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A COMPARATIVE ASSESSMENT OF WATER MARKETS: INSIGHTS FROM THE MURRAY-DARLING BASIN OF AUSTRALIA AND THE WESTERN US

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A Comparative Assessment of Water Markets: Insights from the Murray-Darling Basin of Australia and the Western US

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Water markets in Australia's Murray-Darling Basin (MDB) and the US west are compared in terms of their ability to allocate scarce water resources. The study finds that the gains from trade in the MDB are worth hundreds of millions of dollars per year. Total market turnover in water rights exceeds $2 billion per year while the volume of trade exceeds over 20% of surface water extractions. In Arizona, California, Colorado, Nevada, and Texas, trades of committed water annually range between 5% and 15% of total state freshwater diversions with over $4.3 billion (2008 $) spent or committed by urban buyers between 1987 and 2008. The two-market comparison suggests that policy attention should be directed towards ways to promote water trade while simultaneously mitigating the legitimate third-party concerns about how and where water is used, especially conflicts between consumptive and *in situ* uses of water. The study finds that institutional innovation is feasible in both countries and that further understanding about the size, duration, and distribution of third-party effects from water trade, and how these effects might be regulated, can improve water markets to better manage water scarcity.

Keywords: water markets, US west, Murray-Darling Basin, gains from trade

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1. Introduction

Due to growing worldwide concern about freshwater supplies and ability to meet new demands, water security, defined as 'the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies' (Grey & Sadoff 2007, p. 548), is becoming an increasingly important issue.

Presently, 70% of the world's population lives in countries that withdraw more than 40% of the available water resources. If current trends continue, by 2025 up to a third of humanity will be living in regions where water withdrawals exceed 60% of the amount available (Shiklomanov, 2003). Furthermore, climate change is likely to increase both the intensity and variability of precipitation, resulting in more frequent heavy rainfall events and thereby more flooding, as well as more frequent dry spells leading to more droughts (Bates et al., 2008). The effect of such changes is likely to exacerbate water shortages, with a forecasted reduction in growing-season precipitation in key agricultural areas, such as Southern Australia and the western US (Barnett et al., 2008; World Water Assessment Program, 2009), and increased water stress in many locations should rapid warming occur (Fung *et al*., 2010).

Various supply strategies are being implemented to reduce water shortages including: construction of desalinization plants; increased dam and reservoir construction; and inter-catchment transfers of water. Given the high cost of future supply augmentation, alternative and demand-based approaches need to be developed. One way to mitigate water scarcity is to reallocate water from relatively low-value but high consumptive uses of water, such as in agriculture that accounts for 70% of all freshwater globally appropriated for human use (World Water Assessment Program, 2006, p.245), to higher value consumptive and non-consumptive uses.

A demand approach to mitigate water scarcity includes the facilitation of water trading regimes and markets that allow lower-to-higher-value reallocations, thereby increasing the net value of production from a given water supply (Easter *et al.*, 1998; 1999; Howe *et al.*, 1986; Saleth and Dinar, 2000). Water markets also provide price signals that can encourage investment in water-use efficiency and indicate the costs of shifting water from consumptive applications to alternatives, including *in situ* uses. Typically, water markets have been limited to certain types of consumptive applications, in particular within irrigated agriculture, but they could be applied to the environment and across a range of consumptive uses (rural or agricultural and urban).

When markets exist and are competitive, prices emerge from voluntary exchange between numerous buyers and sellers for homogeneous water (water of the same quality, reliability). These prices reveal the marginal values of demanders and suppliers (including the opportunity cost of using water in its current use, such as irrigation, or selling to an alternative buyer), as well as conveyance costs and any regulatory restrictions that are incorporated into the supply price. When an exchange takes place, one can conclude that the buyer's willingness to pay for water is greater than or equal to the exchange price; that there is no seller available to complete the transaction at a lower price at that time; and that the seller's value foregone by completing the transaction is less than or equal to the transaction price.

Competitive, voluntary markets can have the desirable feature that no user can be made better off with a water reallocation without making any other user worse off provided there are no unaccounted for third-party effects associated with subsequent water use. Differences in marginal water values across uses, as reflected in market prices (agriculture-to-agriculture exchange prices as compared to agriculture-to-urban exchange prices), that are not due to conveyance or other costs, indicate that there are potential gains for both buyers and sellers from reallocating water from lower to higher-valued uses (consumptive and non-consumptive).

In this study we evaluate the performance of water institutions in Australia's Murray-Darling Basin (MDB) and the US West from the perspective of the gains from trade and institutional challenges that may limit these gains, as well as looking at the insights the two markets provide for water markets and policy reform. Both locations have defined water rights and conveyance structures to assist in the reallocation of water across competing demands. As these two regions are located in semi-arid areas subject to large climate variability which increases the risk of both droughts and floods, their experiences in water markets provide insights to other parts of the world where water scarcity is an issue. While both locations have a number of factors in common, there are also important differences regarding the nature of water rights and the extent of water markets that provide guidance as to what aspects of their institution and market framework are most effective at coping with water scarcity. Our contribution is to: (1) provide one of the first economic and institutional comparisons of water rights and regulatory structures for these two regions; (2) document the extent of water trading; (3) provide estimates of the gains from further trades; and (4) evaluate the institutional challenges that limit gains from trade in the two water markets.

