Price formation on the Northern Victorian water exchange

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Abstract

The opportunity cost of water in the irrigation industry is a contentious issue at present because of the commitment made by the State and Commonwealth governments to get water out of the irrigation industry for environmental flows. The estimated value of the opportunity cost will affect farmers' claims for compensation. Variation in the opportunity cost over space and the functioning of the spatial market will determine whether the efficiency costs of a simple across the board reduction in rights can be mitigated by trade or whether strategic buy back of water is required. The extent of variation in the opportunity cost of water according to seasonal conditions will affect the cost of flow policies that impact on the reliability of rights.

To date, most economic advice on this opportunity cost of water has centred on gross margin analysis of the main irrigation uses of water and the composition of these industries across space compared to the quantity of rights held. However, there has been a large volume of trade on temporary water markets in recent years and there is potential for using this data to better understand some of the characteristics of water demand and the market for water. This paper presents a preliminary analysis of market data from the last 5 years of trade on the Northern Victorian water exchange. The nature of bidding behaviour and spatial and temporal variations in water prices is illustrated, and the impact of water allocations and seasonal conditions on water prices is estimated.

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Introduction

In November 2003 the Murray Darling Basin Ministerial Council committed to giving back 500GL of water to the environment, which is to be funded out of a $500 m commitment made by COAG to address water over-allocation issues in the basin. This 500GL represents about 6% of entitlements owned by the irrigation industry on the Lower Murray system, and is deemed to be a first step: Measures of up to 1500GL claw back (almost 20% of current water use) are the subject of scientific and economic evaluation.

With money specifically set aside for the purpose of reclaiming water for the environment, the idea of compensating the irrigation industry has become a feasible policy option. Mechanisms for reclaiming water whilst delivering compensation include direct purchase of existing entitlements via tender; targeted purchase of water from specific regions; and across the board claw back with compensation. Alternative policy instruments have disadvantages and disadvantages in terms of administrative ease; political acceptability; management of third party effects; and targeting of unproductive water users. The true economic superiority of one over another can probably only be determined by empirical analysis and may be conditional upon broader policy reform. Yet despite having been through more than a decade of water policy reform, not that much is known by economists about the value of water in order to inform decision makers about one policy or another. In particular, while the emphasis of economists and hydrologists has been on the value of water *on average*, it is likely that a good environmental flow regime will impact on reliability of rights as well as on the average quantity that can be delivered to the irrigation industry[1].

The emphasis in this paper is on examining the data from temporary (seasonal) water trades in Northern Victoria over recent seasons, with the aim of understanding the value of water in the irrigation industry across time and space. Trading behaviour on the seasonal market can be used to draw some generalities about other issues regarding the purchase of water for the environment, and to indicate where future research might provide better information on the value of irrigation water. Some of the key questions that are considered are the effect of physical bottlenecks on spatial price differences, and the impact of allocations and climatic conditions on the seasonal price of water.

The outline of this paper is as follows. First, an outline of the temporary water market is provided, with an emphasis on recent water trade on the Northern Victorian water exchange. Some of the rules affecting trade between locations are described and data on spatial price patterns are used to illustrate the effect of physical trade constraints on price

[1] To date, the method of assessing the hydrological impact of environmental flows has simply been to reduce the quantity allocated to irrigators, which in simulation modeling has indicated that remaining water rights will be more reliable, because effectively dam capacity has been increased per volume of water entitlement and irrigators have first call on available water. In reality, strategic management of environmental flows will require use of dam space too, and it is possible that this will result in adverse impacts on reliability.

spreads. This is followed by a discussion of some of the factors likely to influence trading decisions on the seasonal water market then data on temporal price patterns and individual bids are explored. Econometric analysis of the impact of seasonal conditions on water markets is then presented, and the final section of the paper draws some conclusions about lessons learned from the data, particularly in the context of the environmental flows debate, and suggests avenues for future research.

Status of water trading

Temporary water trading began in Victoria in 1987/8 but it wasn't until 1994/5, when the CAP was implemented that serious water trading began, and continued throughout the 1990s at around 5-10% of the water right depending on seasonal conditions (Marsden Jacob 1999). The focus on this discussion is on 3 trading zones which are presented in Table 1, these are the main zones that have been active in water trading during the period discussed. Water trade can occur through private negotiation, or through a public water exchange that has been in operation in Northern Victoria since 1998/9.

The volume of water purchased in each region on temporary and permanent basis is illustrated for the 2000/1 and 2001/2 season, and the proportion of water sold through the water exchange is shown. The Goulburn valley is the region where the highest degree of water trading occurs on the seasonal basis. The extent to which growers are using the Exchange compared to private contracts varies between regions and between years. Compared to the temporary market, activity in permanent markets is minimal.

Table 1: Comparison of permanent and temporary trade volumes

Historical Trades	Greater Goulburn	Hume to Barmah	Barmah to Nyah
Water Right ML	979,054	296,097	458,821
2000/1	Water Purchased/Right		
Permanent trade – Water Right	1%	0%	0%
Temporary trade - Water Right	15%	3%	3%
Final Allocation	100%	200%	200%
Water Right Sold through Exchange %	38%	9%	68%
2001/2			
Permanent trade	1%	0%	0%
Temporary trade	18%	5%	7%
Final Allocation	100%	200%	200%
Water Right Sold through Exchange %	28%	6%	16%
includes all sales not just on water move			

Source: Watermove website (www.watermove.com.au)

The difference between the temporary and permanent markets is that in the seasonal market a physical quantity of water is traded, whereas the permanent market is a trade in a "permanent" right to use water. In the temporary market, farmers can only trade the water that has been allocated for the particular season, and buyers must use it in that same season.

