demand for a private market good (health insurance) among uninsured Americans. Water entitlements are a market good in Australia, hence trade is "familiar" to respondents. Irrigators were asked the following question:

"We would now like you to think about different high security and low/general security permanent water entitlement prices in your region and your participation in the water market today. Below we will present you with a range of $/ML. For each price we would like you to indicate how many ML of each type of permanent water entitlements you would buy today [in 2010–11][6] *for your farm (or do nothing)."*

An example was provided in the survey (see figures A.1 and A.2 in the supplementary online appendix). The irrigators were presented with two lists of ten prices on a payment card (one column was for HS and one column was for GS/LS water entitlements) and asked to fill in how much (e.g., in mega-liter; ML) of each type of entitlement they would buy at each corresponding price. Respondents were then asked the same type of question, but for selling water entitlements instead. Irrigators were asked to only complete the selling column relevant for them for water security ownership.[7] This information gave us a maximum of 5,350 total observations, although not every observation was used for elasticity estimates due to missing values and the fact that some irrigators did not own any high, general, or low security water entitlements.

It should be noted that there are a number of potential issues[8] with the payment card method in contingent behavior studies, as discussed in the literature (e.g., Thayer 1981; Cameron and Huppert 1989; Rowe, Schulze, and Breffle 1996; Carson and Groves 2007; Krueger and Kuziemko 2013; Carson and Czajkowski 2014). Since our approach has similarities to payment card methods, it is possible that some of the challenges with payment cards may apply. These challenges are often due to the fact that the approach is commonly used with public environmental goods where respondents have limited information about the qualities of the good and limited or no experience with the price of such goods. This is not the situation in our study, as irrigators have had decades of exposure to water markets.

Revealed Trade Data

For the purpose of comparing stated and revealed water trade preferences, volumes and prices of actual transactions of all past water entitlement trade were also collected. For the purpose of our econometric analysis, we focused solely on the water entitlements traded by respondents in the past two years (2010 and 2011). These two years were both non-drought years, with most receiving their full water allocation (see table A.1 in the supplementary online appendix). There were 13 actual purchases and 51 sales of HS water entitlements in our sample of 535 irrigators. The 13 "buy" observations provided too little information for modeling the impact of price on volume purchased, hence it was only possible to combine revealed sale observations with the stated sale observations for modeling the impact of water price on sale volume. For respondents who did not trade any water entitlements within the past two years, a volume of zero and a price consisting of the mean regional price in the respective year was entered as their revealed trade data observations (RP; hence, all respondents had at least two RP observations examined for analysis).[9] These no-trade observations

[6] Because there can be quite lengthy transfer times associated with permanent water sales, it is very possible that the water cannot be used until the following season. Trading water entitlements is usually associated with long-term planning for the farm, rather than short-term needs in the current season.

[7] This was verified from entries in the survey.

[8] Mitchell and Carson (1981) first proposed a payment card approach, which performs well in a variety of settings and is the only non-discrete choice experiment format currently receiving widespread use. A payment card approach presents choices to the respondents at one time, which does not require the respondents to exert effort to formulate the matching response and eliminates anchoring effects (Carson and Czajkowski 2014). Range and centering biases may also be issues for the payment card approach in contingent behavior studies. Rowe, Schulze, and Breffle (1996) tested for these biases using versions of the payment card that had different ranges and center values, and did not find evidence for bias except when the payment card truncates or does not present the upper end of the value distribution that respondents may desire to select. It is important to note that our study does not use a traditional payment card approach, as we list prices and ask respondents to match quantities. Our range of choices is from AUD $500–$5,000 /ML of HS water, which covered almost all the desired and plausible values of water from observed market transactions at the time, for both sellers and buyers. Hence, we believe range and centering biases are not likely to be present in our study.

[9] For a robustness check, an anonymous referee suggested using the market's maximum regional price in the respective year for respondents who did not trade any water entitlements. Because the maximum price was often not available for all areas, we used the entitlement price at the 75 percentile, which is reported on the DoE webpage (http://www.environment.gov.au/topics/water/rural-water/restoring-balance-murray-darling-basin/

Table 1. Characteristics of Irrigators Purchasing/Selling HS Water Entitlements (Stated Preference Data)

Price (AUD $/ML)	Buy (%)[a]	Mean buy volume (ML)	Sell (%)[a]	Mean sell volume (ML)	Sell all water (%)[a]	Average proportion of HS water offered for sale (%)
500	49	447	0.0	0	0	0
1000	32	319	0.2	10	0.2	0
1500	17	263	1	71	1	1
2000	5	133	11	128	2	6
2500	2	120	24	158	4	11
3000	0.4	17	37	222	8	20
3500	0.2	25	43	222	10	25
4000	0.2	25	52	241	13	31
4500	0.2	20	54	244	14	33
5000	0.2	20	71	286	26	50

Note: Superscript [a]denotes that the percentage figures for buy and for sale are based on the total sample of 535 respondents, and all the 418 irrigators who own any HS water entitlements, respectively.

indicate that the price was not high enough to induce those sellers to enter the water entitlement market in those years. Since the revealed trade data are individual observations, individual volume will be too small to influence the market price and hence price is still considered as exogenous in the equation with volume as the dependent variable.