Section 2 provides an overview of the two water markets while section 3 focuses on the extent of water trading and the underlying institutional framework in the two regions. Section 4 explains the price differentials for water in different uses and quantifies the gains from trade in the two markets.

Section 5 reviews the institutional framework that limits the gains from trade. Concluding remarks about Australian and US water market experiences are provided in section 6.

2. Overview of the Murray-Darling Basin, Australia and US West Water Markets

2.1. Water Rights in US West

In the US West, most water is allocated through appropriative water rights. The appropriative doctrine emerged in the 19th century in response to the development of mining and agriculture in this semi-arid region where growing numbers of people and economic activities were increasingly concentrated in areas where there was too little water (Kanazawa, 1998). Prior appropriation allowed water to be separated from riparian land and moved via canals and ditches to new locations (Johnson *et al*., 1981).

Under prior appropriation, individuals do not own water as they might own land. Each state owns the water, which it holds in trust for its citizens. Individuals hold user rights that are capitalized into land values and that transfer with the land, or that can be sold or leased separately from it. This attribute is the basis for water markets and security for investment in water-delivery infrastructure, agriculture, and other endeavors.

Appropriative water rights in the US west grant possessory rights to a *fixed* quantity or flow, usually in cubic feet per second of water for diversion from a stream, based on the date of the original claim (Johnson *et al.*, 1981, p.282; Smith, 2008, p.452, 467-72). These physical volumes assigned to holders of appropriative rights must be used 'beneficially' whether by the right holder or by those who purchase the water if it is traded. Entities with the earliest claims or senior rights have the highest priority and subsequent claimants have lower-priority or junior rights. Diversions are filled by rank so long as there is sufficient stream flow. During times of drought when only senior appropriators may have their allotments fulfilled, junior appropriators, who bear most of the downside risk of drought, are especially dependent upon return flows from senior appropriators. Actions by senior rights holders to change the location, nature, or timing of use can affect water consumption and influence the amount of water released downstream. Accordingly, water trading from agriculture to urban uses that involves export out of the basin and reduces return flows can impair third parties and is subject to state regulation to ensure that no damage is inflicted on junior diverters (Getches, 1997, p.161).

Appropriative rights are conditional upon water being placed into beneficial use—the 'use-it-or-lose-it' mandate ─ and no harm to third parties. Objections to trades can be lodged, and the burden of proof of impairment rests with the applicant. The regulatory process and the costs associated with it vary across states, in part because the 'no harm' mandate is defined differently (Colby *et al.*, 1989; Colby, 1990; MacDonnell, 1990; Thompson, 1993, p.704-5). If water is not used beneficially, the right may lapse under the doctrine of abandonment. The driest western states ─ Arizona, Colorado, Idaho, Montana, New Mexico, Utah, and Wyoming recognize only appropriative water rights whereas, the wetter states of California, the Dakotas, Kansas, Nebraska, Oklahoma, Oregon, Texas, and Washington recognize both riparian and appropriative institutions (Kanazawa, 1998). Riparian rights grant water to adjacent land owners for reasonable use and riparian rights generally cannot be separated from the land.

Beneficial use, however, can contribute to waste as rights holders devote water to low marginal-value 'approved' applications in order to maintain ownership and the neglect of higher marginal-value uses that may not be considered consistent with the doctrine. It is this 'marginal' water devoted to low-value uses that is the basis for most potential water trades.

2.2. Water Rights in Murray-Darling Basin

In Australia, surface statutory water rights in the MDB are defined in terms of diversions per irrigation season. Beginning first with the State of Victoria in 1886, states have transformed riparian water rights into statutory water rights (McKay, 2008) although vestiges of riparian rights still remain in the form water harvesting for 'stock and domestic use' that can neither be traded nor used for other purposes.

In the first half of the twentieth century, Australian states used their acquired water rights to encourage farming settlements in the southern MDB with the free allocation of statutory water rights, typically one acre-foot (Martin, 2005), and the construction of water storage facilities and public irrigation works (Connell, 2007). By the 1980s an over allocation of statutory water rights had led to increasing pressure for water rights to be separated from land, and be tradable so as to access increasingly scarce water. This led to the establishment of water markets for permanent water in the States of South Australia in 1982, New South Wales and Queensland in 1989, and Victoria in 1991 (Murray-Darling Basin Commission, 1995, p.37). Further reforms to water trading and the register of water entitlements occurred in the 1990s following an agreement by the Council of Australian Governments (CoAG) in 1994 to separate all statutory surface water rights from land rights (Bjornlund, 2003). This reform greatly boosted water trade and this has been accelerated by further water market reforms in another CoAG agreement in 2004 called the National Water Initiative. Among other commitments, the signatory governments agreed that water entitlements should be exclusive, divisible and tradable and also recorded in public water registers. State governments also committed to the freeing up of the trade of water entitlements across state borders.