A number of reasons have been cited for the predominance of temporary trade, that relate to transactions costs and speculative behaviour. On the transactions side, the administrative constraints to trade are far more restrictive and costly on the permanent market, and include more time consuming approvals, higher fees, and outright constraints on trade of a permanent nature in many cases. For example, Victorian water authorities can refuse applications to sell water on the permanent market if the annual volume of applications exceeds 2% of entitlement in that year (Goesch 2001). In contrast, temporary trade in the Northern Victorian water exchange is only restricted by rules relating to physical delivery (explained below). Transfer fees on the seasonal market are low – less than 1% of the cost of buying and about 3% of the revenue from selling.

Another reason for reluctance to trade on a permanent basis may be that sellers are holding on to their water rights because they are doing quite well out of trading on the seasonal market in the short run whilst they are holding on to potential capital gain. For buyers the temporary market may represent the only way of accessing water due to restrictions on permanent trade; or may just provide a mechanism for opportunistic seasonal water use decisions (such as watering more dairy pasture, or planting annual crops), which may only be viable under certain prices and seasonal conditions.

The charge structure of water gives an added incentive to sell – a storage and infrastructure access fee (e.g. $25.86 in year 2003/4) is paid on the entire water right regardless of use. Thus there is a cash flow incentive for irrigators to sell water if they are certain they won't use all their allocation in the current season.

The average size of individual bids for the last 5 seasons is shown in Table 2, and compared against the financial size of trade. Since the average size of water entitlements per holding in Northern Victoria is about 150ML; the quantity of water being bought and sold is quite significant – from 30% to 50% per farm. The total cash cost/benefit of trade can be compared to fixed water charge of about $4,000 per farm[2].

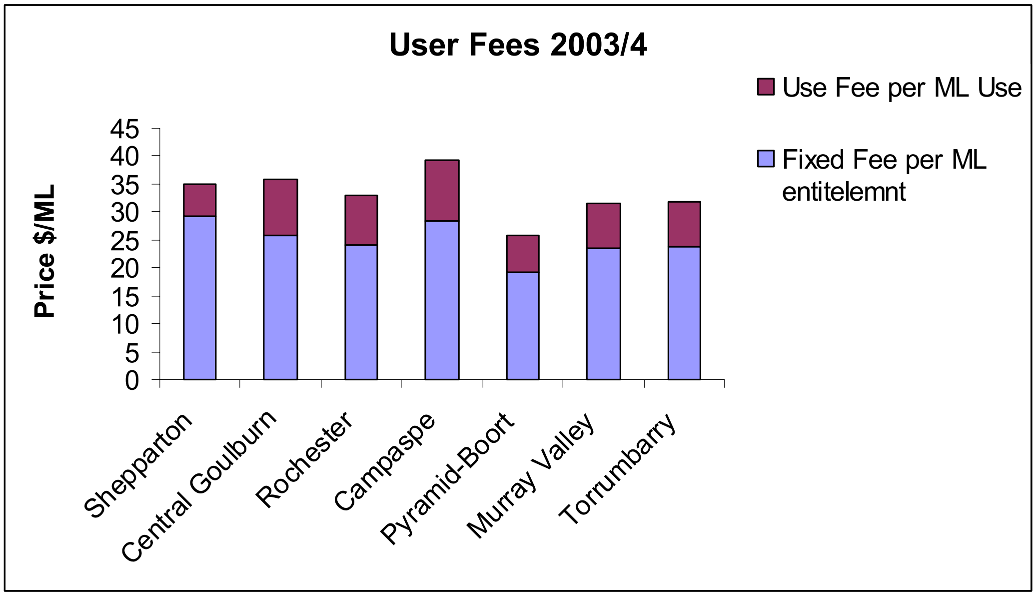
Table 2: Greater Goulburn Trading: Prices, bid sizes and farm level costs

	Average price $/ML	Avg Individual Bid Size ML		Net Value of trade per farm	
		Sellers	Buyers	Sellers	Buyers
1999/2000	56.58	58	87	$3,158	$4,930
2000/1	33.50	68	76	$2,218	$2,562
2001/2	99.99	49	74	$4,741	$7,376
2002/3	364.02	20	68	$7,187	$24,859

Source: Price and quantity from statistics provided by Watermove; rest calculated by author based on trading rules and quantity traded.

[2] Based on 2003/4 fees and 150ML entitlement per farm

Figure 1 illustrates the fee structure charged by Goulburn Murray Water in the 2003/4 season. There is some variation in fees across the different regions, but the total degree of difference is small, the difference between the greater Goulburn and the Murray regions (Murray and Torrumburry) is only about $5/ML.