Combining the revealed and stated trade data allowed us to examine whether the hypothetical volume to be sold was under- or overstated by irrigators under the same circumstances. However, it should be noted that even 51 revealed sale records offer relatively little information on the variation of volume and they only accounted for 5% of the total revealed sale observations (1,070 over the two years). Therefore, the results regarding the revealed sale data should be treated with caution.

An alternative for comparing the stated and revealed water sale preferences is the *ex post* statistical calibration method (e.g., Fox et al. 1998; List and Shogren 1998; 2002; Bernheim et al. 2013). *Ex post* calibration seeks to establish a statistical relationship between stated and revealed preferences and uses the former as a predictor of the latter. This option is explored further below.

market-price-information). This sensitivity check of the elasticity estimates was very close to the mean price results, hence we just report the mean price results.

Overview and Sensitivity Testing of the Stated Preference Data

The consistency of the stated preference (SP) data was examined to ensure that our individuals responded to price levels in a manner consistent with theory. Responses to price levels should resemble the pattern shown in table A.2 in the supplementary online appendix, namely, irrigators could either buy or sell zero water entitlements at all of the ten price levels specified in the survey, but once they buy or sell any volume, the law of demand/supply must apply. Only one irrigator's purchase response was found to be non-monotonic.[10] There were a further five irrigators who indicated they would both buy and sell at the same price level. The very small number of inconsistent responses suggests evidence of valid response to the instrument.[11]

Tables 1 and 2 present the initial results on irrigators' buying and selling responses to prices. Almost half (49%) of the irrigators who answered our survey in 2011–12 stated they would buy some HS water entitlements if the price was AUD $500/ML. When the price increased to AUD $3,000/ML, there were only two irrigators who would buy any HS water, and only one irrigator would

[10] The irrigator indicated a purchase of 1,000 ML of HS water at the price of AUD $500/ML; 2,000 ML at the price of $1,000/ML; 50 ML at the price of $1,500/ML, and 0 ML for higher prices.

[11] Sensitivity testing was conducted by dropping these individuals from the analysis, and given that the results did not change, those individuals were included so as to maximize the number of observations.

Table 2. Characteristics of Irrigators Purchasing/Selling LS and GS Water Entitlements (Stated Preference Data)

	Victoria LS				NSW GS			
Price (AUD $/ML)	Buy (%)[a]	Mean buy volume (ML)	Sell (%)[a]	Mean sell volume	Buy (%)[b]	Mean buy volume	Sell (%)[b]	Mean sell volume (ML)
300	6	293	2	119	22	986	1	40
600	2	88	4	161	14	785	1	45
900	1	73	5	183	05	1381	11	1020
1200	0.4	10	6	187	01	10000	21	1217
1500	0.4	10	10	632	0	0	31	1146
1800	0.4	10	12	594	0	0	41	1081
2100	0.4	4	16	467	0	0	46	1068
2400	0	0	18	423	0	0	47	1168
2700	0	0	19	416	0	0	47	1171
3000	0	0	28	328	0	0	54	1288

Notes: Superscript [a]denotes that the percentage figures for purchase and sale of LS water entitlements are based on the total Victorian sample of 205, and of these, those who own any LS water (146). Superscript [b]denotes that the percentage figures for purchase and sale of GS water is based on all the total NSW sample of 176, and those NSW irrigators who own GS water (140).

buy if the price further increased to AUD $3,500/ML and beyond. On the selling side, no one would sell any HS water at the price of AUD $500/ML. Only one irrigator would sell if the price increased to AUD $1,000/ML. When the price was at AUD $4,000/ML, more than half (52%) of the irrigators would sell some HS water. Due to the small number of irrigators who would buy at high prices and sell at low prices, price levels above (and including) AUD $3,000/ML were excluded from our purchasing volume models; while price levels below (and including) AUD $1,000/ML were excluded in the volume selling models.[12] In addition, table 1 also suggests that only 26% of irrigators would sell all their HS water entitlements at the maximum price specified in the survey, AUD $5,000, and the average proportion of HS water offered for sale is 50%, which is substantial. At the prevailing HS water market price during 2010–11 (below AUD $3,000), less than 10% of irrigators would be willing to sell all their water.

Few irrigators would buy any low reliability water entitlements at the prices specified in the SP data, even at the lowest price of AUD $300/ML. Even when the price increased to levels well above the existing current market price for low reliability water entitlements, there were still not a large proportion of irrigators selling. The supply side for low reliability water entitlements was as weak as the demand side.

No irrigators would buy any GS water entitlements if the price reached AUD $1,500 and beyond. On the supply side, only when the price reaches AUD $900/ML are there significantly more irrigators willing to sell their GS water.

