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WATER SCARCITY AND WATER MARKETS: A COMPARISON OF INSTITUTIONS AND PRACTICES IN THE MURRAY-DARLING BASIN OF AUSTRALIA AND THE WESTERN US

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Water Scarcity and Water Markets: A Comparison of Institutions and Practices in the Murray-Darling Basin of Australia and the Western US

by

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Abstract

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 among competing uses. Both locations have been in the forefront of the development of water markets with defined water rights and conveyance structures to assist in the reallocation of water across competing demands. They also share the challenge of managing water with climate variability and climate change. As these two markets occur in developed, wealthy countries, their experiences in water markets with different water rights (appropriative, riparian and statutory rights) provide 'best-case' scenarios of what institutional arrangements work best, indicate which are less effective, and demonstrate what might be possible for greater use of water markets elsewhere in the world. The paper finds that the gains from trade in the MDB is worth hundreds of millions of dollars in per year, total turnover in water rights exceeds $2 billion per year and the volume of trade accounts for over 20% of surface water extractions by irrigators. In 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 with over $4.3 billion (2008 $) spent or committed by urban buyers between 1987 and 2008. Despite the clear benefits of water markets in both locations, there are on-going restrictions to trade that limit the potential gains and also third-party effects from use that require resolution.

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1. Introduction

There is growing worldwide concern about freshwater supplies and their ability to meet new demands. Although fresh water is abundant at a global level, only a tiny amount, less than 0.3 %, is easily accessible for human use [*Dinar et al*., 2007]. An increasing amount of this water is utilized, with global water withdrawals tripling since 1950. 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].

Climate change is likely to exacerbate water shortages by making precipitation more variable, 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 other locations should rapid warming occur [*Fung et al.*, 2010]. Various actions are under consideration to augment supplies and to contain the growth in demand through desalinization; increased dam, reservoir, and aqueduct construction; and more conservation and metering of current water use. Investment in desalination alone is expected to be worth $90 billion over the period 2010-2016 [*Pike research*, 2010] while total investments in all forms of water infrastructure are estimated at $75 billion annually [*World Water Vision*, 2000]. Given the high cost of supply augmentation, alternative approaches must be developed for relatively low value but high consumptive uses of water uses, such as in agriculture, where much current consumption takes place.

Markets that allow water to be traded from low-to-higher-value uses are an important means to mitigate the effects of scarcity by facilitating a greater net value of production from a given supply, encouraging investment, and generating price signals about opportunity costs. Water markets can be limited to particular types of consumptive uses, such as for agriculture, or be applied across a range of alternative consumptive uses such as between rural and urban sectors, and also *in situ* uses. Given that irrigation accounts for about 70% of all freshwater globally appropriated for human use [*World Water Assessment Program*, 2006, p. 245], with at least some of it applied to comparatively low-valued irrigated farming, there can be substantial gains from trade for both sellers and buyers of water from voluntary rural-urban trades.

The growing interest in water markets has arisen from the recognition that 'cap and trade' mechanisms can promote economic efficiency across competing uses for a variety of natural resources [*Costello et al*., 2008; *Stavins*, 2007]. Markets help mitigate water 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 uses and 'in situ' use. Consequently, water markets can facilitate more rapid and flexible adaptation to new demands and to climate change, processes that are especially important for arid and semi-arid regions.

Two areas of the world that have been in the forefront of the development of water markets include Australia's Murray-Darling Basin (MDB) and the US West. Unlike many other places, both locations have defined water rights and conveyance structures to assist in the reallocation of water across competing demands. They also face growing water scarcity associated with climate variability and climate change. As these two regions exist in developed, wealthy countries, their experiences in water markets provide 'best-case' scenarios of what institutional arrangements work best, indicate which are less effective, and demonstrate what might be possible for greater use of water markets elsewhere in the world. There are also important differences in the two regions regarding the nature of water rights and the extent of water markets that provide guidance as to what approaches have coped effectively with increasing water scarcity. We provide the first detailed comparison of their water rights and regulatory structures; the extent of water trading; and estimate the gains from further trades in the MDB and the US West. The insights from our evaluation provide guidance as to the potential of water markets to mitigate water scarcity among competing users.