A fixed cap on surface water extractions Basin-wide was imposed in 1995, but was implemented at a point when the nominal volumes of water rights within the Basin exceeded the long-term surface water availability. Although the Cap has stopped further growth in water extractions Basin-wide, it has also created a scarcity value for water rights which has helped to trigger the activation of previously unused water licences, called 'sleeper' licences, or rarely used water licences, called 'dozer' licences. The activation of sleepers and dozers has reduced the overall level of reliability of entitlements when these rights were activated (Quiggin, 2008) to the loss of those who held and actively used water licences.

A possible concern asscoaited with higher prices for water rights is that could lead to investments in on-farm water use efficiency that may reduce return flows that arise from water leakage in both water delivery and use. A study by Qureshi et al. (2010) on the Murrumbidgee River in the Murray-Darling Basin shows that, although it is possible for on-farm efficiency improvements to lead to reduced environmental flows overall, this is an unlikely occurrence and would require direct subsidies for irrigation efficiency improvements.

Statutory water rights in the MDB are called water entitlements. They provide the owner with a share of a consumptive pool, but the actual quantities of water that holders of entitlements are permitted to divert depend on the seasonal allocation that is assigned each year to the water entitlement. The seasonal allocation represents an actual volume of water that can be diverted in a given irrigation season. The seasonal allocation, unlike the nominal quantity of the water entitlement is not fixed, but depends on the water entitlement's level of reliability that determines the preferential access to the consumptive pool, the overall limit on diversions in the Basin that are set by catchment, expected inflows into the system, and water storage levels. The higher the reliability of the water entitlements the greater would be the expected frequency of years when the seasonal allocation equals nominal volume registered on the water entitlement. In periods of above normal inflows and high water storage levels, the seasonal allocation should equal the nominal amount on the water entitlement. However, in periods of low inflows or drought the seasonal allocation, at least for low reliability water entitlements, can be much less than the nominal amount on the water entitlement, and possibly even zero.

3. Current Patterns of Water Trade

3.1. The Nature of Water Trading in the US West

All western states allow for water trades, but water markets in the U.S. are generally local, within a water basin and within a state due to differential regulations, institutions, and conveyance opportunities. There are three types of transfers—permanent sales of water rights, short-term leases (1 year), and longer-term leases (up to 35 years or more). Among these, there are transfers among those who use the water for the same purpose—irrigated agriculture for example, or among those with different purposes—agriculture-to-urban or environmental, and transfers within a water basin—where sources are interrelated geologically, or across basins—out of one water region to another. Short-term leases within a basin among those who use water for the same purpose, such as farmers, have been the most common. Longer-term leases and sales of water rights often involve changes in the location and nature of use of water.

Given that water markets are, typically, confined and because there are no central registries of trades, it is difficult to determine the overall extent of water marketing in the western US. Our data are interpreted from transactions listed in the *Water Strategist*. The data are aggregated from 4,220 observations from 1987 through 2008 for 12 western states as compiled from water transactions described in the trade journal (the data is available at http://www.bren.ucsb.edu/news/water_transfers.htm). The *Water Strategist* is a monthly publication that details water transactions, litigation, legislation, and other water marketing activities. The journal publishes each month a 'Transactions' section that lists, by state, various water transfers that typically include the year of the transfer; the acquirer and supplier of the water (both labelled variously as municipality, developer, company, irrigator, farmer, rancher, conservancy district, irrigation district, state, federal agency, etc.); the amount of water transferred; the proposed use of the water; and, if applicable, the terms, such as the price and nature (lease or sale) of the contract. In developing the dataset, we often have to interpret entries in the journal where the discussion is unclear as to the nature of the trade (our methodology is described at: http://www.bren.ucsb.edu/news/water_transfers.htm). The data only include transactions reported by the journal, and hence, is not comprehensive because transactions are likely to be missed, especially those that take place within organizations, such as irrigation districts. Nevertheless, the entries are among the largest available across states, and hence, likely capture the general pattern of water trading.

Figure 1a illustrates the yearly path of transfer volumes in the 12 western states from 1987 through 2008 by the type of contract used: sales of water rights; one-year leases; and multi-year leases. Although one-year leases of water rights appear to have been the most active type of trade in terms of per-year volume, this is misleading. Sales commit water permanently to a new user. Therefore, a sale of water in a given year actually commits that quantity of water in perpetuity. Figure 1b shows the total committed water transferred each year by contract type. These "committed" quantities are calculated following the procedure outlined in (Brewer *et al.*, 2008, p.99). Water quantities are projected forward and the quantity discounted back at 5% in a manner analogous to finding the present value of a multi-year bond so that a comparison can be made between one-year leases and permanent sales. Like a financial perpetuity, a purchased water right continues to provide access to the same volume of water indefinitely into the future. Committed flow, like present value, is a construct to improve understanding.

