

# SUPPLY AND DEMAND ELASTICITY OF IRRIGATION WATER – IMPLICATIONS FOR WATER MARKETS

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## **Abstract**

Water markets have become an integral part of water and property management in Australia over the last twenty years or so. Land and water rights have been separated with wide ranging consequences for many property professionals. A number of papers on PRRES conferences over the last five years have been dealing with the operations and implications of water markets and analysing water market prices and behaviour. This paper continues this line of research by looking at the elasticity of demand and supply for agricultural water. This information is essential to better understand price fluctuations and market behaviour and to make better informed decisions in water market both as a water user and as an investor.

Bid prices for the demand and supply of water in the Goulburn-Murray Irrigation District of Victoria between 2001 and 2006 are analysed to estimate monthly price elasticities. Based on bid prices, the elasticity of demand for irrigation water appears high. The price elasticity varies over the season, with low elasticities in early season, increasing to maximum elasticity mid season and then becoming inelastic towards the close of the season. Elasticity also increases considerably in higher price ranges. The traded volumes and mean monthly prices actually paid for water allocations are then analysed to investigate the factors influencing water demand and to estimate price elasticities. Using actual prices paid, water demand appears positively related to price but volume trade is more influenced by demand the previous month, rainfall and evaporation, seasonal factors, rural commodity prices and farm GDP.

**Keywords:** water markets, elasticity, water demand, water supply, water prices

## **1. Introduction**

Since 1994 Australia has promoted markets as an integral part of agricultural water management. Compared to most other countries, markets in water allocations (the right to short-term use of water) have developed to a high level of maturity. By contrast, markets for water entitlements (the long-term right to access water), as in other countries, have been more subdued as irrigators perceive water entitlements as an inherent part of the farm (Tisdell and Ward 2003). However, as ongoing policy reform in Australia removes current impediments to water trading, market activities for both water entitlements and allocations are likely to increase in the near future and more complex market instruments are therefore likely to emerge (Bjornlund and Rossini, 2007). This development will continue to have wide ranging consequences for many property professionals, a trend that started when first water markets and then the separation of land and water rights were introduced (Bjornlund and O'Callaghan, 2004). It can be expected that water entitlements will be part of the investment portfolio of property trusts and other investment vehicles. When the managers of such investments have to make ongoing sell and buy decisions in these markets, timing will be of the essence as shown by Bjornlund and Rossini (2007). Understanding irrigators' responsiveness to changes in water prices is an essential element in making such decisions.

Despite agricultural water markets being in existence for almost twenty years in Australia, there have been relatively few attempts to estimate the price elasticity of traded water allocations and entitlements or to identify the factors impacting on volumes traded in such markets. While there has been some attention given to the price elasticity of water in the international literature, most of this work have been based on economic models rather than on real time series of prices paid and volumes traded in water markets. This is mainly because of a paucity of water pricing data, 'thin' markets in many areas, and the private nature of price information. To overcome these obstacles this paper combines publicly available price and quantity data from the Goulburn-Murray Irrigation District (GMID) in Northern Victoria, with information from the major water broker in the region. The

result is a consistent time-series of prices and volumes traded in the market for agricultural water allocations in Australia's largest irrigation district.

## 2. The Study Region and Water Trading Background

The GMID is located in Northern Victoria along the River Murray (Figure 1). Irrigation within the district is mainly supplied by two major sources: the Goulburn and the Murray Rivers. Initially, trade in this region, in both the markets for water allocations and entitlements, was low (Bjornlund 2004a; Tural *et al.* 2005). To date irrigators have displayed a preference for using the allocation rather than entitlement market, probably because entitlements are still perceived as an inherent part of the farm and irrigators may be reluctant to buy water entitlements due to the uncertainty associated with the long term level of seasonal allocations yielded by these entitlements (Bjornlund 2003a; Tisdell and Ward 2003).