In the following section we outline our theoretical framework and methods of analysis and comparison. Section III focuses on the extent of water trading and the underlying institutional framework in the two regions. Section IV outlines existing patterns of water trading. Section V gives evidence of further gains from trade by examining water price data in urban and agricultural uses and provides estimates of the economic gains from trade. Section VI turns to the institutional framework that exists in the two countries to help explain the differential patterns observed. Concluding remarks about Australian and US water market experiences are provided in section VII.

2. Methods

2.1. Theoretical Concepts

All markets require an exchangeable right to a flow of benefits in excess of transactions costs; otherwise there is no basis for trade. The less secure are water rights, such that there is greater uncertainty over the ability to access the flow of benefits and the smaller those gains, all else equal, the lower will be the willingness to pay.

When markets 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. 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 social gains from reallocating water from lower to higher-valued uses. In the absence of conveyance or other transaction costs, the marginal net benefits of water should be equalized and it is possible to conclude that the allocation is Pareto efficient. We use this notion to evaluate the performance of water institutions in the western US and the MDB.

A water allocation is Pareto efficient if no user can be made better off with a reallocation without making any other user worse off. Competitive, voluntary markets by definition are Pareto efficient, in the absence of third-party effects, and this result is known as the First Fundamental Theorem of Welfare Economics. If we identify the maximum willingness of the buyer to pay for the water, B, and subtract the opportunity cost of the seller, the maximum value of an alternative use, S, we have the net gain from trade, B-S. If the price of the transaction were P, then B-P of the gain goes to the buyer, while P-S goes to the seller. This simple framework provides a useful method for demonstrating the potential gains from water trade in the western US and Australia, holding differences in water quality, conveyance, and possible impacts on third parties constant.

In water markets, increased water scarcity is revealed by gradually rising equilibrium prices. That is, as demand grows for a fixed stock of water (due to new uses, higher incomes, and so forth), prices rise. Similarly, if supply declines then the remaining water has a higher marginal value forcing existing demanders either to pay more or to cut back consumption, equating their marginal values with the new higher supply price. For these reasons, rising water prices in real terms in competitive markets are indicators of increased scarcity. In this sense water scarcity is comparable to scarcity in other resources that can also be measured by a rising price [*Brown and Field*, 1978; *Barnett and Morse*, 1963].

Water markets in both the MDB and US west are less than ideal, particularly due to third-party effects and high conveyance and regulatory costs that limit trades between prospective buyers and sellers. Markets, especially in the US are often very local and limited in number of trades, but as we show, this is gradually changing. Water quality differences also affect water values and prices. In our analysis, we assume water is of similar quality, although we often cannot directly control for quality in the data available to us. Similarly, regulatory costs limit trade although there may be legitimate reasons for regulating water exchanges due to the potential for negative impacts on non-trading parties. The manner in which regulation takes place also influences its cost, and in our analysis of the institutional structures in the US and Australia, we compare regulatory arrangements that appear to promote trade and those that do not.

2.2. Other Methodological Issues

2.2.1. Volumes of water traded

The US data on water transactions include sales, long-term leases, and short-term (one year) leases. In the MDB prices are for annual volumes of water called seasonal allocations and for water rights, called water entitlements that provide the holder a share of the consumptive pool of water in a given catchment in perpetuity. Seasonal allocations in the MDB are comparable to a one year lease in the US west, which we term, annual flow. Prices for one year contracts present no problem in terms of comparisons, but multi-year leases and sales commit water long term and hence, the annual flow amount understates the volumes of water traded. Accordingly, following the procedure outlined in *Brewer et al.* [2008, 99], for all multi-year contracts in the US we project the water quantities forward and discount back at 5% in a manner analogous to find the present value of a multi-year bond. We label this contracted amount, committed water.