Regression Models and Results

The dependent variable in each of our models includes a large number of zero observations and thus was a continuous random variable over strictly positive values. Ordinary Least Squares was not used in our analyses as it would fail to account for the qualitative difference between the zero and non-zero observations. The tobit model (Tobin 1958) is a standard method to cope with the problem of zero observations and is often referred to as a censored regression model.[13] However, since multiple responses from each irrigator are observed,

[12] If all the price points were included, the panel tobit model does not converge due to a lack of variation of volume above AUD $2,500/ML in the purchase model and below $1,500/ML in the sale model.

[13] The positive volumes to be bought or sold could be considered as outcomes after a first step, where irrigators decide whether to buy or sell. Under this two-step decision making assumption, the Heckman two equation sample selection model would be appropriate. However, in the context of our SP exercise, irrigators are likely to make the trade and volume decisions simultaneously and thus the same set of independent variables would influence whether an irrigator trades and how much to trade. The tobit model is regarded as more appropriate in this case. Nevertheless, we employed the Heckman model as a sensitivity check and found no sample selection bias in either the demand or supply equation.

Table 3. Descriptive Statistics

	Buy Volume Model (2)[a]				Sell Volume Model (6)[b]			
	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Buy water volume (1000 ML)	0.08	0.48	0	10	–	–	–	–
Sell water volume (1000 ML)	–	–	–	–	0.07	0.24	0	8
Water Entitlement Price (AUD$/in 1000 ML)	1.50	0.71	0.5	2.5	–	–	–	–
Water Entitlement Price_revealed (AUD$/in 1000 ML)[c]	–	–	–	–	0.43	0.82	0	3.9
Water Entitlement Price_stated (AUD$/in 1000 ML)[d]	–	–	–	–	2.54	1.68	0	5
Age (years)	55.27	10.94	24	83	55.44	10.91	23	85
Low education dummy (1 = year 10 and below, 0 = otherwise)	0.14	0.35	0	1	0.15	0.36	0	1
Total HS water entitlement (in 1000 ML)	0.31	0.86	0	14.5	0.38	0.91	0	14.5
Carry-over volume in 2011 (in 1000 ML)	0.31	0.59	0	7.1	0.23	0.53	0	7.1
Irrigated area (in 1000 ha)	0.17	0.34	0	4	0.13	0.28	0	4
Farm net income (AUD$ in 1000)	35.78	36.54	0	100	33.28	34.72	0	100
% of irrigated area with horticulture	28.76	42.71	0	100	34.38	44.84	0	100
% of irrigated area with dairy	20.98	36.23	0	100	22.47	37.08	0	100
% of irrigated area with broadacre	32.25	42.47	0	100	25.34	38.97	0	100
Private diverter (1 = if irrigator is a private diverter, 0 = irrigation district)	0.13	0.34	0	1	0.13	0.33	0	1
VIC (1 = Victoria, 0 = otherwise)	0.38	0.49	0	1	0.46	0.50	0	1
SA (1 = South Australia, 0 = otherwise)	0.29	0.45	0	1	0.34	0.47	0	1

Notes: Superscript [a]indicates model (2) in table 4; [b]indicates model (6) in table 4; [c]indicates price and RP observation dummy (1 if the observation is RP and 0 otherwise) interaction; [d]indicates price and SP dummy (1 if the observation is SP data and 0 otherwise) interaction.

we employed a random effects panel tobit model (Greene 2008).[14]

Price and other variables that are hypothesized to impact the demand and supply of water entitlements are gathered in the vector of independent variables. Other independent variables included a selected range of irrigator characteristics such as age, education, state of residence, being a private diverter, water entitlement ownership, irrigated area size, net farm income, type of agricultural industry, and water carry-over from the previous year. Table 3 provides descriptive statistics. Note that price is the only independent variable that varies both across irrigators and panels, while all other independent variables vary across irrigators only. Although there has been a lack of studies estimating the price elasticity of water entitlements, these independent variables have been found important in influencing water entitlement trade choices in general (Wheeler et al. 2008a; 2010; 2012). Six dependent variables were investigated: *HS water entitlement volume sold; HS water bought;*

[14] As a robustness check, we also used a pooled tobit model with clustered standard errors at the individual irrigator level to account for the fact that each irrigator provided multiple price-volume observations. The results do not differ from those of the panel tobit models, and are made available in table A.5 in the supplementary online appendix.

Table 4. Tobit Estimation Results for Modeling HS Water Entitlement Trade (Linear-Linear)

	Stated preference (SP) data				SP and Revealed Preference (RP)	
	Buy volume		Sell volume		Sell volume	
	(1)	(2)	(3)	(4)	(5)	(6)
Water price	−1.06***	−1.06***	0.22***	0.22***		
Price_stated					0.22***	0.22***
Price_revealed					0.13***	0.15***
Age		−0.02***		−0.004*		−0.004**
Low education		−0.31*		−0.11*		−0.11*
Total HS water entitlement		0.01		0.10***		0.08***
Carry-over volume		0.08		0.12***		0.11***
Irrigated area		0.38**		0.20**		0.19***
Farm net income		0.003**		0.001*		0.001***
% horticulture		0.001		0.0002		−0.0001
% dairy		0.002		−0.0003		−0.001
% broadacre		0.003**		−0.001		−0.001**
Private diverter		0.32**		0.06		0.04
VIC[a]		0.30**		0.33***		0.37***
SA		0.13		0.26***		0.31***
constant	0.17**	0.58*	−1.02***	−1.12***	−1.03***	−1.12***
Wald Chi-2	421***	453***	901***	929***	1086***	1104***
Bayesian Information Criterion	2373	2349	1958	1897	2484	2351
Likelihood-ratio test for the panel-level variance component equal to zero	508***	403***	1435***	996***	1247***	866***
Observations	2675	2535	3344	3168	4299	4055
Uncensored obs.	563	558	1220	1184	1271	1234