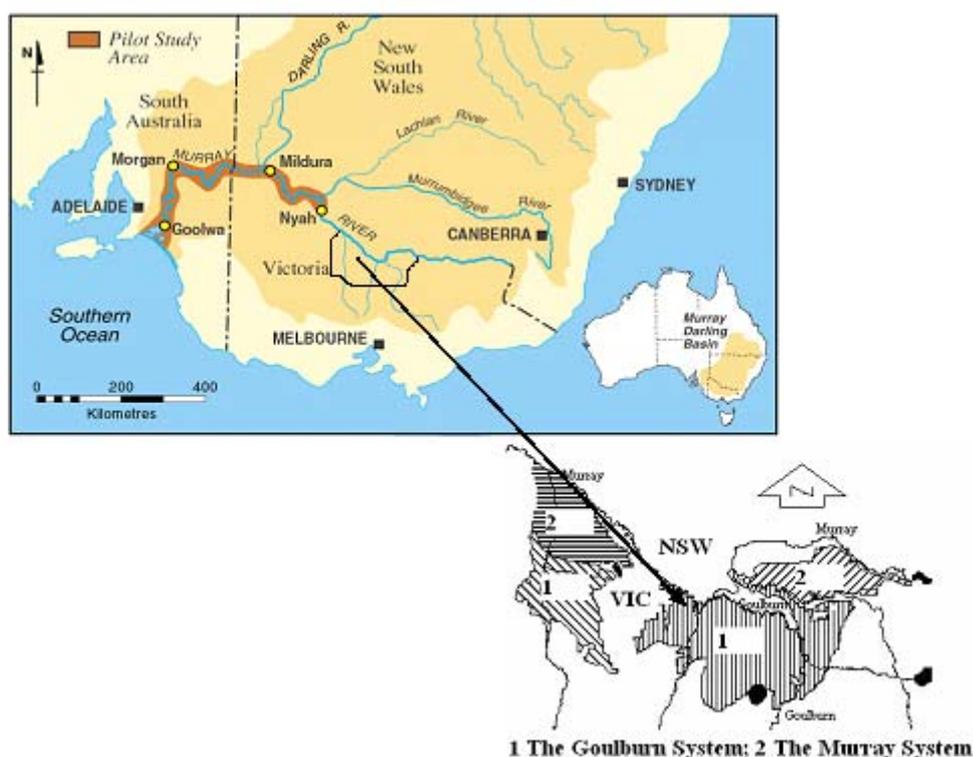


Figure 1: The Goulburn-Murray Irrigation District

By July 2004, less than one in five farm businesses within the GMID had never traded water, and in many areas the figure was less than one in ten. During the very dry seasons of 2002/03 and 2003/04, 60 per cent of all farm businesses were active in the water market (Bjornlund 2006a). Water purchased in the allocation market, as a percentage of total water use within the GMID, has increased from about 3 per cent during periods of high supply in the mid 1990s, to almost a quarter in 2002/03 (Table 1). These are clear signs of increased market adoption among water users.

Irrigators receive an opening, or partial allocation each year in August which is continually updated each month until final allocations are known, normally by February. In most years, irrigators have received their full allocation (Table 1), with the exception of 2002-03 within the Goulburn System. During the current drought year of 2006-07 opening allocations were zero per cent and by December had increased to 24 per cent within the Goulburn System. To use water beyond their allocation, irrigators can purchase water allocations from other irrigators. In general, the volume of water traded has been increasing over time.

In 1998 a weekly water exchange was introduced to ease the administrative pressure on the authority and facilitate faster and cheaper transactions. In 2003 the exchange was extended to cover all of Victoria and the Murray Region of New South Wales. These multiple exchanges were gathered

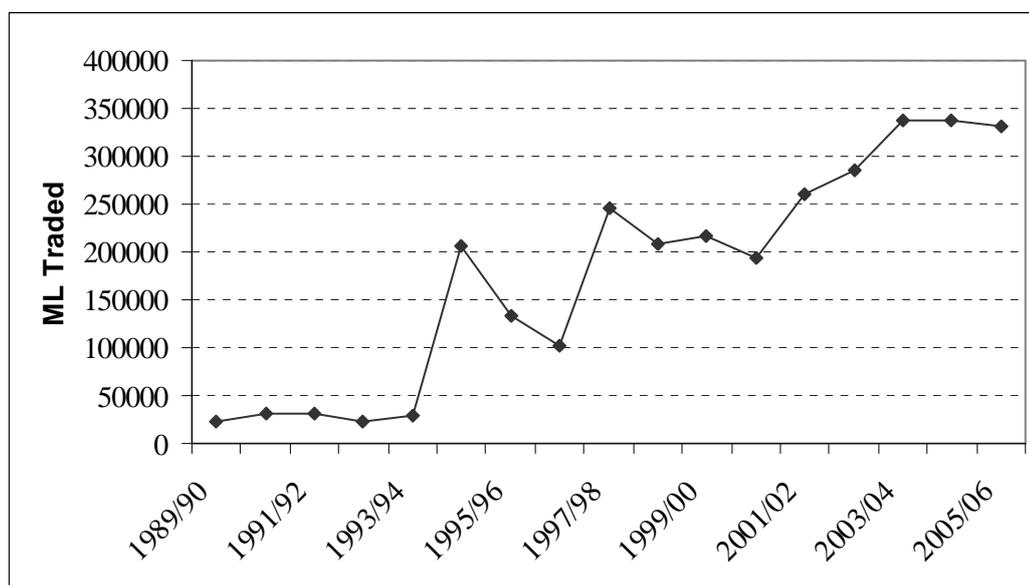
under the umbrella of WaterMove ([www.watermove.au](http://www.watermove.au)). Brennan (2006) and Bjornlund (2003a) provide more information on the Victorian water market and its operations.

**Table 1 Volume traded as percentage of water use - the Goulburn and Murray Systems**

Season	Goulburn System		Murray System	
	Allocation (%) <sup>1</sup>	% of trade <sup>2</sup>	Allocation (%) <sup>1</sup>	% of trade <sup>2</sup>
1995/96	150	7	200	3
1996/97	200	4	200	3
1997/98	120	9	130	13
1998/99	100	13	200	5
1999/00	100	14	200	8
2000/01	100	16	200	2
2001/02	100	18	200	5
2002/03	57	24	129	16
2003/04	100	16	100	18
2004/05	100	18	100	22
2005/06	100	22	144	14

<sup>1</sup> Maximum seasonal allocation; <sup>2</sup> total water trade for season as percentage of total water use  
Source: Based on Goulburn–Murray Water’s Records.