Figure 2 shows the price differential between one-year leases and permanent sales in dollars per committed ML (one ML = one million liters) in 11 western states excluding Colorado. Colorado is excluded because the large number of high-price, low-volume sales in the Colorado-Big Thompson Project (discussed in a later section) overwhelms the general trends in median prices in other states. The patterns in the figure indicate that although the committed measure compares one-year lease prices with the value of a one-year supply of permanently traded water, in recent years there has been a premium paid for permanent rights. This is not an historic rule, however, as observed during the significant drought that hit the Western US in 1987-1992. In this time period, it was not uncommon for one-year lease prices to exceed the committed price of permanent transfers as parties sought additional short-term water sources.

Transactions vary substantially across the states reflecting differences in water supply and demand, as well as differences in property rights and regulatory institutions. Colorado dominates in terms of total quantity of market transactions, where most are sales water. Sales as a share of transactions also are important in the most arid states of Arizona, Nevada, New Mexico, and Utah. Short-term leases (1-year) are most common in California and Texas. Sales and long-term leases are limited in California, for example, by county ordinances that prohibit exports of water, and irrigation district bylaws that limit out-of-district trades.

3.2. The Nature of Water Trading in Murray-Darling Basin

In Australia, both entitlements and seasonal allocations can be traded. Water trade in the Murray-Darling Basin accounts for about 60% of all entitlement trade and over 80% of seasonal allocation trade in Australia. By volume, over 12% of all water entitlements were traded in 2008-09 (National Water Commission, 2009, p.5) while about 20% of seasonal allocations were traded over the same period (National Water Commission, 2010a, p.21). For the period 2009-10 total water entitlement trade was over 1,800 GL (one GL = one thousand million liters) in nominal volumes of water while seasonal allocation trade totaled over 2,300 GL (National Water Commission, 2010b, p.5). The total value of turnover in entitlement trade was about $2 billion and in terms of seasonal allocations about $500 million in 2008-09 (all prices are given in US dollars while Australian dollars are converted at par because as of November 2010 1$US = $1Aus).

After seasonal allocation trade was permitted in the 1980s, the MDB water market expanded greatly. Substantial increases in trade occurred in the 1990s coincident with the freeing up of the water entitlement trade, and again in the past five years as a consequence of the drought. Figure 3 shows the growth in the water traded by volume for water entitlements and seasonal allocations over the past 25 years. The trade in terms of volumes for seasonal allocations has typically been much greater than water entitlements, but water entitlement trade has expanded at a faster rate in the recent drought as irrigators have sought to readjust their portfolios of entitlements in terms of their reliability.

The millennium drought that lasted about a decade and that ended in 2010 fostered greater trading because of the dramatically reduced seasonal allocations of water. The drought led to zero opening seasonal allocations for many low reliability water entitlements in the recent past, and historically low allocations to high reliability water entitlements at the start of the irrigation season. To make up the shortfall those irrigators with high marginal values of water entered the water market to secure water that, in the past, they would have received as seasonal allocations assigned to their own water entitlements. As a result, the volume of water trade has risen steeply. For instance, water entitlement volume trade increased by 75% between 2007-08 and 2008-09 and increased by a further 20% between 2008-09 and 2009-10 while seasonal allocation volume trade rose by 41% between 2007-08 and 2008-09 and rose an additional 22% between 2008-09 and 2009-10 (National Water Commission, 2009, p. 5; National Water Commission, 2010b, p.5).

Beneficiaries of water trading in the MDB include, but are not limited to, perennial-crop farmers who irrigate orchards and vineyards and who, despite having high-reliability water entitlements, found during the millennium drought that their assigned seasonal allocations were less than they expected and required. Without the ability to purchase seasonal allocation water during the worst years of the drought, many of their vineyards and orchards would have suffered major harm or died. Sellers of seasonal water have also benefited as the increased volume of sales, at high water prices, provided an important source of income that has helped offset reduced irrigation and associated crop production.

Market prices have responded to changes in supply and demand. For example, the severest years of the drought from 2006-2008 coincided with a peak in seasonal allocation prices, as shown in Figure 4. Higher prices have encouraged investments in on-farm water efficiency and have contributed to annual productivity improvements of about 3% per year over the past two decades (Australian Bureau of Statistics, 2008). The ability to trade and to adjust the volume and mix of high and low reliability water entitlements to reduce risks of insufficient water supplies has also permitted investments in perennial agriculture that may otherwise not have been contemplated.

4. Price Differentials and the Gains from Water Trades

Water markets help mitigate economic scarcity because they allow users with higher marginal values in use to purchase or lease water rights from those who have lower marginal values and, thereby, increase the aggregate benefits of water applications. These trades also produce important information about relative water values for regulators and judges in setting policy and resolving disputes across competing consumptive and *in situ* uses. Thus, large price differences across alternative uses of water that cannot be accounted for by differences in water quality, conveyance or other costs indicate unrealized gains from trade.

4.1. Price Differentials in the US West

In the US, a general lack of regional river basin-wide organisation for market trades makes price comparisons difficult to assemble since most water markets are local and comparable observations of trades within and across sectors are therefore limited. Accordingly, examining available price data must be done with caution, but the patterns are indicative of the benefits from further water re-allocation.