Notes: Superscript [a]indicates the reference state is NSW; $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$ indicate significance at the 10%, 5%, and 1% levels, respectively.

GS water volume sold; GS water bought; LS water volume sold; and LS water volume bought.

Results on HS Water Entitlements

The results of the panel tobit random effects models for HS water entitlements are presented in tables 4 (linear-linear form) and 5 (linear-log).[15] The likelihood-ratio (LR) test for the panel-level variance component equal to zero was rejected at the 1% significance level, suggesting that the data are more appropriately fit by a panel rather than a pooled model.[16] In each table, models (1) and (3) are the impact of price only on demand and supply, respectively. Models (2) and (4) are the models for demand and supply with a range of other independent variables, and the remaining models are for supply only, including RP and SP price data only (model 5), and RP/SP data with a full set of other variables (model 6). The independent variables in models (2), (4), and (6) are not significantly correlated. The highly significant coefficient estimates of water price are robust with and without the inclusion of other covariates, suggesting that price is uncorrelated with other covariates, as expected since price was exogenously assigned. Higher prices are associated with lower purchase volumes and higher sale volumes. When using combined SP and RP data,

[15] There was no prior expectation on the appropriate functional form used to model volume and price; hence, we undertook sensitivity analysis by modeling a variety of specifications (though it was not possible to test log-log as we could not take logarithms of a dependent variable that contains a large amount of zero values). Given the varying model statistics for demand and supply, we decided to compare two functional forms: linear-linear and linear-log.

[16] The random-effects model was calculated using quadrature, which is an approximation and its accuracy partially depends on the number of integration points used. When the choice of quadrature points does not significantly affect the outcome, the coefficients should not change by more than a relative difference of 0.01%, and hence one can confidently interpret the results (StataCorp 2011).

Table 5. Tobit Estimation Results for Modeling HS Water Entitlement Trade (Linear-Log)

	Stated preference (SP) data				SP and RP	
	Buy volume		Sell volume		Sell volume	
	(1)	(2)	(3)	(4)	(5)	(6)
ln_water price[a]	−1.08***	−0.97***	0.74***	0.74***		
ln_price_stated[b]					0.56***	0.55***
ln_price_revealed[c]					0.54***	0.53***
Age		−0.01***		−0.004*		−0.004**
Low education		−0.31***		−0.11*		−0.11*
Total HS water entitlement		0.02		0.10***		0.08***
Carry-over volume		0.09		0.12***		0.10***
Irrigated area		0.35***		0.20**		0.18***
Farm net income		0.003***		0.001*		0.001***
% horticulture		0.002		0.0002		−0.0001
% dairy		0.002*		−0.0003		−0.0006
% broadacre		0.003***		−0.001		−0.001**
Private diverter		0.31***		0.06		0.04
VIC[d]		0.24***		0.33***		0.35***
SA		0.10		0.26***		0.30***
constant	6.40***	6.07***	−6.24***	−6.32***	−4.81***	−4.84***
Wald Chi-2	433***	502***	882***	916***	942***	971***
Bayesian Information Criterion	2430	2580	1887	1827	2674	2539
Likelihood-ratio test for the panel-level variance component equal to zero	489***	212***	1459***	1016***	1149***	788***
Observations	2675	2535	3344	3168	4299	4055
Uncensored obs.	563	558	1220	1184	1271	1234

Notes: Superscript [a]indicates logarithm of the price of HS water; [b]indicates ln_price and SP dummy (1 if the observation is SP data; 0 otherwise) interaction; [c]indicates ln_price and RP observation dummy (1 if the observation is RP; 0 otherwise) interaction; [d]indicates that the reference state is NSW; $p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$ indicate significance at the 10%, 5%, and 1% levels, respectively.

we can only model the impact of revealed sale on volume through an intercept shift dummy variable, or include an interaction term between this dummy and price. Ideally, both the intercept dummy and price interaction need to be included and tested for significance, but they are highly correlated (hence are not statistically significant if included together). The results suggest that the marginal effect of price is smaller for sale volumes in the RP data than the SP data. The smaller effect of price in the RP data might arise from the smaller price range of RP data, making it unlikely to observe a large response of volume on price. However, this difference should be treated with caution since we have not controlled for RP trade as an intercept.