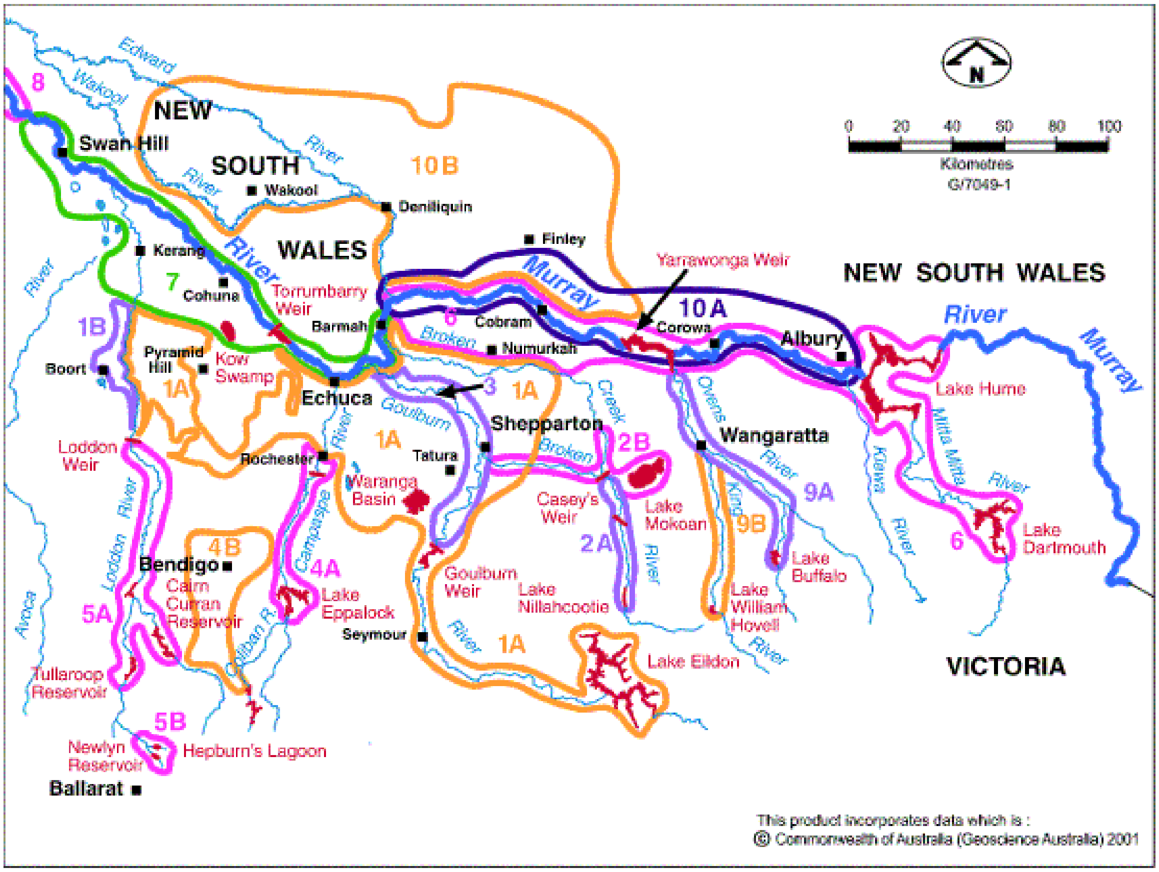
Source: Goulburn Murray Water

Figure 1: User fees for the 2003/4 in the Goulburn Murray region

Trading on the Northern Victorian Water Exchange

The data discussed in this paper comes from the public water exchange, "Watermove". The exchange is in its second year of operation as a state-wide service, but its predecessor, the Northern Victorian water exchange, had been trading as a formal exchange since 1989. The water exchange acts as a clearing house that coordinates the trade of water on a weekly basis throughout the irrigation season.

The Northern Victorian (Goulburn Murray) region covers the irrigation districts in the Goulburn, Broken, Loddon, Campaspe and Ovens valleys, and the main Murray River. These regions are illustrated in Figure 2, where trading boundaries as defined by Watermove, are shown. These zones are defined on the basis of physical delivery constraints. For example, the tributary valleys are separate trading zones, and irrigation areas on the main Murray are divided into regions below and above the Barmah choke – a narrow part of the river that represents a physical delivery constraint during irrigation season.



Source: Watermove, www.watermove.com.au

Figure 2: Water trading zones in Northern Victoria

Each week, farmers can submit offers to buy or sell water. In making a bid they must specify a quantity, a price and the number of weeks the offer will be current, and must nominate the region to which they want to sell or from where they want to buy. These offers are all checked by Watermove staff for legitimacy, including whether the bidder has any water to sell and whether trade into the nominated zone is allowed. Farmers must submit offers by Monday, can withdraw by Wednesday, and then the exchange clears the market each Thursday throughout the irrigation season, publishing prices that day. The market is cleared in each region by determining the intersection of that region's buy/sell offer curves. Where more than one offer is placed at the market clearing price and there are insufficient volumes traded to satisfy all offers, a ballot process is used to determine the successful bidder at that price.

Rules relating to spatial zones are complicated by special conditions. In Table 3, the rules regarding transfers between the Goulburn (a tributary of the Murray) and two locations both on the main Murray channel are shown. Whilst farmers within regions are able to freely trade with each other, the restrictions on trade between regions are set according to physical delivery constraints. Neither of the Murray regions can trade into Goulburn, except via the substitution account rules. The substitution account measures the amount of water that has previously been traded in the other direction in the current season, thus ensuring that the total amount of water traded into the Goulburn valley does not exceed the amount allocated (that can be delivered) out of the Lake Eildon, the water storage in this valley. Substitution accounts are also defined at other critical delivery points in the system but are unlikely to be of much use when there is a strong price differential, as this would imply that the substitution account would be never be in credit.

Rules regarding trading on the Murray are that Murray irrigators are able to buy water from Goulburn farmers, but trade between the Murray regions is restricted. Those below the Barmah choke have restrictions on buying from farmers upstream because of the channel capacity constraints between these two regions.

Table 3: Trading constraints in the temporary market due to physical factors

To / *From*	Goulburn	Above Barmah	Below Barmah
Goulburn	Yes	Yes	Yes
Murray Above Barmah	Not allowed to trade upstream*	Yes	Restricted delivery through choke*
Murray Below Barmah	Not allowed to trade upstream*	Yes	Yes