Of the many regions covered by WaterMove, this study concentrates on the largest and most active zone; the Greater Goulburn trading zone within the Northern Victoria Regulated region. The exchange facilitates transactions in a number of ‘products’ including: Temporary Water Rights / Diversion Licenses (here called water allocations), Temporary Sales, Permanent Used Water Rights / Diversion Licenses and Permanent Unused Water Rights / Diversion Licenses. This study analyses trade in the Temporary Water rights / Diversion License market, because it is the most active market. Trading typically occurs 10 months in every year (except June and July, the wettest months). Yearly data on the volumes of water allocations traded is available from 1989-90 (Figure 2), and monthly mean prices paid for water allocations are available from July 1993 (Figure 3).



**Figure 2 Volume traded in the allocation market in the GMID from 1989/90 – 2005/06**

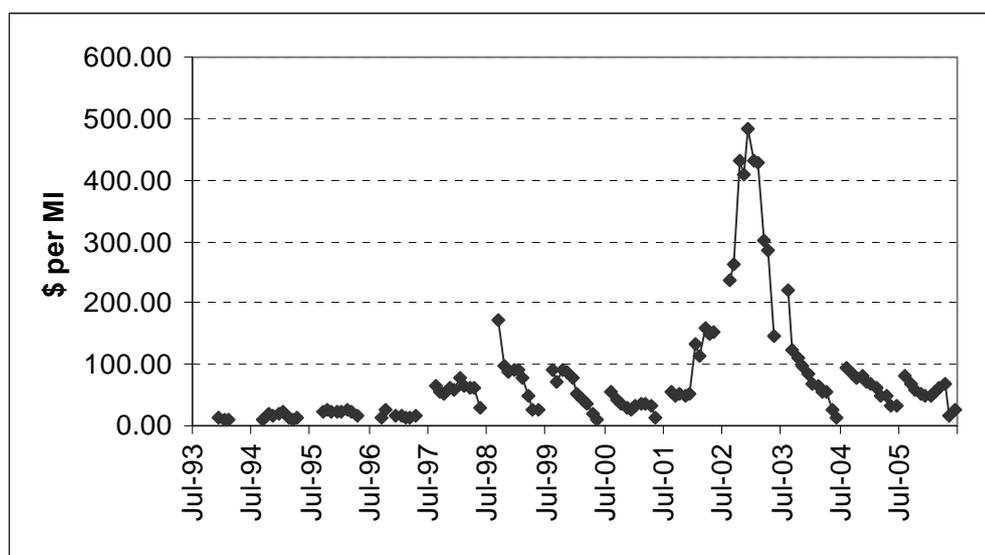
Source: Based on the records of Goulburn-Murray Water

The annual volume of water traded has increased from less than 50,000 MI in 1989 to almost 350,000 MI by 2006, a seven-fold increase (Figure 2). While the quantity of water traded has steadily increased, prices have been much more influenced by seasonal conditions, such as the drought in 2002-03. Prior to 2001-02, average monthly pool prices ranged from \$10/MI to \$100/MI (except for one month where it reached \$170/MI), and increased to \$480/MI in 2002-03, and then falling again during the seasons of 2003-04 to 2005-06 (Figure 2). Large variations are also reflected in the weekly pool price and quantity traded. For example, in 2002-03, the weekly pool price varied between \$500/MI and \$105/MI; the maximum quantity traded in a week was over 2,500 MI and the minimum under 200 MI. In contrast, in 2004-05 the weekly price ranged between \$103/MI and

\$26/MI while the quantity traded each week ranged from over 4,000 MI to only 10 MI. During the drought season of 2006/07 prices reached \$950/MI by December while the accumulated volume traded at that time exceeded any other year and the volume traded in one single exchange was 13,856 MI.

WaterMove conducts water exchanges within specified trading zones. Buyers and sellers submit their bids to buy (sell). The bids must include the amount that they are prepared to buy (sell) and the price at which they are willing to buy (sell) the water. The exchanges are held every Thursday and the rules stipulate that the buyers be stacked in descending price order with the highest bidder eligible to buy first. The sellers are stacked in ascending order, with the lowest bidder eligible to sell first. The pool price is set at the level where the maximum volume is traded while no buyer pays more than their bid and no seller receives less than their bid. The pool price is the same for all successful buyers and sellers with some buyers paying less and some sellers receiving more than their bids.

As a consequence of WaterMove's transaction procedures, consumer surplus (i.e., represented by the proxy of the difference between what the buyer bids for water and what they actually pay for it) is highest for the buyer who bids the highest price and then only pays the 'pool' price. This implies that a 'demand' curve for water constructed from the offer bids may contain spurious bids because of strategic behaviour from buyers to ensure a position on the top of the demand schedule. Such bidders are likely to know that the 'pool price' that they pay will be lower than their bid price, and that their bidding strategy will have little or no impact on the final pool price. Nevertheless, this study uses all the weekly supply and demand bids to construct bid curves for the five years from 2001-02 to 2005-06.



**Figure 3 Monthly mean prices paid for water allocations in the Greater Goulburn 1993-94 to 2005-06**  
Source: PlanRight, Tatura 1993 to 1998, Water Exchange 1998 to 2006

## 2.1 Price Elasticity Literature Review

The elasticity of demand for a product is defined as the percentage change in demand in response to a unit change in its price. Since, for a normal good, there is an inverse relationship between price and quantity demanded, the elasticity of demand is usually negative and the elasticity of supply is usually positive, as price goes up so should quantity supplied.