In terms of choice of functional form, both linear-linear and linear-log specifications provided highly significant coefficient estimates for price and exhibited a good overall fit. The BIC (Bayesian Information Criterion) was used to select the "best" functional form. The linear-linear functional form was chosen for the demand model, and linear-log was chosen for the supply models.

It is interesting to observe that a few independent variables have the same positive or negative impact on both water volume bought and sold, suggesting that irrigators who trade (either buy or sell) HS water may have similar characteristics. For example, irrigators' age and low education levels are negatively associated with both volumes to buy and sell; and farm net income is positively associated with both buy and sale volumes. One key difference is that HS water ownership and carry-over volumes are only significant in the water supply model. The higher the volume of water entitlements owned by the irrigator, and the higher their carry-over volume from the previous season (which indicates surplus water factors), the higher the water volume offered for sale. The percentage of irrigated area with horticulture or dairy grazing variables is statistically insignificant, while the percentage of irrigated

Table 6. HS Water Entitlement Price Elasticities in the Southern MDB

	Linear-linear			Linear-log		
Price ($/ML)	Buy (SP)[a]	Sell (SP)[a]	Sell (RP)[a]	Buy (SP)[b]	Sell (SP)[b]	Sell (RP)[b]
1,700	−0.53 [0.02][c]	0.27 [0.01]	0.15 [0.02]	−0.32 [0.01]	0.41 [0.02]	0.35 [0.02]
1,800	−0.55 [0.02]	0.28 [0.01]	0.16 [0.02]	−0.31 [0.01]	0.41 [0.02]	0.36 [0.02]
1,900	−0.57 [0.02]	0.30 [0.01]	0.17 [0.03]	−0.31 [0.01]	0.42 [0.02]	0.36 [0.02]
2,000	−0.59 [0.02]	0.32 [0.01]	0.18 [0.03]	−0.31 [0.01]	0.42 [0.02]	0.37 [0.02]
2,100	−0.60 [0.02]	0.34 [0.01]	0.19 [0.03]	−0.30 [0.01]	0.43 [0.02]	0.37 [0.02]

Notes: Superscript [a]indicates Buy (SP) elasticity estimates are based on the regression in column (1) of table 4. Sell (SP) and Sell (RP) elasticity estimates are based on the regression in column (5) of table 4. Superscript [b]indicates Buy (SP) elasticity estimates are based on the regression in column (1) of table 5. Sell (SP) and Sell (RP) elasticity estimates are based on the regression in column (5) of table 5. Superscript [c]indicates that standard errors are estimated by the delta method and are shown in square parentheses.

area with broadacre crops is positively significant in the demand model and negatively significant in the supply model. This suggests that broadacre irrigators demand more water entitlements while supplying less, everything else being equal. This result is not surprising, as crops such as rice and cotton require large amounts of water.

The coefficient estimates of price presented previously represent the marginal effects on the latent variable y_i^* (equation 5). However, elasticity estimates of price on the conditional dependent variable $y_i \mid y_i > 0$ may be of more interest given our interest in the response of the observed positive water volume to changes in prices. Price elasticity estimates change with respect to price levels in the tobit model. Table 6 estimates price elasticity for a condensed price level range (at $100 intervals around the mean price for HS water entitlements in 2010–11; AUD $1,900/ML (NWC 2011b)) for both linear-linear and linear-log functional forms. Elasticity estimates for demand became more inelastic from the linear-log form while, for supply, they became less inelastic. Again, elasticity estimates for RP need to be treated with caution as they are based on the coefficient estimates of price_revealed and ln_price_revealed in the regression results reported in column (5) of tables 4 and 5, respectively.[17]

In addition to the price elasticities for different types of water entitlements, we report elasticity estimates for several subsamples for HS water in table 7. Due to space limits, elasticity estimates are calculated from the linear-linear functional form for demand and the linear-log form for supply. The following farm characteristics are associated with a lower price elasticity of demand for irrigators: having a low education level; being aged 55 and over; residing in NSW; having a smaller irrigated area; and having a larger area under horticultural production. Price elasticity of supply (SP) is generally more elastic than the mean for the following categories: irrigators aged 40 and younger; irrigated area being mainly in broadacre; NSW farmers; and a larger farm irrigated area.

Wheeler, Zuo, and Hughes (2014), using actual water allocation market data and farms' financial return data from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), found that the marginal impact of one additional ML of water allocation sale (from 2006/07 to 2010/11) for horticulture, broadacre, and dairy industries, respectively, was AUD $632, $465, and $219. Estimates of the cost of one more ML of water allocation purchase were $240, $125, and $81 for the horticulture, broadacre, and dairy industries, respectively. The value of foregone production (and additional production) from one unit of water sale (purchase) is clearly the highest for perennial crops and lowest for annual crops (i.e., pasture, rice, and cotton). Such results partly reflect the fact that annual producers' use of irrigation water is more flexible (in terms of substituting other inputs for water use, such as feeding cows barley instead of watering pasture, and broadacre farmers can choose to not produce and sell their water allocations) versus perennial crops that are high value and permanent

[17] We also calculated the price elasticity of supply based on a regression using RP as an intercept dummy. The elasticity estimates for both SP and RP are very close to the estimates in the "Sell (SP)" column.