*Trade can occur on substitution accounts

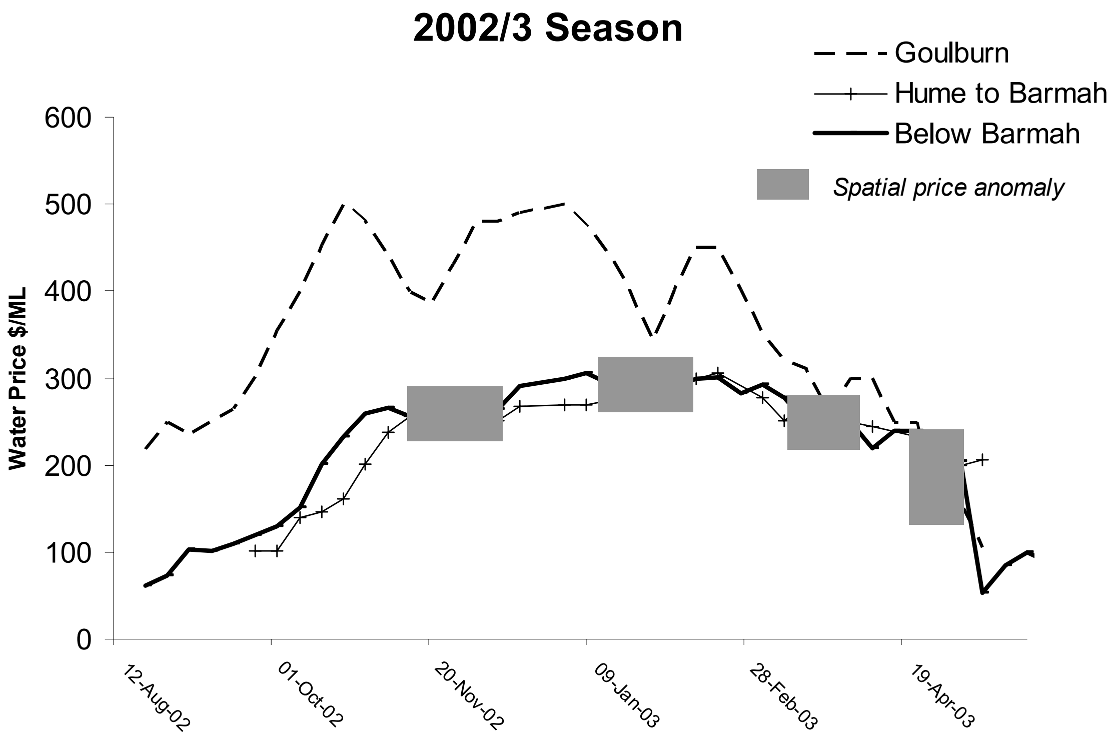
These restrictions on trade imply that price wedges will persist in a spatial equilibrium. The theoretical relationship between prices is defined in Equation 1.

$$P_G \geq P_{AB}, P_G \geq P_{BB}, P_{BB} \geq P_{AB} \qquad (1)$$

Where subscripts refer to locations: G for Goulburn, AB for above Barmah and BB for below Barmah.

The requirement that buyers and sellers must specify a zone from/to which to trade is an odd one that means that spatial equilibrium is not met automatically through market exchange. It implies that the efficiency benefits of a market exchange are not being fully exploited, although the regular posting of market information may promote price convergence over the season. In Figure 3, spatial price data is illustrated for the 2002/3 season, and there is some evidence of market inefficiency can be seen. The highlighted areas show periods when the theoretical equilibrium conditions outlined in Equation 1 are breached. For example, at several times in the season, prices above the Barmah choke exceed those below it. This price anomaly should not occur because farmers below Barmah can sell water to those above Barmah. This perverse price relationship can be attributed to the bidding rules on the Exchange; where water put up for sale is not allowed to go to any region in which sales are permitted, but instead, farmers must specify a single region they want to sell to. The price anomaly persists for several weeks before correcting itself – presumably from adjustment to bids as market information is revealed.

The price premium on the Goulburn River in the 2002/3 season was around $150/ML. This premium reflects the physical delivery constraint placed on trade. Water shortages were more severe in this region than in the other regions, traders in the Murray were not able to benefit from selling to the Goulburn region because their water could not be physically delivered.



Source: Watermove trade data. Spatial anomaly occurs where Hume to Barmah price is above below Barmah price (trade should occur to remove shortages above the Barmah choke); and when Goulburn price is below Hume to Barmah Price.

Figure 3: Spatial price data in the 2002/3 season

This price premium on the Goulburn is illustrated further in Figure 4, where average price data over the past 5 seasons is shown. The persistence of this price premium implies that there is a general water shortage in the Goulburn compared to the other regions, and this can be supported by the fact that allocations have never exceeded 100% over this period, whereas they have in the Murray. The size of the price premium was substantial in relative terms in the years preceding the 2002/3 drought; with prices about double those in the Murray, on average. This implies that the cost of sourcing more environmental water out of the Goulburn region would be substantial. Moreover, since this price wedge represents a physical bottleneck, it is likely that the efficiency costs of sourcing water out of the Goulburn are unlikely to be mitigated by an improvement in permanent water markets.

One possibility that could reduce the severity of the physical delivery constraints during droughts is to create quotas for downstream delivery responsibilities (e.g. delivery into South Australia) that could be traded between states and between valleys. This would enable the valleys experiencing water shortages to use more of their available water and reduce tributary outflow. Of course, this would also affect environmental outcomes in the tributary so the extent to which such flexibility could improve the spatial allocation of water may be limited.