Elasticity estimates are sensitive to the method used to estimate them. In a recent paper, Scheierling *et al.* (2006) present a meta-analysis of 24 studies on irrigation water demand in the United States. Estimates are more elastic if they are derived from econometric studies or based on mathematical programming and less elastic if derived from models based on field experiments. Their work reveals a mean price elasticity of 0.48 and a median of 0.16 (in absolute terms), with larger elasticities in the longer run. They also reveal a large variation in the results, with elasticities ranging from 0.001 to 1.97.

This variation in results highlights the difficulties of estimating water price elasticities. Additional to differences associated with the choice of estimation methods, Scheierling *et al.* highlight that: i) studies differ in whether they assume that all other inputs (other than water) are held constant; ii) water demand is more elastic at higher prices; iii) studies vary in the range of prices and the time

frame (and hence the opportunity for irrigators to alter behaviour) they study; iv) the type of response that irrigators make to increasing prices (for example, moving to higher value crops) in itself affects the value of additional water and the shape of their demand curve; v) the mix of low, medium and high value crops covered in particular studies varies (different elasticities are associated with crop value); vi) differences in climate impact on production functions; and vii) the actual data used varies from study to study. In addition, we would highlight that not all water 'markets' are the same (with variation in the degree of regulation, utilization, acceptance and efficiency of the market) and that most price elasticity studies are based on the price that water supply authorities charge to supply water (normally heavily subsidised) and not on prices paid in water markets.

Caswell and Zilberman (1985) and Caswell *et al.* (1990) showed positive effects of increasing water price on the adoption of water conservation technology whereas Verela-Ortega *et al.* (1998) showed that such effects are related to the potential of diversification, water allocation and risk of water delivery. Others stipulate that an increase in water price may induce positive responses only in the range of prices where the demand is elastic (de Fraiture and Perry 2002) and that such price ranges often will be outside what is politically feasible (Perry 2001). For example, de Fraiture and Perry (2002) found that water demand is inelastic at low price ranges and became elastic only after a certain threshold price, suggesting that price increases in the order of five to ten times were needed to induce water saving behaviour. They suggest that there is a gap between actual price and the productive value of water. Schoengold *et al.* (2006) found that water demand is more elastic than previously thought if considering the impact of higher marginal water prices on both the choice of crop or fallowing and on the choice of irrigation technology. Gomez-Limon and Riesgo (2004) found in Spain that within even homogeneous areas in terms of soil, climate and other factors, there are significant differences among farmers' reactions to price changes due to great variability in management criteria used to plan their crop mixes.

Zekri *et al.* (2006) found price elasticity of irrigation water demand in water markets in Oman to range from -0.10 to -0.28. In Australia, given the limited number of market transactions and the lack of pricing information, most previous research has used mathematical programming models to derive price elasticities for water. This approach first estimates the value of the marginal product of water in an agricultural production system (Appels *et al.* 2004). It then estimates the optimal response of an individual to changes in the price of water under varying parameters, assuming they choose rationally. However the literature suggests that irrigators' response to pricing and other policy instruments are driven by many other factors than just financial and therefore are not always rational in an economic sense (Gomez-Limon and Riesgo 2004; Maybery *et al.* 2005; Kuehne and Bjornlund 2006; Bjornlund, 2002). All estimates of Australian price elasticities based on this approach have found the demand for irrigation water to be very inelastic at low prices, consistent with the international findings. Short run elasticity estimates range from -0.02 to -2.81, depending on the range of prices per megalitre (ML) (Pagan *et al.* 1997; Jayasuriya *et al.* 2001). For water prices below \$50/ML, demand was found to be relatively inelastic (Appels *et al.* 2004).

The lack of information on individual's explicit demand for water has meant that previous estimates of elasticity have only considered average prices paid (Moore *et al.* 1994; Nieswiadomy 1988; de Fraiture and Perry 2002; Schoengold *et al.* 2005). In this study we use both information on whole bid curves for each exchange *and* average prices paid to calculate elasticities. The only other analyses that have been conducted on the entire demand and supply bid curves are Brooks and Harris (2005) and Zaman *et al.* (2004). Brooks and Harris (2005) estimated simple weekly demand and supply price elasticities for water allocations for the Greater Goulburn, Barmah-Nyah and Hume-Barmah zones from mid-2002 to March 2005. They estimated the average demand elasticity at 3.20, and the average supply elasticity at 3.50 for the Greater Goulburn trading area (both in absolute terms). Zaman *et al.* (2004) estimated weekly price elasticities in the Goulburn-Murray for 2002-03. Both of these studies suffered from widely varying elasticity estimates because of thin trading in some weeks. Our study avoids these problems by calculating elasticities on a monthly basis and using data covering a longer time period.