Table 7. Estimates of Purchase and Sell HS Water Price Elasticities, by Irrigator and Farm Characteristics

	Buy (SP)[a]	Sell (SP)[a]	Sell (RP)[a]
All	−0.57 [0.02][b]	0.42 [0.02]	0.36 [0.02]
Education level year 10 and below	−0.46 [0.07]	0.49 [0.05]	0.49 [0.06]
Education level higher than year 10	−0.59 [0.03]	0.41 [0.02]	0.35 [0.02]
Age 40 and younger	−0.69 [0.08]	0.61 [0.06]	0.58 [0.07]
Age 55 and older	−0.53 [0.03]	0.37 [0.02]	0.30 [0.02]
Irrigated area in bottom quartile	−0.54 [0.05]	0.45 [0.04]	0.43 [0.04]
Irrigated area in top quartile	−0.67 [0.05]	0.53 [0.04]	0.49 [0.04]
% of area in horticulture is 50% or above	−0.54 [0.05]	0.35 [0.03]	0.30 [0.03]
% of area in dairy is 50% or above	−0.60 [0.05]	0.43 [0.03]	0.34 [0.03]
% of area in broadacre is 50% or above	−0.61 [0.04]	0.53 [0.04]	0.51 [0.05]
Private diverter	−0.60 [0.07]	0.46 [0.05]	0.41 [0.06]
Irrigation district diverter	−0.56 [0.03]	0.43 [0.02]	0.38 [0.02]
NSW	−0.52 [0.04]	0.52 [0.05]	—[c]
VIC	−0.67 [0.04]	0.49 [0.03]	0.43 [0.03]
SA	−0.57 [0.05]	0.35 [0.03]	0.31 [0.03]

Notes: Superscript [a]indicates that Buy (SP) elasticity estimates are based on the regression in col. (1) of table 4, estimated separately for each subsample. Sell (SP) and Sell (RP) elasticity estimates are based on the regression in column (5) of table 5, estimated separately for each subsamples. Superscript [b]indicates that standard errors are estimated by the delta method and are shown in square parentheses. Superscript [c]indicates there are no uncensored revealed trade observations in NSW.

and take time to change production systems. This also explains our experimental water entitlement results, with horticultural farmers having the lowest price elasticity of water entitlement demand and dairy and broadacre producers having higher price elasticity of supply.

Calibration of Supply for HS Water

For robustness checks, we compared the stated and revealed water sale preferences using an *ex post* statistical calibration approach. The following regression was estimated:

$$(1) \qquad Y_i^{RP} = \alpha + \beta Y_i^{SP} + \varepsilon_i$$

where Y_i^{RP} is the revealed volume of HS water sold by an irrigator at a given price level, Y_i^{SP} is the stated volume of HS water that an irrigator would sell given the same price level, α and β are parameters to be estimated, and ε_i is the classical error term (Bernheim et al. 2013). For perfect calibration, the parameter α will be zero and β will be 1, indicating that an irrigator's volume for sale from the SP survey instrument is the same as the past revealed volume sold given the same price.[18] The calibration regression was run using a database of actual sale transactions (including volumes and prices) for the period 2008 to 2011 from the *RtB* program operated by the Department of Environment (DoE). In order to have a time background similar to our SP survey, 360 sale records of HS water entitlements from this database in 2010 and 2011 were used for calibration. As our SP sample and the DoE sample consist of different irrigators, we undertook an approach to match the revealed sale volume from the DoE dataset with a stated sale volume from our SP dataset. First, we divided the SP sample into four groups based on their HS water ownership so that the first group's HS water ownership lies within the first quartile of the HS water ownership of the DoE sample, the second group within the second quartile, and so forth. This was done to ensure that the matched stated volume is from irrigators with comparable HS water ownership since, in addition to price, ownership is the most important influence that determines how much volume an irrigator is willing to sell. Second, for each transaction of the 360 DoE sale records, we identified the closest price in the SP sample. For example, if the price of a transaction in the DoE dataset is AUD $1,800/ML and the volume

[18] It should be noted that it is difficult to observe the same or similar revealed and stated volumes of water sale under the same price since irrigators have a limited supply of water entitlements and, once they sell all of their water, they are not able to state that they would sell, even at the comparable prices to the previous transactions.

is 15MLs, the closest price in the SP dataset is AUD $2,000/ML (the price points in the SP dataset are from AUD $500 to $5,000 at intervals of $500). The HS water ownership of the irrigator associated with this transaction falls in the first quartile. Under the price of AUD $2,000/ML, the average volume offered for sale by the irrigators in the first group (matched with the first quartile) of the SP sample is calculated as 33.8MLs. Hence, for this record at the price of AUD $2,000/ML, the revealed volume is 15MLs and the stated volume is 33.8MLs.