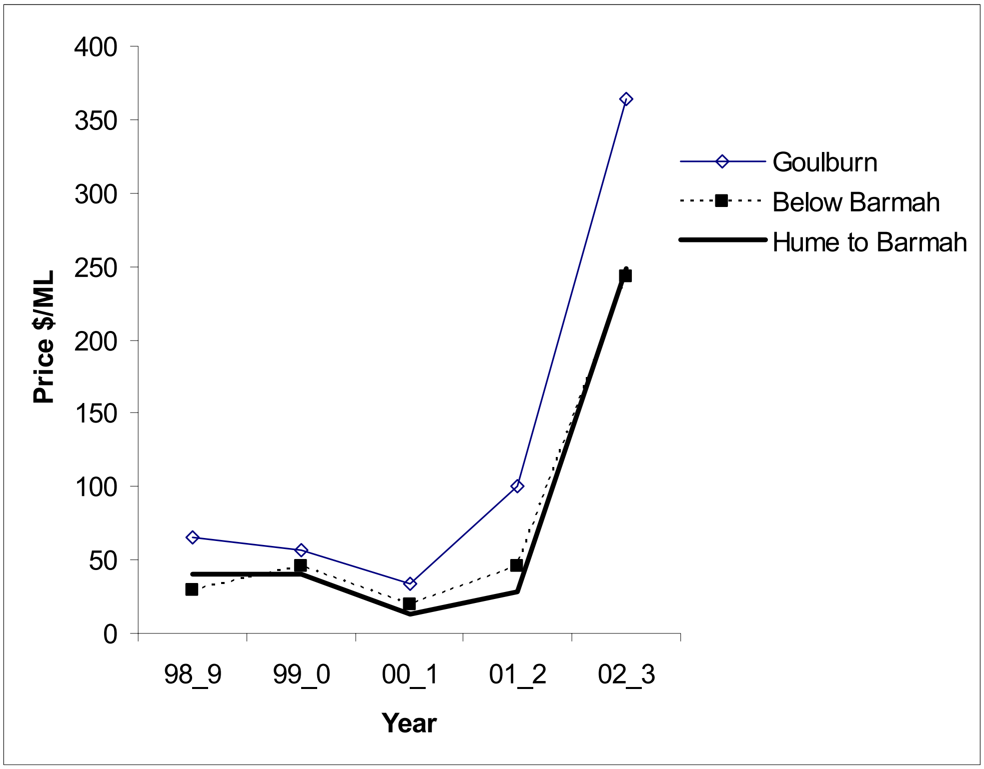


Figure 4: Price spreads in the northern water exchange: 5 seasons

The evidence presented here on the size of the price wedge created by a physical delivery constraint raises questions about the methodology that has been applied by economists in quantifying the value of unrestricted trade in the lower Murray. In general, most analyses of trade ignore the extent to which physical capacities can constrain spatial reallocation of water, and simply compare the economic value of current water allocations with "unrestricted trade" outcomes (e.g. Eigenraam 1999, Heaney, Beare and Goesch 2002). Future analysis of the benefits of trade in water between valleys should take account of these important physical constraints.

Price movements over the season

Trading occurs on the seasonal water market on a weekly basis over the 8 month irrigation season. During this time, information relevant to the value of water is only gradually made available, which means there are strong stochastic drivers in the water market. For example, the demand for water is a derived demand for soil moisture, and as a result the value of marginal product curve (for irrigation water) is dependent on seasonal rainfall, which is unknown when plans are being made. Similarly, the amount of water that farmers have available for use in irrigation, and subsequently their decisions about buying or selling, depend on the seasonal allocation. Early season announcements of water allocation are generally conservative, and are usually revised upwards over the season, although the extent to which they will be revised is uncertain. Aside from climate, the main driver of the water market is the heterogeneity of farm enterprises, in terms of irrigation specific investments, and presumably attitudes to risk. Some of the farm related and climatic factors affecting the seasonal water market are illustrated in Table 5. Differences between farmers in terms of irrigation specific investment, efficiency, size of entitlement, and risk attitudes and perceptions; combined with uncertainty in rainfall and seasonal allocations means that the water market is active throughout the season, as farmers valuations of marginal productivity of irrigation, and willingness to buy or sell water change throughout the season.

Table 5: Influences on demand for water as a factor of production

	Agronomic	*Climatic*
Farm level returns to irrigation water	Level of irrigation specific investment - long term (e.g. perennial plantings, irrigation layout) - Seasonal (e.g. annual plantings, which are dependent on risk attitudes) Farmer efficiency	Seasonal Rainfall
Water price	Returns to irrigation water at industry level i.e. Irrigation specific investment including within season; water investment decisions and risk attitudes at industry level. Location (due to restrictions on trade)	Seasonal rainfall Amount of water allocated in season

Data is available on the bid offers made by buyers and sellers throughout the season and this data could provide fruitful research on demand for water as a factor of production in the variable Australian climate. As well as providing information for economic policy analysis, such information could be used to improve specification of hydrological models. These simulation models require behavioral assumptions about water use in response to allocation announcements and seasonal conditions, in order to close the storage equation that determines water available in the subsequent season (and hence to calculate reliability). At present, water demand is represented in these models by arbitrary assumptions about annual plantings and very conservative expectations about rainfall.

However, in order to use the bidding data to estimate the derived demand for irrigation water it would be necessary to have more information on the characteristics of farmers making the bids, including their physical location; their enterprise mix and opportunities for making tactical adjustments in watering plans over the season; the size of their entitlements; their perceptions about allocation revisions; and their attitudes to risk and the extent of trading by private treaty.

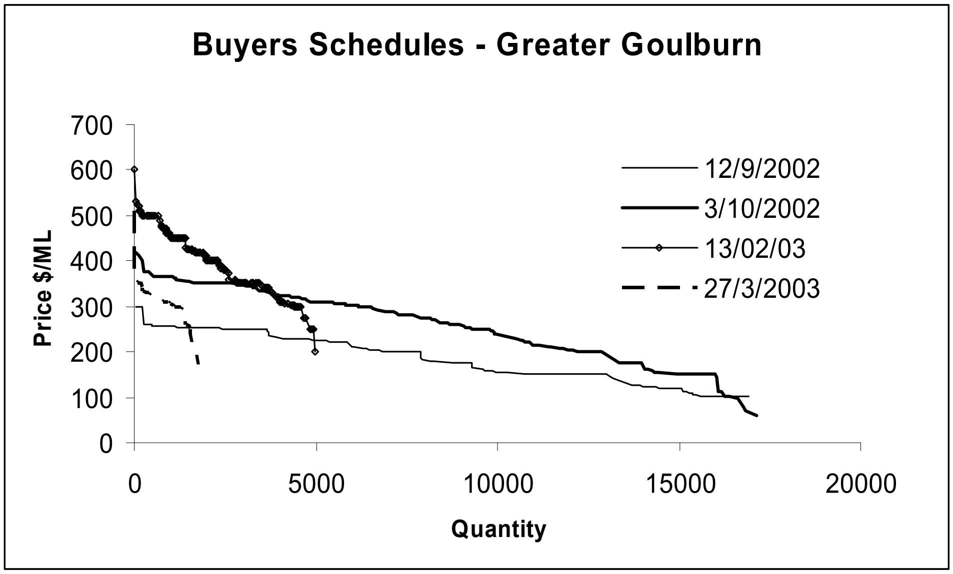
Time limitations and lack of supporting information has precluded analysis of such bidding data in this paper. However, bidding data from the 2002/3 "drought" year has been analyzed for presentation here, and indicates some differences in behaviour between buyers and sellers. The 2002/3 season was a sellers market as illustrated by the summary statistics presented in Table 5. This table shows the number of bidders, the frequency with which bids are successfully traded, and the frequency with which submitted bids are withdrawn before intended bid offer expires. When bids are placed farmers specify the number of exchanges for which bid offer will remain current (if not immediately traded); on average, the intended length of bids was about the same for both buyers and sellers (at 2.5 weeks). However, whilst buyers let these offers remain in the exchange as intended, sellers frequently withdrew their bids if unsuccessful in the first week of offer. The high level of withdrawals of sellers compared to buyers indicates that traders were quite different in nature. Sellers, having made their production plans and decision to sell, seem to play the market like speculators, trying to extract rents from their unused allocations. In contrast, bids from buyers would reflect the marginal value product of water, and would be less likely to be revised over the period of offer.