### 3. Results

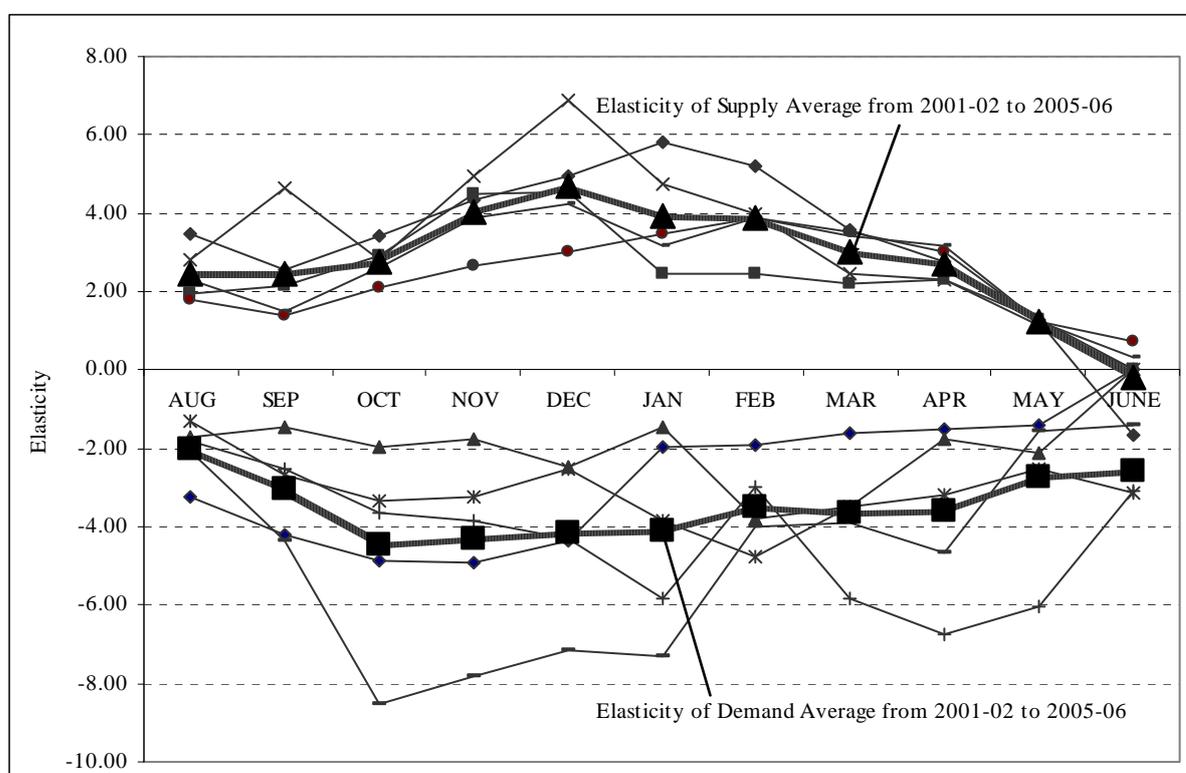
#### 3.1 Monthly Price Bid Elasticities of Demand and Supply

Firstly, monthly demand and supply price elasticities are calculated based on five years of allocation trading from July 2001 to June 2006 via simple regression analyses using non-linear (log-log) models:

$$\text{LnDML}_t = \beta_0 + \beta_1 \text{LnDPrice}_t \quad (1)$$

$$\text{LnSML}_t = \beta_0 + \beta_1 \text{LnSPrice}_t \quad (2)$$

where  $t$  is the time period, DML is the volume demanded by buyers in megalitres, SML is the volume offered by suppliers, Dprice is the dollar amount offered per MI by buyers and SPrice is the dollar amount asked for per MI by sellers. The entire set of individual offers to buy and sell a given volume at a given price is used.



**Figure 4 Monthly Demand and Supply Bid Price Elasticities in the market for Water Allocations in Greater Goulburn Region from 2001-02 to 2005-06**

One hundred and six simple demand and supply monthly regression analyses were conducted for the period. Figure 4 illustrates the monthly patterns of elasticities in each year as well as the simple average demand and supply elasticity pattern across all five years. These reveal a relatively stable seasonal pattern which to a large extent follows the decision making pattern in water markets identified through surveys (Bjornlund 2006b). As the lower panel shows, the average demand-bid price elasticity is in the elastic range through the entire season. It is lowest during the first two months while the market is dominated by more well-off and more conservative farmers buying what they need for the season. It hits a peak in October when most irrigators have committed their area under irrigation and established their water needs for the season and those irrigators initially reluctant to purchase are forced into the market as their allocation runs out. From November demand-bids slowly become less elastic until April when it generally declines sharply as irrigation stops. From this point demand is normally only driven by irrigators' need to balance their water account for the season to avoid paying a penalty of \$1,000/MI for excess use. The upper panel shows that the average supply-offer price elasticity also is in the elastic range for most of the season and also starts out lowest in the beginning of the season when the supply side is dominated by people who are selling all or a substantial part of their water each year (in effect their farming output is water). It then slowly increases as low value active irrigators consider whether they will be better off selling their water or growing a crop. Elasticity reaches its highest in December when (in most seasons) irrigators' full water allocation is known and supply is provided either by water sellers who are speculating in finding the best time to sell or irrigators being convinced by good water prices to abandon their lower valued crop. The mean elasticity then also declines until April as active irrigators sell what they do not need in order to recover unavoidable supply costs and eventually becomes inelastic.

On average, water demand-bid price elasticities are marginally more elastic than water supply-bid price elasticities. Demand-bid elasticities also fluctuate substantially more as active irrigators

adjust their trading activities during the season and from season to season in response to changing rainfall, evaporation, allocation levels and market conditions. On the other hand supply-offer elasticities fluctuate far less, especially after December, as the supply side is dominated by farmers selling all their water each year and lower-value producing farmers who make the decision to sell their water early in the season. Supply-offer elasticities therefore fluctuate most early in the season as farmers decide whether to sell or irrigate and while water sellers try to read the market and find out when it will be most profitable to sell.