The calibration result indicates that $\hat{\beta}$ is 0.80 (SE = 0.06) and $\hat{\alpha}$ is 7.18 (SE = 10.88), with a regression R^2 of 0.28. An F-test of the null hypothesis ($\hat{\beta} = 1$ and $\hat{\alpha} = 0$ jointly) suggests that it can be rejected at the 1% significance level, suggesting that irrigators overstated the volume for sale in the SP survey: if the stated volume were 1ML, the revealed volume would be 0.8 ML (25% overstatement).

We further divided the DoE sample into two groups: those who sold part of their water entitlements (265 transaction records) and those who sold all their water (95 transaction records). For the first group, $\hat{\beta}$ is 0.78 (SE = 0.08) and $\hat{\alpha}$ is 6.73 (SE = 12.91), with a regression R^2 of 0.28. An F-test of the null hypothesis ($\hat{\beta} = 1$ and $\hat{\alpha} = 0$ jointly) still suggests that the null hypothesis can be soundly rejected. Hence, the stated volume is still an overstatement for farmers selling part of their water entitlements. For the second group, $\hat{\beta}$ is 0.87 (SE = 0.13) and $\hat{\alpha}$ is 7.10 (SE = 20.32), with a regression R^2 of 0.33. An F-test of the null hypothesis ($\hat{\beta} = 1$ and $\hat{\alpha} = 0$ jointly) suggests that the null cannot be rejected at the 10% significance level. Hence, the stated volume is not a significant overstatement of the revealed volume for farmers who sold all their water entitlements, unlike for farmers who only sold part of their water. In our sample, less than 10% of irrigators would be willing to sell all their water at the prevailing market price in 2010. This implies that most irrigators overstate the volume for sale in the SP exercise since most are only willing to sell part of their water.

Given that the calibration parameter $\hat{\beta}$ is estimated as 0.80 overall, this suggests a smaller actual price elasticity of supply. Mathematically, to derive the actual price elasticity using the calibration approach one must multiply the stated price elasticity estimated previously by 0.80. For example, at the AUD $1,900 level, the stated price elasticity of supply is 0.42 and hence the actual price elasticity after calibration is 0.34, which is even more inelastic and closer to the estimate of 0.36 from the RP data.

GS and LS Water

The results for GS (NSW) and LS (VIC) entitlements are presented in table A.3 in the supplementary online appendix. Only those models with price as the sole independent variable are presented due to space limitations, as well as this study's focus on price. Except for the supply model for GS that used a linear-log functional form, all the other models used a linear-linear model, as suggested by the BIC. The coefficient estimate on price is robust to the inclusion of other covariates; there are only 19 uncensored observations for the LS model, suggesting that few irrigators are willing to purchase LS water at the prices in our SP survey instrument. There were also a relatively small number of irrigators in NSW willing to buy GS water entitlements. On the other hand, irrigators are much more willing to sell their LS or GS water.

The mean price for GS water entitlements in the NSW Murray and Murrumbidgee irrigation areas in 2010–11 was AUD $940/ML, and the mean price for LS water in northern Victoria was AUD $155/ML (NWC 2011b). Hence, we calculated the elasticity estimates of price on the conditional dependent variable $y_i \mid y_i > 0$ for GS and LS water at five price levels around their respective means in 2010–11 (presented in table A.4 in the supplementary online appendix).

One can observe that demand is most inelastic for LS, which could be due to the fact that the price for it is so low that irrigators are irresponsive to price changes in the relevant range. Supply for HS and GS price elasticities are almost the same in their respective relevant price range, while LS supply remains extremely inelastic. Also, only Victorian farmers own LS water entitlements and the size of their water ownership is less than HS. Given the low price level and small size of ownership of LS water, it is reasonable to expect its supply to be extremely inelastic. The NSW irrigators usually hold large amounts of GS water and do receive full water allocations up to 90% of the time, which is almost the same as HS water owners. Hence, the supply for GS has the same price elasticity as for HS water, even though the price range for GS water is much lower. Further analysis suggests that the supply for GS would be less price inelastic than for HS at the HS price range.

Cost Projection of the Restoring the Balance Program

One question of policy interest that this study can inform is how much it would cost the Australian Commonwealth to purchase all the remaining water to meet the environmental targets under the RtB program. Historical information on the DoE webpage (DoE 2014) suggests that the remaining volume of LTAAY entitlements to be recovered was 1155.49 GL for the three states of NSW, VIC, and SA in the southern MDB as of December 31, 2011. This represented almost 9% of current diversions for surface water entitlements to be recovered.

As elaborated in figure C.1 in the supplementary online appendix, if all the 1155.49 GL remaining were purchased as HS water by the government,[19] our supply curve suggests a price around AUD $3,623/ML.[20] However, since the calibration indicates that irrigators are likely to overstate the amount of water for sale, a conservative estimate from the calibrated supply curve results in a price around AUD $4,154/ML, with a total cost to purchase 1155.49 GL of AUD $4.8 billion. Table 8 presents the projected cost for this under Option One.