2.2.2. Calculating the gains from further market trades.

To take advantage of the price data that we do have, we use the notion of Pareto dominance to derive a method for finding gains from trade with real-world data. Historically, most water has been used in agriculture in the US West and the MDB. There are active markets between agricultural users typically involving short-term trades. Because the water does not leave the basin where it is sourced, conveyance costs are low and there are few third-party effects as unconsumed, released flows remain in the area. Water quality also is homogeneous. For these reasons, agriculture-to-agriculture transfers often occur routinely and do not require regulatory review.

There is also an additional demand for water from growing urban populations in the US West, and agriculture-to-urban transfers are more complicated in terms of understanding the gains from trade. Water may leave the basin or watershed so that return flows are no longer available and, thereby, impose costs on third parties that would have otherwise use the return flows (third-party impairment). Accordingly, there are often regulatory reviews of proposed trades that add to transaction costs. These reviews may require that less water be traded or that compensation be paid to the parties that may be injured. In addition, conveyance costs typically are greater and urban demanders require higher quality and more secure water. These factors add to the supply price of water, and will lead to a divergence between agricultural and urban water prices. Any reduction in these costs (lower conveyance charges, smoother regulatory processes) will allow more water to be transferred.

Observed differences between the prices of agriculture-to-urban transfers and agriculture-to-agriculture transfers represent the maximum potential economic gains from trade. We can estimate these gains by multiplying the price difference times an amount of water to be moved from one use to another after accounting for differences in supply and treatment costs. If the amount of water in each transaction is small relative to overall consumption either in agriculture or in urban use, then marginal values will not change appreciably due to the transaction, and the exercise will indicate the potential benefits from trade.

2.2.3. Water Rights in US West

In the US West, most water is owned through appropriative water rights. The appropriative doctrine emerged in the 19th century in response to the development of mining and agriculture in the semi-arid West 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. Instead, individuals hold *usufruct* rights that are capitalized into land values and that transfer with the land or that can 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 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, 282; *Smith*, 2008, 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 drought, water is progressively rationed according to priority of the right, and junior diversions may be halted.

Appropriative rights are conditional upon water being placed into beneficial use—the 'use-it-or-lose-it' mandate─ and no injury to third parties. If not used beneficially, the right may lapse under the doctrine of abandonment. Beneficial use is a low-cost way of determining if there is excess water to be appropriated. 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]. Beneficial use, however, contributes to waste as rights holders devote water extensively to low marginal-value 'approved' applications in order to maintain ownership and neglect 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.

2.2.4. 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: 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 government agreed that water entitlements should be exclusive, divisible and tradable and also recorded in public water registers. State government also committed to the freeing up of the trade of water entitlements across state borders.

The imposition of a fixed cap on surface water extractions Basin-wide, imposed since 1995, was coupled with an allocation of the nominal volumes of water entitlements in excess of the long-term surface water availability. As a result, although the cap has stopped further growth in water extractions Basin-wide it also triggered the activation of previously unused water licences, called 'sleeper' licences, or rarely used water licences, called 'dozer' licences. The activation of sleepers and dozers 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.

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. Water Markets in the US West and the Murray Darling Basin: Current Patterns of Water Trading

Notable reviews of water trading include: *Easter, Rosegrant and Dinar* [1998; 1999], *Howe, Schurmeier and Shaw* [1986], *Rosegrant and Binswanger* [1994], *Saleth and Dinar* [2000], among others. These studies focus on the benefits of water markets and provide guidance as to how they may be improved, typically from an economic efficiency perspective. Our goal is to detail the origins, constraints and outcomes of two of the world's largest water markets. We show how water markets can, and do, function in very different legal and institutional frameworks, and what this implies in terms of efficiency. Prior to making comparisons across the two water markets we provide an overview of current water market activity beginning with the US west.

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, typically 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 *Water Strategist* 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 *Water Strategist,* and hence, is not conclusive because transactions are likely to be missed, especially those that take place within organizations, such as irrigation districts. Nevertheless, the entries are among the most comprehensive 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. As discussed previously, 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.