The average yearly elasticities between 2001-02 and 2005-06 were also calculated (Table 2). They indicate that demand-bid elasticities were steadily increasing except in 2004/05 where an exceptional increase in elasticity was experienced; possibly due to lower prices following two years of very high prices. On the other hand, mean annual supply-offer elasticities were steady but fluctuating and inelastic. These findings are consistent with the previously discussed behaviour of active irrigators on the demand side and water sellers and lower value irrigators on the supply side.

**Table 2: Mean annual elasticities from 2001/02 to 2005/06**

	Yearly elasticities	
	Demand	Supply
2001-02	-1.07	0.00
2002-03	-1.64	0.63
2003-04	-1.77	0.22
2004-05	-2.86	0.71
2005-06	-1.87	0.97

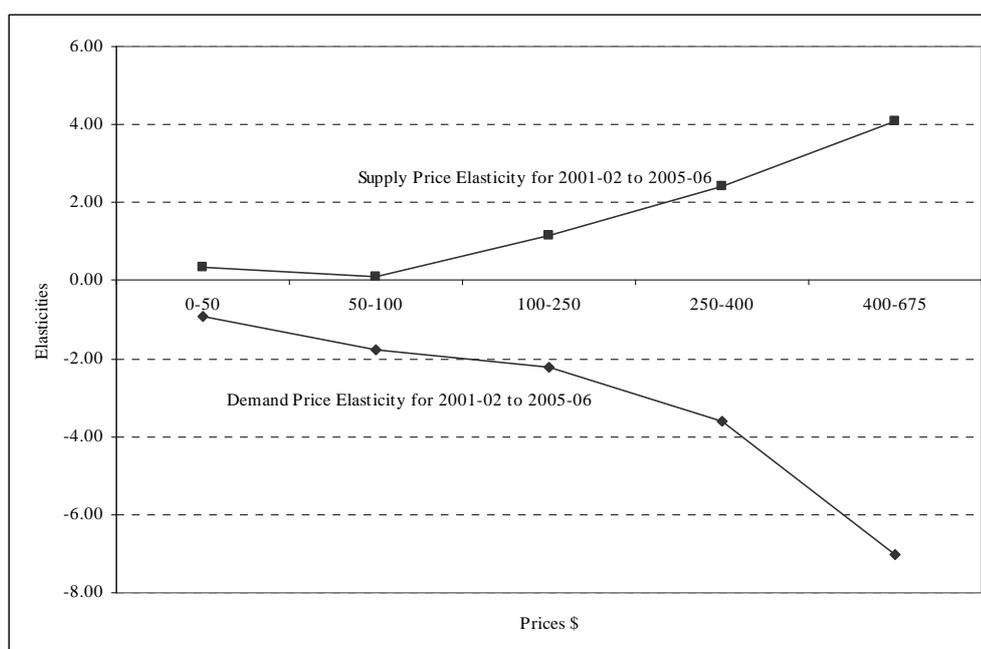
### 3.2 Price Range Bid Elasticities of Demand and Supply

To examine elasticity by price range, demand and supply price elasticities were calculated for five bid price ranges as follows:

$$\text{LnDML}_t = \beta_0 + \beta_1 \text{LnDPrice}_t + \beta_2 \text{MonthD}_t \quad (3)$$

$$\text{LnSML}_t = \beta_0 + \beta_1 \text{LnSPrice}_t + \beta_2 \text{MonthD}_t \quad (4)$$

where MonthD are monthly dummies to allow for seasonal variation (given the results from the previous section). Ten demand and supply regression analyses were conducted for the bid price ranges of \$0-50, \$50.01-100, \$100.01-250, \$250.01-400 and \$400.01/MI or more. Figure 5 illustrates the results. In general, both supply and demand bid price elasticities rose considerably over the bid price ranges.



**Figure 5 Demand and Supply Bid Price Elasticities within Price Ranges in the Allocation Market in the Greater Goulburn Region from 2001-02 to 2005-06**

Source: Watermove, authors' calculations. Horizontal axis is nominal dollars.

At prices below \$100/MI, the supply bid price elasticity is inelastic, while it rises steadily at prices above \$100/MI. This result is consistent with the incentives influencing most graziers and mixed farmers who, at prices over \$100/MI are better-off selling their water than producing agricultural outputs. In the highest price ranges sellers may consider selling all their water or decide not to irrigate at all or to abandon the crop which is already in the ground. The demand bid price elasticity is only inelastic at prices below \$50/MI as at that price most producers are willing to buy to increase production and many purchases at that price are late in the season when water is only demanded by buyers needing to balance their accounts. Demand bid prices then become elastic for prices between \$50-100/MI as some of the lower value users still buy water because they have committed their irrigated area for the season and need the water to secure their crops to harvest. Above \$100/MI they are likely to be unwilling to buy and prefer to stop irrigating their crop and degrade it to feed. Demand bid elasticities rise steadily until the price range of \$250-400 and become steeply elastic above \$400/MI as buyers in this range is limited to horticulturalists and some dairy farmers buying to protect their long term investments in plantings, herds and equipment. In this range irrigators tend to buy smaller volumes more frequently to manage their cash flow and in the expectation that allocations might be increased or rain might come.