Considering that the total budget for water buyback is up to AUD $4.03 billion, it is not feasible for the government to purchase the remaining 1155.49 GL all at once in the form of HS entitlements. One way to reduce the cost would be to also purchase general security and/or low security water entitlements,[21] under which option two in table 8 estimates a total cost of AUD $2.16 billion (details of the calculation are explained in the supplementary online appendix). Given that AUD $2.02 billion has been spent on water buyback as of December 31, 2011[22] (DoE 2011), and that the total budget for the RtB program is about AUD $4.03 billion, there was AUD $2.01 billion remaining for water buyback in MDB. Hence, our estimate of AUD $2.16 billion for the southern MDB suggests that the government needs to manage the remaining water recovery program carefully in order to keep within budget.

Table 8. Projected Cost for Securing the Remaining 1155.49 GL in LTAAY in the Southern MDB

	Option 1 Buy HS water only	Option 2 Buy HS and GS water	
	HS	HS	GS
Price (AUD$/ML)	4154	2938	919.6
Volume (GL)	1155.49	541.49	614
Cost (AUD billion)	4.80	1.59	0.57
Total cost (AUD billion)	4.80	2.16	

Our estimates are based on a scenario that all the remaining water will be acquired at one time based on irrigators' valuations in 2011. When such a huge demand by the government is present in the market at one time, and the price elasticity of supply is quite inelastic, price can rise sharply. Hence, an approach of multiple rounds of purchase tenders (e.g., buying water in a number of different tenders at different times)[23] could be more effective at reducing the prices paid.

Conclusion

Stated and revealed preference water trading data collected using a survey instrument were

[19] It should be noted that the current policy now plans for water entitlements to be purchased through 2017–18. Previous modelling by ABARES (2011) suggested that the Basin Plan would reduce the gross value of irrigated agricultural production in the Basin by 3.6% while the gross value of agricultural production of the Basin would decrease by 1.7%.

[20] The assumption is that the unit price paid by the government is the same for every irrigator and equal to the marginal cost of supplying the last unit of water by irrigators to meet the recovery requirement.

[21] It is important to note that buying LS entitlements may partially defeat the purpose of providing water for the environment in the times when water is needed the most (e.g., severe droughts). The LS entitlements deliver zero allocations in times of water scarcity, hence their benefit for environmental water is only when extra flows are needed in times of floods and larger water allocations, or when carry-over provisions exist.

[22] We chose this figure to calculate the impact on the budget as it represents the date that matches closely with our irrigator survey.

[23] The Australian government has been calling for multiple rounds of water purchasing tenders since the beginning of 2008.

used to estimate how individual irrigators in the southern MDB may buy and sell water entitlements in response to different prices, thereby allowing the development of price elasticity estimates.

There are two major contributions of the approach employed in this study to the literature. First, the methods employed allowed construction of price elasticities of water entitlement supply and demand, which are rare in the literature. The stated preference approach in concert with fusion of actual market trades overcomes the shortcomings of many existing studies of elasticities that suffer from scarce real market transaction data with limited price range and endogeneity issues.

Second, the survey instrument was validated using revealed water entitlement sale data, with the validated results suggesting that the stated preference instrument accurately predicted the revealed preference for high security water entitlement sales for irrigators who sell all their water; but overestimated (by about one-quarter) the revealed preference for irrigators who sell part of their water. Our results indicate that both demand and supply of HS water entitlements in the southern MDB are inelastic in the relevant market price range between AUD from $1,700 to $2,100/ML, while supply is relatively more inelastic than demand. For general security and low security water, the price elasticity of demand is estimated to be even more inelastic than that of HS water. The price elasticity of supply for GS water is almost the same as that of HS water, while the supply of LS water is extremely inelastic. Existing literature suggests that price elasticity of demand for water allocations in Australia ranged from −0.52 to −1.9, and price elasticity of supply for water allocations was 0.89. Our estimate for demand for high security water entitlements was around −0.57, which is at the lower end of the range obtained from the existing literature on price elasticity of demand for water allocations. Our estimate for supply for HS water entitlements was around 0.42, or half that of water allocations. The relatively irresponsive demand and supply for water entitlements to price could be explained by the fact that irrigators usually employ long-term plans to buy or sell water entitlements, whereas it is a much more flexible and temporary decision for irrigators to buy or sell seasonal water allocations.

Inelastic price elasticity of supply for water entitlements suggests that price may not be a very effective instrument to encourage irrigators to sell more water. Indeed, our simulations show that if the entire remaining water required by the Australian Commonwealth for environmental flows were acquired at once in 2011, it would have been too cost prohibitive. Our findings suggest that a multiple-tender approach across years may be a more cost-effective way of obtaining water entitlements for the environment.

When additional water entitlement trading data become available in the future, more accurate calibration of the demand schedule could be undertaken. The stated preference survey instrument could also be used to elicit price elasticity of demand and supply for annual water allocations, which would be interesting to compare with the price elasticity estimates derived by other techniques in the literature. Comparisons between water allocation and water entitlement elasticities would also be of significant policy interest. Most importantly, the consistency of our stated and revealed results provides support for the use of this methodology in water basins in other regions of the world.

Supplementary Material

Supplementary online appendix is available at http://oxfordjournals.org/our_journals/ajae/online.

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