Table 5: Success of bidding in 2002/3 season, Goulburn region

	Number of Bids		Withdrawals		Success		Total Bids ML	
Month	Sellers	Buyers	Sellers	Buyers	Sellers	Buyers	Sellers	Buyers
8	46	129	74%	0%	3%	11%	2,113	25,786
9	57	76	6%	0%	88%	25%	2,440	19,510
10	99	61	3%	0%	82%	43%	2,503	9,955
11	101	60	12%	0%	57%	39%	4,508	5,360
12	59	62	3%	0%	93%	49%	2,028	5,244
1	73	43	16%	0%	57%	87%	2,111	1,971
2	82	82	2%	0%	82%	45%	2,202	4,209
3	128	49	18%	0%	67%	72%	2,483	1,766
4	93	93	3%	0.27%	92%	46%	1,295	3,152
5	35	21	9%	0%	80%	63%	370	627

Source: Calculated from bid data obtained from www.watermove.com.au

Over time, new bids were being placed (possibly by the same unsuccessful buyers) and over the few months of the season the buyer bid schedule jumped by about 25%, as shown in Figure 5. It can be seen in these figures that, as would be expected, the total quantity of bids diminished over the season, because the total amount of water required per hectare (for the rest of the season) reduces over time. The jump in the buyers bid curve between September and October probably reflecting emerging market conditions – in particular, since Greater Goulburn had never before received an allocation of less than 100%, so at the start of the season farmers would have expected upward revision of allocations. By October, when allocations remained at 57%, the true nature of the water shortage was reflected in buyers' bids. The buyers bid curve reached a peak in February, and then receded in late March. The sellers' schedules moved in a similar pattern throughout the season.



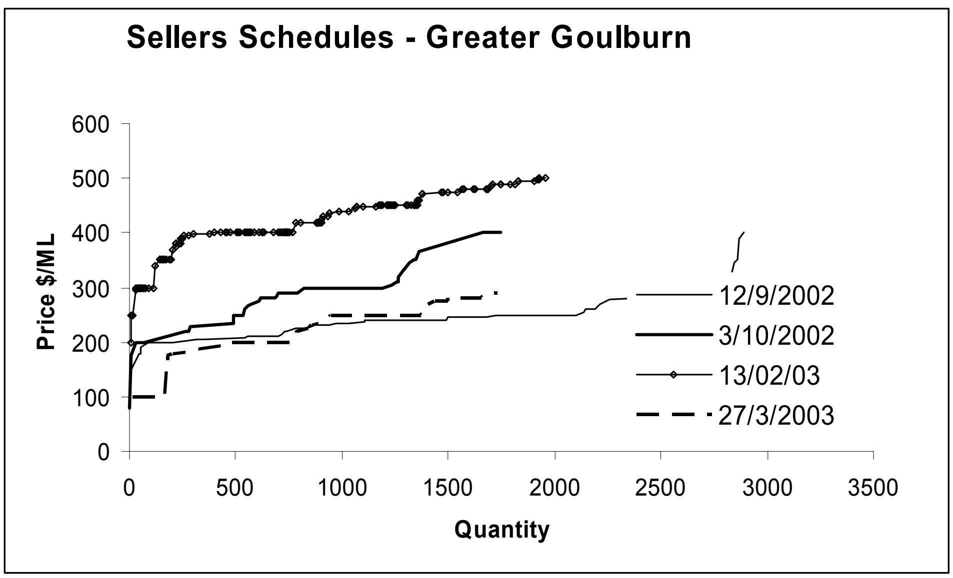


Figure 5: Bid curves offered in the Goulburn region

Temporal price patterns

The temporal price patterns experienced over the last 5 seasons are illustrated in Figure 6. Inter-temporal arbitrage should ensure that current prices reflect expected future prices over the season, and temporal price patterns actually achieved will reflect how expectations compared with realised seasonal conditions. For example, a flat seasonal price curve indicates that things panned out according to expectations; whereas a more volatile price pattern indicates that farmers had a few surprises. For example, from the Goulburn market data it can be seen that in 1998/9 the price was very high in the first few weeks of trading, but then gradually fell over the season. This price fall might have been caused, for example, by better than expected rainfall, or a greater than expected revision of allocation announcements. In 2001/2 prices were fairly constant in the first half of the season but rose sharply in the summer, possibly due to drier (or hotter) than expected climate.

The very high price in 2002/3 reflects the unprecedented occurrence of an allocation below 100% of entitlement. The extent of the price rise –from around $200/ML in august to $500/ML in October corresponds to the large jump in offer curves that was illustrated in Figure 5. As discussed, it is likely that farmers failed to make sufficient adjustments to farm plans early in the season, gambling on allocations eventually being revised up to 100%. The temporal price pattern was also highly variable, indicating that realized conditions were difficult for the market to predict.