### 3.3 Overall Price Elasticities of Water Allocation Demand

The previous two sections have considered simple price bid elasticities of demand and supply from two viewpoints: by month and by price range. It is important to note, however, that these are based on weekly individual offers and bids incorporating the entire range of values signaling willingness to pay and minimum acceptable prices - but not what traders actually paid and received. This section calculates price elasticities of demand for water for the longer period of 1997-98 to 2005-06 utilising average monthly prices paid for allocations and taking into consideration the wide range of possible influences on the demand for water. Prior to 1997 volumes traded are only available on an annual basis.

The demand for rural water is traditionally expressed as a function of price, income and other factors. The preferred model would express each farmer's demand for water as a function of a range of their farm and socio-economic characteristics over time. However, given the limited available data, a region-level model is specified where the monthly total quantity of water allocations (DML) purchased by farmers in the GMID is the dependent variable. The independent variables hypothesized to influence rural water demand include: the price of water allocations; demand for water, water supply, farm income, seasonal factors, trend, and drought. Water demand functions have traditionally used linear, log-log or log-linear functional forms (Schoengold *et al.* 2006). The best fit of the model was achieved with a linear functional form:

$$DML_t = \beta_0 + \beta_1 DTPrice_t + \beta_2 DML_{t-1} + \beta_3 NDKyab_t + \beta_4 Alloc_t + \beta_5 FarmGDP_t + \beta_6 CommodityPrices_t + \beta_7 YearD_t + \beta_8 YearNo_t + \beta_9 SeasonalMonthsD_t \quad (5)$$

The first independent variable ( $DTPrice_t$ ) is the average price for water allocations in the current month. The majority of water demand studies have found a negative relationship between prices and water demand. The second independent variable ( $DML_{t-1}$ ) represents lagged demand for water, it is expected that the current month's demand is related to the previous month. Including such a term allows for the estimation of the long-run price elasticity (Hoffman *et al.* 2006). The third independent variable ( $NDKyab_t$ ) is the net monthly water deficit in the region. This is calculated by subtracting monthly rainfall from monthly evaporation rates obtained from the Bureau of Meteorology for the Kyabram station. This variable is a proxy for the volume of water that the irrigators must apply additional to the needs of the plant. It is hypothesised that an increase in the net water deficit (that is, more water is evaporating from the soil than is being replaced by rainfall), will lead to an increased demand for water. Brennan (2006) found a negative relationship between rainfall and prices in the Goulburn region's water allocation market. The fourth independent variable ( $Alloc_t$ ) is the current allocation level. It is hypothesized that farmers base their water demand and supply decisions on their current level of water allocation. Previous analyses of prices and volumes traded in the allocation market suggest that the main drivers of water market activities are low allocations and an increasing accumulated net deficit of water (i.e., Bjornlund 2003b; Bjornlund and Rossini 2005; Brennan 2006). Irrigators receive their seasonal allocation at the beginning of the season and there are no rules that they have to space their use of the water. They can, for example, use it all in spring and then rely on buying water later in the season. As a consequence some irrigators do not buy when scarcity first sets in, rather, initially they will use the part of their allocation that they know they will need later in the season. This is especially true if water prices are high. By deferring the purchase, they hope prices will decrease, perhaps because of later rains or increases in the

allocation level which might avoid the need to buy or reduce demand in the market resulting in lower prices. The fifth independent variable (FarmGDP<sub>t</sub>) is the average monthly farm GDP as estimated by the Reserve Bank of Australia (RBA). It is hypothesised that farm GDP will be positively related to water demand. The sixth independent variable (CommodityPrices<sub>t</sub>) is an index of rural commodity prices, also sourced from the RBA. Previous studies have found that water demand is positively related to commodity prices, although they appear to be less important than water scarcity (Bjornlund and Rossini 2005; Brennan 2006). Bjornlund and Rossini (2005) suggested that when prices on the allocation market increased to \$500/MI in 2002/03 this was driven by horticultural farmers protecting their long-term investments in plantings, with dairy farmers protecting their long-term investments in dairy herd and milking equipment at prices up to around \$300/MI. They do this to prevent selling dairy cows when prices are depressed, or sending them to pasture in areas not affected by drought as it will reduce milk production and thereby farmers' ability to service their debt. Further, it takes many years to build up a productive dairy herd. As a consequence, it is rational for farmers to pay more for water than appears profitable in the short-run. There is anecdotal evidence of banks lending money to dairy farmers to purchase water at loss making prices to ensure their long-term ability to service debt. The seventh independent variable (YearD<sub>t</sub>) is a dummy for the drought year of 2002-03. It is hypothesized that during severe drought more water will be traded in the market as high value users will have to purchase a larger proportion of their total water need. The eighth independent variable (YearNo<sub>t</sub>) is a yearly time trend, to reflect the increasing demand as water markets develop in the region. The last independent variable (SeasonalMonthsD<sub>t</sub>) is a dummy for the high trading months of the irrigation season: January, February and March, which are the hottest and driest parts of the year. Bjornlund (2003b) suggests that this pattern of trading is driven by farmers who postpone buying water until they have used their seasonal allocation and find that their crop still needs water. They do this in the hope that prices will be lower later in the season, as has historically been the case during several seasons, or that opening winter rains arrive early.