Data assembled by Clay Landry and reported in Libecap (2011a, 2011b) for two regional markets, the Reno/Truckee Basin, Nevada and the South Platte Basin, Colorado, show significant price gaps between agriculture-to-urban and agricultural-to-agriculture transactions. For the Truckee Basin, the median price of 1,025 agriculture-to-urban water sales between 2002 and 2009 (2008 dollars) was $17,685/acre foot (an acre foot = 1,233.482 Cu. M. or 1.233482 million litres) or some $14,337/ML, whereas for 13 agriculture-to-agriculture sales over the same period the median price was $1,216/ML. For the South Platte, the median price for 138 agriculture-to-urban sales between 2002 and 2008 was

$5,285/ML as compared to $4,304/ML for 110 agriculture-to-agriculture sales. Note that the above prices are given as per yearly flow volume.

Aggregating transactions across markets and time can compensate for limited comparable transactions within markets in order to gain a better sense of differences in value across uses. Of the 4,220 transactions in our data set with information on the transacting parties, amounts, and nature of use, a smaller number, 2,765, had price data. Median prices across 12 western states between 1987 and 2008 per volume of committed flow are presented in Table 1 for leases and sales for agriculture-to-agriculture and agriculture-to-urban transactions. The annual mean and median sale and lease prices for agriculture-to-urban transactions are significantly higher than are agriculture-to-agriculture trades. This condition in part indicates the benefits of out-of-sector water transfers. If these price differentials are in excess of the differences in transactions costs, such as those due to regulatory review and conveyance costs, transfers from irrigators to urban users should result in a mutually beneficial exchange.

4.2. Water Price Differentials in the MDB

During the millennium drought the price differentials between urban and rural water users was much less than in the western US. This is because markets are more active spatially across catchments in the MDB, at least in the southern part of the Basin. The market price for seasonal allocations of water varies by catchment and over an irrigation season, but range from $100 to $500/ML, although much lower prices have been recorded ($7/ML), and also much higher (up to $1,200/ML) during record low inflows in 2006-2007. By contrast, urban water consumers living in or near the MDB pay, depending on the city or town and their household consumption, between $1,100 and over $3,000/ML for potable water and Australia wide paid on average $1,930/ML for urban water in 2008-09 (Australian

Bureau of Statistics, 2010, p.44). Given the substantial costs involved in disinfecting and conveying potable water to consumers 24 hours per day, 365 days per year there was essentially no price differential between urban water consumers and irrigators at the bottom end of the prices charged to urban households during the recent drought. However, in periods of normal flows there is a basis for further trade because, even with pumping and water treatment, the price in urban communities is much higher than in rural water markets.

To date there have been relatively few rural-urban water trades (Quiggin, 2006). South Australia purchased 18 GL of water entitlements in 2005 to provide additional urban water supplies (South Australia Water, 2006). The State of Victoria has spent over $700 million to construct pipelines from its northern catchments to pipe over 100 GL/year of water to towns and cities in the South. The Australian Capital Territory government, and its private-sector partner, is building a pipeline to pump water from the Murrumbidgee River, one of the largest tributaries to the Murray River, to a storage facility. After the pipeline is built, the plan is to access rural water by purchasing water entitlements to provide an additional source of supply of up to 20 GL/year.

4.3. Gains from Greater Market Trading in the Western US

The growing urban population in the American Southwest, with US Census data locating all 10 of the US counties adding the most population between 2000 and 2010 in Arizona, California, Nevada, and Texas, indicates that water markets can provide substantial welfare gains in these states by transferring some water from agriculture to urban use. We can estimate the potential welfare gains under varying scenarios of a hypothetical increase in water trading from the agriculture to urban sector. In 2009 the US Geological Survey (USGS) published water diversions by state for 2005 (Kenny *et al.*, 2009). Using those measures as indications of long-term water diversions and the annual trading data from the Water Strategist (2008), it is possible to present those trades as a share of the USGS 2005 data. The most rural states, Idaho, Montana, and Wyoming, have markets which annually trade, in committed acre-feet, less than 3% of their total freshwater withdrawals (excluding thermoelectric withdrawals). For the key states of Arizona, California, Colorado, Nevada, and Texas, trades of committed water annually range between 5% and 15% of total state freshwater diversions. Data from *Water Strategist* indicate that over $4.3 billion (2008 $) was spent or committed by urban buyers between 1987 and 2008, with nearly $4.18 billion spent by urban buyers in the five key states indicated above.

Price differentials indicate possible welfare gains from increased urban acquisitions. For example, Table 2 reports the potential yearly welfare benefit of transferring 5% of the water currently used for irrigation to urban users at the median historical prices for both sectors. These indicative values are estimates of the relative social gains from moving some water from agriculture to urban use. They illustrate that the potential gains from rural-urban water trade for the five states, excluding Colorado that faces high conveyance costs in moving water to where the urban population is located, is in excess of $50 million/year. Although there is a limit to the amount of agricultural water urban areas will buy before agricultural water prices rise and urban prices decline, for Arizona, California, Nevada, and Texas, high urban growth indicates strong continuing demand. Arizona, which has a centralized population and sufficient transportation infrastructure in place, already trades more water as a percentage of total volume extracted of any western state. It, therefore, has more modest gains from increased transfers by our methodology, but there still exist significant price differences at the margin. For example, *Robert Glennon* reports (2002, p.207) that land developers near the Grand Canyon National Park offered more than $16,000/ML in 2001 for Colorado River water used by farmers in the Imperial Irrigation District (IID) who paid about $11.00/ML.