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 state 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 premium paid for permanent rights. This is not an historic rule, however, as seen 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. 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

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*, 2010, p.21]. For the period 2008-09 total water entitlement trade was over 1,000 GL (one GL = one thousand million liters) in nominal volumes of water while seasonal allocation trade totaled some 1,700 GL. 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 to 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 increased by close to half, in terms of volume, from 2004-5 to 2007-08 and increased by 75% for entitlement trade and by 40% for seasonal allocation trade between 2007-08 and 2008-09.

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, have found 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 millennium 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. Potential for Additional Water Trades

4.1. Price Differentials in the US West

Water price differentials across different uses can signal the opportunity for beneficial exchange. In the US case, price comparisons are difficult to assemble because most water markets are local with limited comparable observations of trades within and across sectors. 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* [2010a, 2010b] 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 liters) 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 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 are presented in Table 1 for leases and sales for agriculture-to-agriculture and agriculture-to-urban transactions. These prices are given per volume of committed flow, so that a comparison can be made between one-year leases and permanent sales. 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 Pareto dominant allocation.

4.2. Water Price Differentials in the MDB

During the millennium drought the price differentials between urban and rural water users was much less that 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.

5. Estimates of the Welfare Gains from Further Water Transfers

5.1. Gains from Greater Market Trading in the Western US

Given the observed differences in water values between agriculture and urban applications, we can estimate what the welfare gain might be 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*, 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, if we examine the five states mentioned above the potential gains from moving water from agriculture may be significant. We assume that the benefit to urban buyers of the additional water remains at the prevailing agriculture-to-urban market price. (The net gain is this value, less the opportunity cost of water in agriculture as approximated by the agriculture-to-agriculture price.) Table 2 reports the 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 values provide estimates, for the first time, of the relative social gains from moving some water from agriculture to urban use. Because this exercise proposes transferring a relatively small amount of irrigation water, it minimizes the potential impact on water prices in agriculture and urban areas.

The nature of available water price data dictates the broad approach used here in estimating the returns to greater water transfers. The revealed gains can be interpreted as the potential benefits from further water transfers. In the five key states, water trades captured by the dataset total more than $190 million per year. In Colorado, high conveyance costs in moving water from the west slope of the Rocky Mountains to the east where the urban population is located leads to an overly optimistic estimate of gain. Nevertheless, our estimate excluding Colorado indicates a yearly $56 million welfare gain (over $1.1 billion in perpetuity, at a 5% discount rate). 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.

5.2. 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* [2010] 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].

6. Water Institutions

6.1. US Water Institutions: Appropriative Water Rights

Appropriative water rights allow water to be separated from the land provided it has a beneficial use and, as such, provide a basis for water trades and water markets across users and sectors. Additionally, when water rights have been secure enough, they have promoted private and government investment in a reliable water supply and delivery infrastructure that has expanded agriculture and urban development in the semi-arid American West [*Hansen et al.* 2010, *Libecap*, 2010a]. All of this has been in general, positive but there are also issues of concern.

Under prior appropriation there is a critical interdependence among diverters from the same water source with different priority rights. As much as 50% of senior diversion is not consumed by plants or evaporation, and flows back to the stream or percolates down to the aquifer to be available for subsequent users [*Young*, 1986, 1144]. 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 these return flows. Actions by senior rights holders to change the location, nature, or timing of use can affect water consumption and, thereby, 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 insure that no damage is inflicted on junior diverters [*Getches*, 1997, 161].

Applications for transferring rights are filed with the relevant state regulatory agency for approval. The applicant specifies the location and amount of water, the duration of the contract, the timing of the exchange, type of water right involved, consumptive use, and possibly hydraulic and other legal information. Objections can be lodged, and the burden of proof of non-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, 704-5].

By assigning ownership to *specified amounts* or flows of a highly variable resource stock, appropriative water rights exacerbate third-party effects occasioned by trades initiated by senior rights holders. The potential for third-party impairment raises the likelihood of protests and litigation by junior rights holders over water trades. Conflicts over claims of third-party impairment can be an important barrier to trade by raising transactions costs.