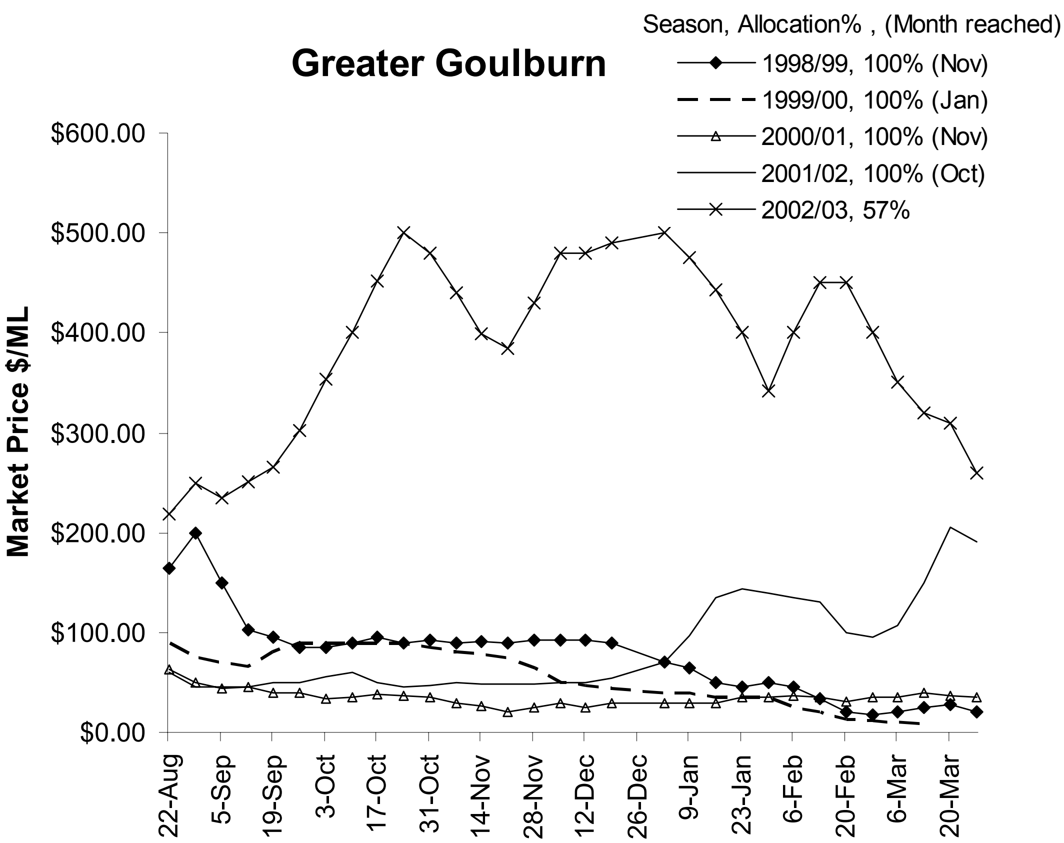


Figure 6: Temporal price patterns in Goulburn over 5 seasons

Price response in the market

Since the level of irrigation specific investment is fairly fixed in the short term[3], it is likely that variability in water prices within and between seasons will be driven largely by climatic/seasonal factors i.e. rainfall and seasonal allocations. Whilst analysis of the weekly pattern of prices would require information on the timing of allocation announcements, and rainfall patterns, and their interface with critical points in the crop/irrigation season, a more rudimentary analysis can be done at the aggregate level.

Two parameters were used to represent seasonal conditions, these were cumulative rainfall in mm over the irrigation season (realized rainfall); and the October allocation announcement. The conservative nature of dam management and irrigation allocations in Victoria means that there is no significant correlation between agronomic crop water demand (seasonal climate) and allocations in that season[4]. The dependent variable was the trade-weighted average prices in the Goulburn Murray region, by trading location and season. Shepparton rainfall was used for the Goulburn regions and Echuca was used for Murray regions. Ordinary least squares regression was applied, and diagnostic tests revealed a good fit; with the best equation shown in Equation 2. Predicted prices are plotted against actual prices in Figure 7.

$$\text{Ln(Price)} = 7.0333 + -0.48466 \text{ Allocation Squared} + -0.0086. \text{ Rainfall mm} \quad (2)$$

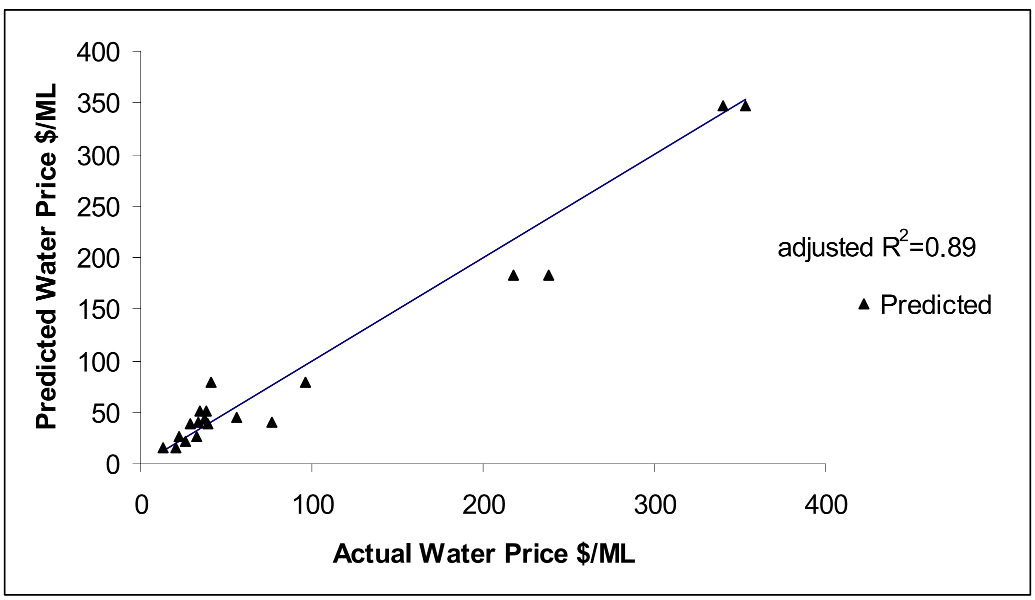


Figure 7: Predicted and actual seasonal water prices

[3] Whilst annual plantings can be varied, longer term land improvements are required to allow this flexibility in water use on the farm.