4.4. Gains from greater water trading in Australia:

Peterson *et al.* (2004) use a computable general equilibrium model to estimate the benefits of water trade in the MDB. The gains from trade within catchments and across states are greatest in years of below normal inflows, and are worth approximately $700 million ($2008) while in a year with above normal inflows the gains are estimated at $300 million ($2008). This approach, and that applied to valuing water-trading in the MDB below, differs from the approach used above with the US data. Because the MDB is a single basin, it is possible to approximate the full-equilibrium affects of complete water trading. In the US dataset, each state's data encompasses several basins. Although some inter-basin trading does take place, valuing potential gains using a free trade model would dramatically overestimate the capacity of infrastructure from the basins where water is sourced to cope with water removal. Thus, the partial-equilibrium model we employ in the US West based on marginal transfers better accounts for the limited nature of potential inter-basin transfers in that region.

The most up-to-date and comprehensive review of water trading in the southern MDB was completed by the National Water Commission (2010a) in June 2010. Its key findings include: water trading increased the gross domestic product of Australia by some $220 million in 2008-09; it raised the gross regional product of the southern MDB by some $370 million; the gains from trade by state were New South Wales ($79 million), South Australia ($16 million) and Victoria ($271 million). The report concludes that, overall, trading between irrigators had a positive effect on the environment during the recent drought because it increased downstream flows that benefitted river systems while trading had no discernible impact on the timing of flows.

There are also likely to be dynamic gains from trade associated with price-induced innovation in farming practices. Such benefits are difficult to quantify, but combined with the static gains from trade help explain why, when there was a 70% reduction in surface water use by irrigators from 2000-01 to 2007-08, the nominal gross value of irrigated agriculture fell by less than 1% (Australian Bureau of Statistics, 2010) although profitability probably fell by a larger proportion because of the high cost of water during the drought.

5. Institutional Challenges that Limit Gains from Trade

The two water markets, while delivering substantial gains from trade, still have considerable potential to increase the benefits of water trade. We review the current challenges to trade in the US west and the MDB of Australia.

5.1. US Water Institutions: Appropriative Water Rights

Appropriative water rights in the US are denominated as *specified amounts* or flows of a highly variable resource stock with senior rights holders given right of use before persons with more junior rights. Consequently, the trading of appropriative water rights by senior rights holders can impose 'third-party' effects on those who are not participants in the transaction such as junior rights holders, especially if the trades move the water downstream of where junior rights holders are located. These effects and their potential for impairment of the holders of more junior rights raises the likelihood of protests and litigation over water trades that can be an important barrier to trade by raising transactions costs. While it is true that until the latter part of the 20th century third-party impairment generally was not an issue because most traded water stayed within the local agricultural community, today, there are much greater pressures to re-allocate water to other uses. Protests of harm from such trades are significant barriers that can keep water locked in lower value uses within agriculture.

Rural communities may also resist water trades to urban areas because of concerns about local economic shocks, such as reductions in demand for agricultural labor and farm equipment. Surface water trades can also lead to excessive aquifer withdrawal—22 of 58 California counties have implemented ordinances to limit surface water transfers if they appear to diminish groundwater resources. Although identifying a legitimate concern, the major intent of these laws is to keep water within rural counties and limit reallocation to urban or environmental uses (Hanak, 2003, p.vii, viii; Hanak and Dyckman, 2003). Additionally, the California State Water Resources Control Board can deny a proposed water transfer if would "unreasonably affect the overall economy of the area from which the water is being transferred."(CA Water Code § 386).

Concerns about pecuniary and technological third-party impairment from water trades generate regulatory and political opposition to greater market activity under the appropriative rights system. If instead, water rights were granted as portions or *shares* of the annual total allowable withdrawal from a water basin, adjustable according to precipitation, then all appropriators would share in any adjustments in total diversions due to precipitation shortfalls. Under this setting 'junior' parties would not be differentially impacted by drought or be as dependent upon released flows. Hence, the potential for at least technological third-party harm from trades would be reduced, especially if they are limited to consumptive use (Burness and Quirk, 1980, p.124; Johnson *et al.*, 1981, p.274).

An indication of this modification of appropriative rights is provided by the Colorado Big Thompson Project (CBT) in northern Colorado, where property rights are assigned via water shares rather than fixed quantities. CBT water is allocated through tradable *uniform* water units, whereby each is a share of the annual amount of water available to the District. The water in each unit fluctuates annually based on water supply, and all shares are adjusted in the same manner. Because shares are homogenous, transfers across users, especially across sectors, occur with minimal fees and paperwork (Thompson, 1993, p.719; Carey and Sunding, 2001, p.305; Howe and Goemans, 2003, p.1058-9). Additionally, the Northern Colorado Conservancy District administers proposed trades and because the water is imported from another basin, all return flows are owned by the District and cannot be claimed separately by other parties. This provision reduces conflicts over potential third-party impairment in water trades. For these reasons, the Colorado Big Thompson is by far the most active water market in the West in terms of numbers of trades, and sales prices for all uses are comparable.