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 where demand was concentrated. In the face of contemporary pressures to re-allocate water to other uses, however, protests of harm can be significant barriers to trade. The standard of ‘harm’, however, can be so vague and the range of standing so broad for parties to challenge proposed exchanges that they can become mired in costly disputes and delay. This situation tends to keep water locked in agriculture even though there are higher marginal values elsewhere.

Rural communities often resist water trades to urban areas because of concerns about reductions in demand for agricultural labor and farm equipment and, hence, overall economic conditions. Indeed, as of 2002, 22 of 58 California counties had 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, vii, viii; *Hanak and Dyckman*, 2003]. Additionally, the California State Water Resources Control Board also 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].

Given that most water transferred from agriculture comes from marginal low-valued uses, the estimated broader pecuniary effects appear to be small. Research [*Hanak*, 2003, x-xii, 72, 81; *Howitt*, 1994] indicates that the effects of fallowing irrigated farmland are likely to have no more than a one percent effect on overall county economic activity, even when payments for economic adjustments are not included. Further, other research [*Libecap*, 2007, 2009] shows that in the case of the famous water transfer between Owens Valley farmers and Los Angeles, often pointed to as an example of the negative consequences of agriculture-to-urban exchanges, the alleged negative consequences did not take place. The added water supply delivered via the Los Angeles Aqueduct made the rapid growth of Los Angeles possible, and analysis of the prices paid by the city for water rights and land reveals that farmers did much better financially than if they had stayed in agriculture. Moreover, those who joined bargaining pools received significantly higher prices.

Despite all of this, 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, 124; *Johnson et al.*, 1981, 274].

In the Colorado Big Thompson Project (CBT) in northern Colorado, property rights are assigned via water shares rather than fixed quantities. The 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, 719; *Carey and Sunding*, 2001, 305; *Howe and Goemans*, 2003, 1058-9]. Additionally, the Northern Colorado Conservancy District administers proposed trades rather than the larger and more politically and institutionally complex Bureau of Reclamation (BOR). As imported water 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. For example, sample agriculture-to-urban and agriculture-to-agriculture sales were priced at $9,350 and $9,300/unit respectively, as reported in the October 2008 *Water Strategist*, p. 7.

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.

6.2. US Water Institutions: Irrigation Districts

Water supply networks require initial fixed investments in dams, reservoirs, canals, and feeder ditches to capture, store, and deliver water. A variety of water supply organizations have developed in the US West [*Libecap*, 2010a]. Among the most important are irrigation districts. They also pose important implications for contemporary water markets.

Irrigation districts covered 4% of irrigated acreage in the West in 1910 and nearly 25% by 1978 [*Bretsen and Hill*, 2006, 293, 312-27]. Many districts, however, have rights to very large amounts of water. One of the country's largest irrigation districts, the Imperial Irrigation District of Southern California, annually diverts 3,450 GL of Colorado River water, nearly two-thirds of California's legal share of the river. The district includes 495,000 acres of cropland as well as urban areas.

Irrigation districts vary across the western states. In general they are political subdivisions and have eminent domain powers to avoid hold-up in laying the network; ability to tax all lands within the district to cover expenses; power to coerce membership in the district once the required majority of voters agree; and authority to issue tax-exempt bonds for construction, backed by assessments against the land within the district. Districts are launched by petitions to county commissioners from land owners seeking to construct an irrigation network. Their irrigation plan is reviewed and subject to vote. The nature of the franchise and required approval majorities varies among the states with important long-term ramifications for water rights and governance of irrigation districts.

In many states, only land owners within the proposed district vote and comprise the governing board. These organizations may be called private irrigation districts. By contrast, in California, Idaho, and Kansas as a trade-off for receiving governmental powers, all registered voters are eligible to select the governing board. A wide franchise grants decision making over water rights, allocation, and management to a diverse group of interests, ranging from land owners, tenants, agricultural equipment sellers, farm labor, school district officials, and so forth. Given such heterogeneity, interests are difficult to merge and water trades complex [*Thompson*, 1993, 678, 728, 740; *Rosen and Sexton,* 1993, 40-1, 49-52; *Bretsen and Hill*, 2006, 320-23; 2009, 737]. These may be called public irrigation districts.