[4] Analysis was conducted on 100 years of simulation data provided by Victorian Department of Sustainability and Environment, on agronomic water demand (driven by a crop water balance model reflecting ET and effective rainfall) and seasonal allocations. Seasonal crop water demands were not significantly correlated to early seasonal water allocations. This is because an allowance 100% of water entitlement is set aside in the dam for the subsequent season, before allocations above 100% are made in the current year.

Figure 8 shows the implied price relationship as a function of water allocations, over the range of observed allocations; for different seasonal rainfall assumptions. Since the announced allocation in October is uncorrelated with subsequent seasonal rainfall, these curves show a plausible range of data over which prices may vary. Clearly, the effect of reducing allocations depends very much on the seasonal conditions, and the opportunity cost of allocating water for environmental flows will be much lower in years of high seasonal rainfall. This would occur, for example, where medium term floods are the target of environmental flows. However, one of the impacts of a large allocation to the environment, in order to achieve a medium term flood for example, would be reduced carryover of water and lower allocations in the subsequent year, which would prove costly to irrigators if the subsequent year was a dry one.

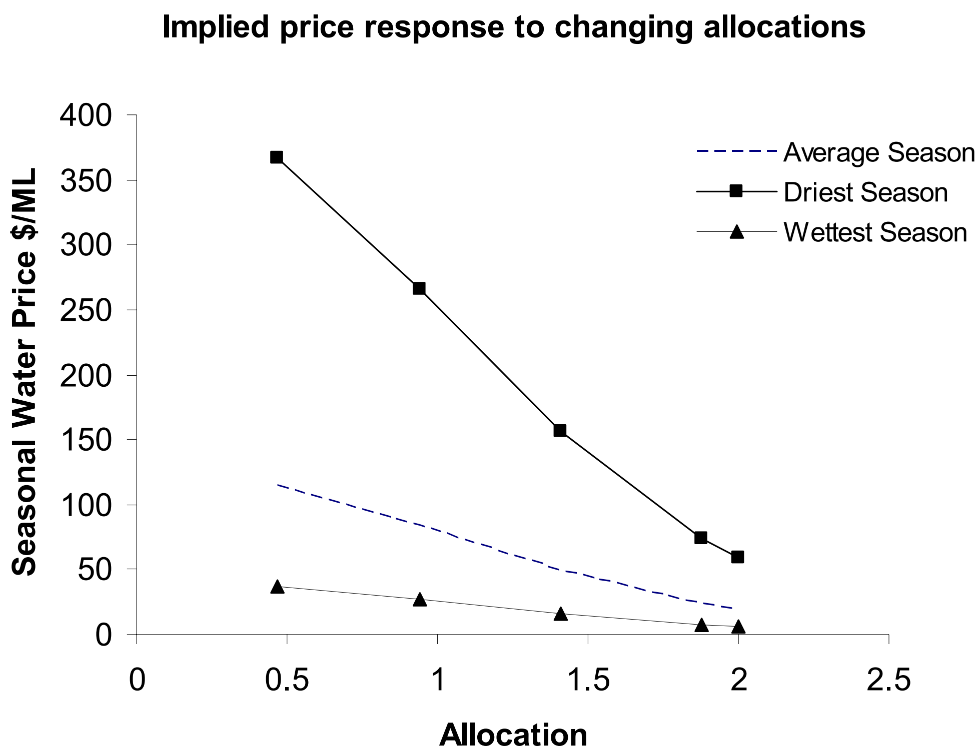


Figure 8: Implied relationship between allocations and water prices under different seasonal conditions

Conclusion

A simple graphical examination of water trading data from the last 5 seasons has revealed a number of insights into the value of water in the irrigation industry. In particular, the data highlight the importance of physical bottlenecks on spatial price relationships, and indicate that analyses of the benefits of "free trade" should account for these constraints; otherwise benefits from trade will be overstated. The data also show a persistent price premium in the Goulburn valley over the entire 5 year period, indicating that sourcing more water from this region for environmental flows will be a costly policy.

Another characteristic of the trading rules on Watermove is that there appears to be inefficient price discovery in the market, and this is attributed to the rule that farmers are not allowed to make general offers (i.e. to trade with all regions where trade is permitted). This results in perverse price relationships between regions where trade should equilibrate prices.

Whilst there is a rich data set of bidding behaviour and temporal price information emerging from the temporary water market, more detailed study of farmer characteristics and attitudes would be required to gain a full understanding of farmer behaviour in response to uncertain seasonal conditions. This information could be used to improve the representation of irrigator behaviour in hydrological models, and to contribute to analysis of the economic value of the reliability characteristics of water entitlements.

Regression analysis of average seasonal prices from the water exchange has indicated that allocations and rainfall explain most of the variation in the price of water traded on the seasonal market. The combined effect of low allocations during years of low rainfall can easily be overlooked when analyzing economic impacts using "average assumptions" as is quite standard practice in the profession.

Since environmental flows are likely to have impacts on the probability distribution of water allocations to farmers, and the results indicate the importance of a reliable allocation to reduce the cost of water shortages in dry years, it is essential that future analyses of environmental flows consider the impact of flow regimes on the reliability of allocations. To date, there has been insufficient attention paid to this problem both by economists and hydrologists. Better collaboration on hydrological-economic modeling could allow examination of bigger picture issues like managing dams for combined benefits of environmental flows and irrigation industry, taking account of the nature of physical bottlenecks in the spatial delivery of water, and external impacts. Such combined analysis could better inform the debate about solving over-allocation in the Murray.

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