Given the long-standing nature of appropriative water rights in the US West, it seems unlikely that they would be broadly replaced by water shares. The distributional issues and uncertainties associated with such re-allocation would be too large. Nevertheless, there is innovation in rights structures in some areas, such as those described by Richards (2008) in New Mexico. In five severely over-allocated and important water basins in New Mexico, appropriative rights have been voluntarily modified to protect high marginal value junior rights holders and to stop excessive withdrawals in the face of growing demand and highly-variable supplies.

5.2. Trade Restrictions in the Murray-Darling Basin

As in the US west, trade restrictions can limit water trade and the potential benefits of water markets. Despite the fact that water worth billions of dollars is traded every year in the MDB, there is virtually no trade of water entitlements across states. While most of the gains from trade appear to come from intra-regional trade (Qureshi *et al*., 2009), restrictions across regions and states reduce the potential benefits of water markets. One of the more important barriers is the so-called 4% rule that was agreed to by state governments as part of the 2004 National Water Initiative, but as temporary measure to help manage regional adjustments from water traded out of irrigation districts. This rule limits out-of-district entitlement trade per year to 4% of the nominal volumes of entitlements in the irrigation district. At the end of 2010, only the state of Victoria has established a legally binding 4% rule and it has been a major barrier to inter-state trade of water entitlements from out of Victoria. The Victorian government has agreed to begin phasing out the rule beginning July 2011 (National Water Commission, 2010a p.2), although it remains to be seen whether this commitment will be fulfilled. In any case, the Australian Competition & Consumer Commission (2010, p.89-109) has also ruled that the 4% rule must be completely removed by 1 July 2014.

Other transaction costs in completing trades across states also have imposed implicit barriers such that there was negligible entitlement trade over the period 2007-2009 (National Water Commission, 2009). Since 2006 inter-state water entitlements have been 'tagged'. This means that the characteristics from the source catchment, in particular the associated reliability, are retained when used at the destination catchment. At the very least, this complicates the portfolio management of entitlements and the delivery of seasonal allocations at appropriate times during the growing season.

A further, implicit constraint on trade is between rural and urban uses. While in many places in the MDB trades could take place between urban water authorities and rural water entitlement holders, such trades have been the exception rather than the norm. This may seem puzzling given the decision to invest multi-billions on desalination plants in cities that can access water from the Basin with existing infrastructure, such as Adelaide and Melbourne. The barrier stems from the state-ownership of urban water authorities, allowing some rural communities to oppose voluntary sales of water from rural areas. Rural communities are concerned that water removed from their irrigation district increases the fixed costs of supplying water to remaining irrigators and may decrease economic activity, and reduce employment. This fear is, to some extent, justified as economic modeling indicates that rural-urban water trade could reduce gross regional product in irrigation areas where water is exported (Dwyer *et al.*, 2005).

A recent study by ABARE (2010) looking at the regional impact of proposed compensated reductions in surface water extractions by irrigators would reduce the gross value of irrigated agriculture in the Murray Darling Basin by about 15% and gross regional product (GRP) by 1.3%. They also predict that the investment in local communities resulting from the buy back of water entitlements from willing sellers and investment in irrigation efficiency would mitigate the fall in GRP to only 0.7%. Further, due to the regional benefits arising from investments in water infrastructure, they find that employment overall would increase by 0.1%. This does not mean, however, that there will be no negative impacts. This is because local communities and small towns that are dependent on irrigated agriculture crops that have a low level of profit per megalitre of water will likely have reduced economic activity. Nevetheless, other studies suggest that issues other than regional water trade have much bigger (positive and negative) impacts on communities than water trade (National Water Commission 2010a). Whatever the cause, an important consideration to policy makers is that communities that may be negatively affected by the sale of water entitlements are given assistance to mitigate these third party effects (Miller, 2011).

Another restriction on trade is the imposition of termination fees on irrigators who wish to sell their water entitlements and exit a defined irrigation infrastructure system. The termination fees are, by federal law, currently no more than ten times the annual access fee. These access fees are fixed charges payable by each irrigator who has water delivered by the infrastructure operator. Termination fees in 2009-2010 in the main irrigation districts of the MDB ranged from about 8% to as much as

27% of the water entitlement sales price. These fees are an impediment to trade, and to the extent that the initial fixed costs in establishing irrigation infrastructure have already been amortized or subsidized by taxpayers, (Musgrave, 2008) are not economically efficient (Productivity Commission, 2010). Whether all the lines and channels in existing irrigation infrastructure can profitably remain in use following water trade or with the buyback of water entitlements for environmental purposes is another important issue, but is not a barrier to trade.