Concern about possible third-party effects resulting from reduced demand for agricultural labor or farm machinery following a switch to less water-intensive crops or fallowing land are important factors in community opposition to water trades. As marginal water values outside of agriculture have become much higher than those within it, long-term transfers increasingly are to out-of-district users. Potential revenues to water sellers, especially, are large for districts near urban areas or with conveyance to them. For example, *Robert Glennon* reports [2002, 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.

In light of the high prices offered for urban water there is potential for opportunism as additional claimants attempt to secure a portion of the rents. Resolving the many disputes that can arise in the presence of large numbers of varied parties can be especially difficult and hence, delay, reduce, or block water trades.

The implications of irrigation district structures for water trading are illustrated by the comparative experiences of two California districts, the public IID and the nearby private Palo Verde Irrigation District (PVID), where only landowners determine board membership and policies [*Rosen and Sexton*, 1993, 43-51; *Haddad*, 2000, 74-92; *Glennon*, 2009, 258-71; *Bretsen and Hill*, 2009, 756-60].

Negotiations between the IID governing board and officials of the Metropolitan Water District of Southern California (MWD) and the San Diego County Water Authority (SDCWA) for long-term water leases occurred between 1984 and 2003. Only after the intervention of the U.S. Department of the Interior that administers Colorado River water, and that supported a re-allocation of IID water, was an agreement finally concluded in 2003 to transfer over 3,700 GL to urban users over 75 years.

Negotiations between the PVID governing board and the MWD, by contrast, were much smoother, faster, and less contentious. The PVID also is a large district, irrigating 131,298 acres with 555,067 ML of water diverted annually from the Colorado River. One set of negotiations over water began in 1986 and were successfully concluded in 1992. Another started in 2002 with agreement in 2004. Both involved dry-year options, whereby farmers were to fallow designated land when requested by the MWD and to release the water to the agency for urban delivery [*Haddad*, 2000, 95-115].

As with appropriative water rights, it is unlikely that public irrigation districts will be replaced, although decision making could be streamlined to promote water markets. The key problem presented by public irrigation districts is that they ‘dilute’ decision-making over water use and distribution among a large number of diverse interests, and hence, raise the costs of exchange. Their arrangements are important reasons why in some states like California contemporary water markets remain local and largely directed toward trade among irrigators, despite apparent high marginal values outside of agriculture.

6.3. Trade Restrictions in the Murray-Darling Basin

Almost all of the water entitlements trade occurs within each state in the MDB and there is negligible trade 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*, 2010 p. 2], although it remains to be seen whether this commitment will be fulfilled. In any case, the *Australian Competition & Consumer Commission* [2010, 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 entitlement also have imposed implicit barriers such that there was negligible water entitlement trade over the period 2007-2009 [*National Water Commission*, 2009]. Since 2006 inter-state water entitlements have been ‘tagged’ such that the characteristics from the source catchment, in particular the 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 such 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, such as Adelaide and Melbourne with existing infrastructure. The barrier to rural-urban trade is that urban water authorities are state-owned and voluntary sales of water from rural areas are opposed politically in some rural communities. This is because 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 from where the water is traded out [*Dwyer et al.*, 2005]. These concerns have discouraged state politicians, and thus urban water authorities that are answerable to state ministers, from pursuing substantial rural water purchases. The one exception has been the construction of a pipeline from the Murray-Darling Basin to provide up to 75GL/year of water to Melbourne. As of November 2010, the pipeline has been constructed, but because of concerns of communities from where the water is sourced, the newly elected Premier of Victoria, Ted Baillieu, has publicly stated that the pipeline will be permanently shut down and will not transfer water to Melbourne [*Baillieu*, 2010].

Another restriction on trade is the imposition of termination fees of 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].

A related issue in terms of trade and risk management is 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. During times of drought they provide irrigators with the opportunity to manage inter-temporal risk [*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 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 that will place them at a disadvantage relative Victorian or New South Wales irrigators.