Table 3 presents the results of the final model using a linear functional form with 96 monthly observations. Serial correlation between the variables suggests that regressing against first differences was more appropriate than a simple regression.

**Table 3: Linear Regression for Water Allocations (DML) from 1997 to 2006**

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TPRICE	139.91	53.31	2.62	0.01
TVOLL	0.38	0.10	3.66	0.00
NDKYAB	55.12	21.77	2.53	0.01
ALLOC	0.27	34.79	0.01	0.99
GDPFARM	6.94	4.34	1.60	0.11
Commodity Prices	751.13	447.75	1.68	0.10
YEAR	4378.19	3069.32	1.43	0.16
YEARTREND	-1056.27	2344.35	-0.45	0.65
Seasonal Mths	13026.39	2769.23	4.70	0.00
Adj R <sup>2</sup>	0.39			
Durbin-Watson Statistic	2.20			

**Notes:** The explanatory power of the first difference model is 0.39 since the impact of trend has been removed. All standard errors were adjusted using White's corrections for heteroskedasticity as the null hypothesis of homoskedasticity was rejected. The condition index (which is a test for multicollinearity) for all variables ranged from 1 to 2, hence indicating no problems with multicollinearity. Elasticities from the linear regression were calculated via the sample means and estimated coefficients. The initial regression (not reported) had an adjusted R<sup>2</sup> of 0.72 suggesting that 72 per cent of price variance could be explained.

The analysis shows that demand for water allocations is significantly (at the 0.01 level) and positively influenced by demand in the previous month, prices in the current month, water deficit, and seasonal factors while the index of rural commodity prices and farm GDP have a less significant positive influence on demand.

In contradiction to many economic studies, the mean price of water allocations in the current month was positively related to water demand. The short-run elasticity is calculated at the means, and the long-run elasticity is calculated from the lagged demand coefficient at the mean. The short-run price elasticity of water demand at the mean is 0.51 while the long-run price elasticity of demand at the mean is 0.82. This indicates that a ten per cent increase in the price of water allocations

increases the demand for water by 5.1 per cent in the short-run and 8.2 per cent in the long-run. Although water demand is more elastic in the long-run than in the short-run, it has been shown to be inelastic and positive during the period from 1997 to 2006. The positive price elasticities for water indicate that water during this period of drought is not treated as a normal economic good. Factors such as crop needs and seasonal factors would appear to be more important in influencing the demand for water. Increased demand is not actually driven by increased price; however, during periods of drought irrigators' demand for water is high while supply in the form of seasonal allocations are low. High value irrigators are therefore willing to pay high prices to avoid losing their plantings or dairy herds and to stay in business. Therefore, as scarcity increases, prices go up and more water is traded.

#### **4. Conclusion and policy recommendations**

This paper has provided estimates of the elasticity of demand and supply for water for one region along the Murray River in Australia over the period 1997 to 2006. Based on traders' bids on WaterMove, the elasticity of monthly demand ranged from -1.32 to -7.82 and the elasticity of monthly supply ranged from 1.13 to 6.88 with low elasticity early in the seasons culminating in mid season and then declining again towards the end of the season. When we examined elasticity by price range, we found that elasticity of demand ranged from -0.90 to -7.03 and the elasticity of supply ranged from 0.11 to 4.09. This suggests that the elasticity of demand and supply for water is highly dependent upon the time of the season and market prices. It was also found that compared to supply elasticity, demand elasticity was much higher and fluctuated considerable more within and between seasons but showed a steadily increasing trend over time. This suggests that active irrigators responding to fluctuating weather and market conditions are dominating the demand side. On the other hand water sellers and lower value producing irrigators deciding to sell all or a large proportion of their water early in the season dominate the supply side. The potentially emerging class of institutional 'investor' sellers in the allocation market is likely to release water onto the market in a more rational manner than the one characterizing a large group of current sellers in the market; a way which is more in line with the more rational behavior displayed by current buyers in the market. This could result in more rational market outcomes from water buyers perspectives and result in returns to investors in the upper end of the range identified by Bjornlund and Rossini (2007)

Regressing several factors that are said to influence water demand (actual water traded against actual prices paid) over the time period from 1997 to 2006, demand elasticity was estimated to be between 0.51 in the short-run and 0.82 in the long run. It was also clear from the statistical insignificance of these results, however, that in the aggregate, other factors influence water demand more heavily than prices paid.

Several implications follow from our results. It is clear there is a need for more and better studies of water demand and supply elasticities. Current government policies that use markets to reallocate scarce water resources depend on irrigators to respond to price signals. Inelastic responses or responses that indicate that it will take decades to reallocate water volumes effectively signal the ineffectiveness of such policies. This in turn requires that governments have a clear target as to the aggregate amount of water they wish to see reallocated. Not only will this require better information about aggregate flows, such policies require a clear differentiation between (and measurement of) water consumption and water distribution elasticities.

It is not immediately clear that the current process of 'stacking' bidders in order of their price signals necessarily leads to the most efficient or equitable outcomes. There are signs of tactical bidding by buyers in order to ensure their buying and selling priority. Requiring the buyer to pay their bid price would ensure that more consumer surplus is transferred to the seller. This would force the buyers and sellers to reveal their 'true' valuation of the water and in times of extreme scarcity may induce more water into the market. At the very least alternative methods of price signaling should be investigated.

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