A related issue in terms of trade and risk management is the carryover rights of seasonal allocations from one irrigation season to the next. Carryover rights have been in place since the 1990s and have been widely used in Queensland and New South Wales and introduced more recently in South Australia and Victoria. Carryover rights differ by state and allow holders of water entitlements to carryover unused seasonal allocations so that water can be acquired when necessary provided there is sufficient storage space for the carryover amounts. This means that, during times of drought, they provide irrigators with the opportunity to manage inter-temporal risk by choosing the optimal time to use water allocations (Hughes and Goesch, 2009). To the extent that carryover rights differ by state this may disadvantage irrigators where carryover rules are more restrictive, especially where there are inter-state barriers to the trade of water entitlements. For instance, as of 30 June 2011, seasonal allocation carryover from previous years for South Australian water entitlement holders will be discontinued, placing them at a disadvantage relative to irrigators in Victoria or New South Wales.

6. Concluding Remarks: Opportunities for Reform

Water markets have developed in both the US west and the Murray-Darling Basin in response to physical water scarcity. Necessary conditions for the existence of such markets include: (1) Decoupling of the use of water from land rights; (2) regulatory support for water trading; and (3) large water storage facilities and conveyance systems that provide ability to trade both upstream and downstream and over time. Trade has expanded in both markets in recent years, but especially in the Murray-Darling Basin where institutional reforms and a decade-long drought increased trade to about 20% of the total volume of surface water extracted in 2007-08.

The gains from trade in both markets are substantial and have allowed for a substantially greater value of use from the water available. During the decade-long drought in the Murray-Darling Basin that ended in 2009-2010, water trade allowed high value irrigation users, such as horticulturists, to continue irrigating because of transfers from broad-acre agriculture. Reduced water availability reflected in higher water market prices over this period also induced productivity improvements that have allowed irrigators to maintain their gross value of production with a fraction of the extractions that they previously enjoyed. In the US, the most arid and most urbanized states, Arizona, California, Colorado, Nevada, and Texas have active water markets, with trades of committed water annually ranging between 5% and 15% of total state freshwater diversions. Over $4.3 billion (2008 $) was spent or committed by urban buyers between 1987 and 2008, with nearly $4.18 billion spent by urban buyers in the five key states indicated above.

Despite the clear benefits of water markets, their use in terms of trades across rural and urban uses is limited in both the US west and the Murray-Darling Basin. As a result, water is not allocated to its highest value in use and much more expensive alternatives to supplying water to urban communities, such as desalination have been implemented. In the case of the US west, the restraints in trade are primarily institutional while in Australia they are primarily choices made by state governments to avoid the objections to trade by some rural communities. In both countries, political opposition to expanded water markets is primarily due to fears about third-party impairment. Third-party effects of trade are important and are, typically, not fully considered in private market transactions. As a result, it is important that future research be directed to examining the pecuniaryt impacts on third parties more fully; particularly at the impacts of water trading on irrigation-dependent rual communities.

Existing imbalances in water allocation are indicated by the continuing price differentials between agriculture-to-agriculture and agriculture-to-urban trades in the US, and by the higher prices paid by urban water consumers compared to rural users during normal flow years in Australia. These imbalances, coupled with growing pressure to provide more water to meet environmental, urban, and recreational demands, as well as the high economic and environmental cost of alternative water sources such as desalinization, show there is a great need for research on water markets. Attention should be directed to finding ways to promote water trade while at the same time addressing legitimate third-party concerns, especially conflicts between consumptive and *in situ* uses of water. As recent history has shown in both countries, institutional innovation is feasible and additional information about the size, duration, and distribution of third-party effects can better address legitimate concerns about the impact of water markets and water reform.

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Figure Captions

Figure 1a. Yearly flow volume of water transferred by contract type in 12 western US States.

Figure 1b. Total committed volume of water transferred by contract type in 12 western US States.

Figure 2. Median price of water transfers by contract type in 11 western US States (Colorado excluded).

Figure 3. Trades in Murray-Darling Basin water entitlement and seasonal allocation transfers, 1983-84 to 2008-09.

Figure 4. Case-study of water prices in Murray-Darling Basin, maximum annual price of water entitlement and seasonal allocations traded from Zone 12 of the River Murray-Darling 1990-2010.

Table 1. Water Transfer Prices by Sector 1987-2008 (2008 dollars per committed million liters)

	Agriculture-to-Urban Leases	Agriculture-to-Agriculture Leases	Agriculture-to-Urban Sales	Agriculture-to-Agriculture Sales
Median Price	$60	$15	$239	$117
Mean Price	$154	$45	$354	$199
Number of Observations	229	239	1,140	215

Table 2. Potential Annual Benefits of Additional Water Transfers in US West

State	Total Irrigation Withdrawals per year (ML)	22-year Median Ag-to-Ag/Ag-to-Urban Price Difference in ML (2008 $)	Yearly Gain of a 5% Transfer of Irrigation Water to Urban Users at 22-Year Median Transfer Prices (2008 $)	Current Value of Urban Market per Year (2008 $)
AZ	3,133,044	$14.28	$2,236,598	$25,252,731
CA	19,365,667	$32.72	$31,680,746	$77,992,925
CO	12,334,820	$191.94	$118,380,995	$33,660,033
NV	1,911,897	$142.50	$13,622,001	$19,092,630
TX	10,780,633	$16.34	$8,805,878	$34,065,103