6.4. Overuse and overallocation of surface water in the Murray-Darling Basin

A fundamental problem in the MDB is the over allocation of water entitlements such that surface water entitlements exceed the amount available for diversions. This arose from a massive expansion in irrigation post World War II, primarily in the Southern MDB, that coincided with a period of high inflows. For instance, average surface water availability over the period 1951-2000 was over 17,000

GL/year, despite substantial year-to-year fluctuations. By contrast, water availability was about 50 per cent less over the period 1900-1950 and was less than a third of this amount over the period 2001-2007 [*Wentworth Group of Concerned Scientists*, 2010]. As a result, an independent audit of the Basin, the *Sustainable Rivers Audit* released in 2008 rated the health of 23 river valleys in the MDB. The 2008 audit found that 20 out of 23 river valleys were in very poor (13) or poor (7) health [*Davies et al.*, 2008]. These environmental outcomes are related to the level of extractions as proportion of pre-development flow. For instance, *CSIRO* [2008] calculates that the relative level of surface water use in the MDB is 'extremely high' and will get worse based on median climate change projections to 2030 under current water planning arrangements.

Although Australian state governments have the legal authority to appropriate water entitlements without compensation, governments have eschewed this option because of the impact on irrigators and their communities. Instead, beginning in 2004, Australian governments have undertaken buybacks of water entitlements and subsidized investments in water efficiency improvements. Initially, the goal was to recover 500 GL of water for environmental purposes. This program was greatly expanded in 2007 and updated in 2008 with funding from the Australian government that includes planned spending until 2018 of $3.1 billion for the purchase of water entitlements [*Burke* 2010], and up to about $5.8 billion to promote efficiency and productivity of water use in irrigation [*Department of Sustainability, Environment, Water, Population and Communities*, 2010a].

The planned buyback of water entitlements and irrigation infrastructure subsidies have been accompanied by a basin-wide planning process that led to the release in October 2010 of guide documents to a proposed Basin plan due to be released in 2011. This Basin Plan is a legislative requirement under the *Water Act 2007* that tries to give effect to the object "… to ensure the return to environmentally sustainable levels of extraction for water resources that are overallocated or overused" (Water Act Section 3, paragraph (d)). The consultative documents recommend that environmental flows should be increased between 3,000GL/year and 4,000GL/year [*Murray-Darling Basin Authority*, 2010, xxi]. These volumes are specified as long-term averages such that in periods of sustained low inflows the volumes allocated to the environment would be less than average, while in period of sustained above-normal flows the volumes allocated to the environment would be greater. Given that the proposed environmental volumes in most catchments within the MDB exceed current environmental flows, based on terms of long-term averages, there will need to be a reduction in water interceptions and/or extractions from water courses in most parts of the Basin.

As of 30 October 2010 the Australian government had holdings of water entitlements equivalent to 806 GL in registered water entitlements [*Department of Sustainability, Environment, Water, Population and Communities*, 2010b] and had delivered over 200 GL in environmental flows form these holdings. To bridge the expected gap between desired and current extractions by irrigators in the proposed Basin Plan, the Prime Minister of Australia, Julia Gillard, in August 2010 committed to the purchase of water entitlements from willing sellers, where required, so that current holders of water entitlements would be not be financially disadvantaged from increases in environmental flows due to water reform [*Hunt*, 2010]. This commitment is estimated to increase the Australian government's budget for the purchase of water entitlement from its current $3.1 billion to between about $6.5 billion and $8.9 billion [*Grafton*, 2010].

7. Concluding Remarks: Opportunities for Reform

Water markets have developed in both the US west and the Murray-Darling Basin in response to 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 following institutional reforms and during a decade-long drought where trade represents over 20% of the total volume of surface water extracted in 2007-08.

The gains from trade from 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 water trade has allowed high value irrigation uses, such as for horticulture, to continue during a severe drought because of transfers from broad-acre agriculture. Reduced water availability reflected in higher water market prices, has 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 greater water markets is due to fears about third-party impairment yet trade restrictions impose their own costs.

Third-party effects of trade are important and are, typically, not fully considered in private market transactions. Nevertheless, 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 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 concerns about the impact of water markets and water reform.

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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. Annual Benefit 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