Chapter 20
Principles for Economically Efficient and Environmentally Sustainable Water Markets: The Australian Experience

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Abstract With growing water demand for cities and irrigation, periods of low inflow increasingly lead to "operative" droughts when supply is insufficient to meet all consumptive and environmental water demands. This chapter focuses on water markets as a mechanism for sharing scarce water in drought. The institutional arrangements in the Australian Murray Darling Basin (MDB) that have allowed emergence of what is arguably the world's most active water market are outlined. The evidence, consistent with economic theory, confirming significant economic benefits from water trade during the recent Murray Darling Basin drought is presented. The yet unresolved challenges arising from increased efficiency of water use in response to water market incentives eroding environmental flow are discussed. The conclusions outline institutional design principles from Australian experience for realizing efficiency benefits and avoiding adverse environmental impacts when introducing water trade.

20.1 Introduction

With growing population and wealth, come growing rates of water diversion for municipal, industrial and irrigation uses, often at the expense of water-dependent ecological assets. When increasing diversions collide with periods of low inflow, the result is often what Pulido-Velazquez et al. (2006) refer to as "operative" drought: a period when supply is insufficient to meet all consumptive and

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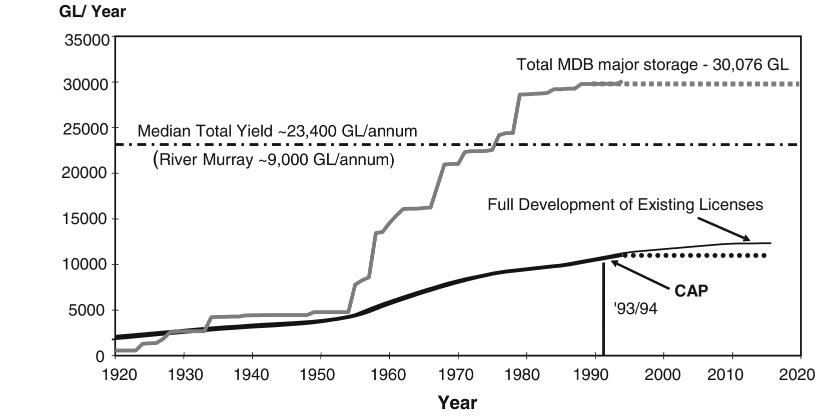

Fig. 20.1 Historic water diversion trends in the Murray Darling Basin

environmental water demands. Climate change predictions for increasing frequency and intensity of such low inflow periods in many of the world's arid and semi-arid basins (Ragaab and Prudholm 2002) are likely to increase the frequency of such operative droughts.

The Australian Murray Darling Basin (MDB) recently experienced an operative drought. Levels of water diversion in the MDB grew over the later half of the twentieth century as shown in Fig. 20.1. As a result, over the period 1990–2006, 56 % of MDB flow was diverted for consumptive uses on average (CSIRO 2008). The second half of the twentieth century, when diversions were growing, was a relatively high-inflow period compared to the first half of the century (Fig. 20.2). A notable feature of this period of growing water allocation was less inter-annual inflow variability than in the periods preceding and prior. As Fig. 20.2 shows, three protracted multiple-year dry periods have occurred over the last 117 years in the MDB—two in the first half of the twentieth century and one from 2000 to

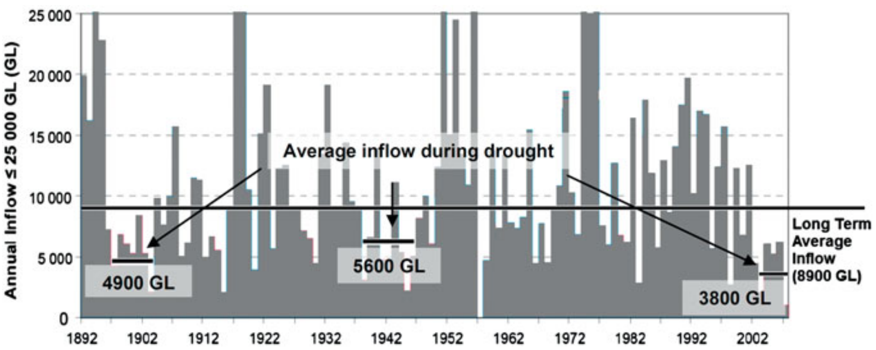

Fig. 20.2 Historical inflows and periods of multiple year drought in the Murray Darling Basin

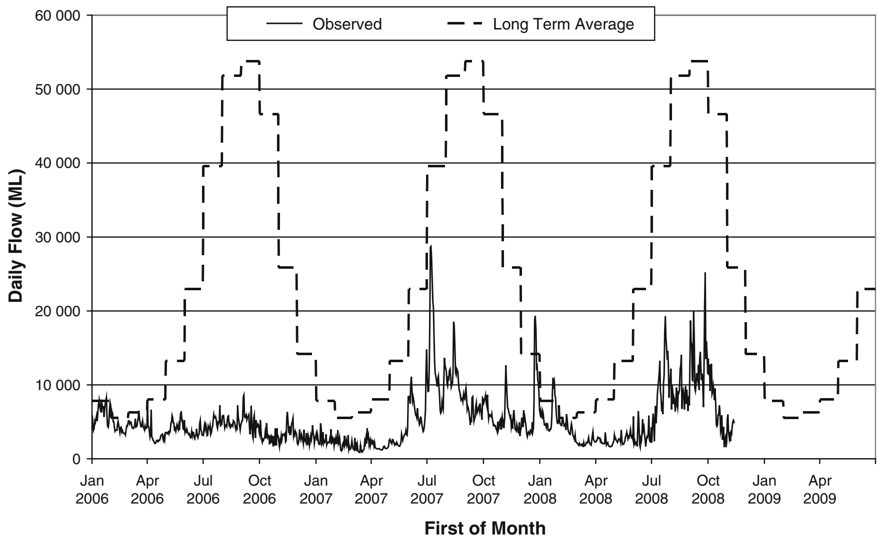

Fig. 20.3 2006 to 2009 Murray Darling Basin inflows

2010. Notably, all three droughts fell outside of the wet second half of the twentieth century when allocations grew.

As shown in Fig. 20.3, the years 2006–2009 represent an unprecedented set of consecutive years of very-low inflows. The result is the most severe operative drought on record, with water available for irrigation diversions at about 25 % of the previous 114-year average in 2008–2009. Results include threats to viability of the water supply from the Murray to the city of Adelaide, with a population of 1.3 million (see Maier et al. 2013 for more detail), and deterioration of the condition of key ecological assets dependent on environmental flow (see Overton and Doody 2013 for more detail).

The introduction of water policy reforms in the 1990s leading to volumetric, metered, and tradable water rights led to the evolution of efficient water markets in the southern part of the basin.[1] This created an opportunity to re-allocate water from low- to high-value uses in the recent drought and thus reduce the overall economic impact. In this chapter: (1) the Australian institutional context that has led to what is now arguably the world's most active water market is described; (2) the evidence regarding the extent to which this economic instrument has reduced the adverse economic impacts of current operative drought is synthesized; (3) the

[1] In the northern part of the system, consisting of the Darling its tributaries and the Lachlan, a northern tributary to the Murray, little trade takes place. As inflows are extremely variable, water is captured in on-farm dams, with allowable diversions a function of flow, as opposed to a volumetric water right. With this allocation system, if an upstream party trades water downstream, water rights holders between the two could divert flows intended for the downstream party.

yet unresolved challenges arising from increased efficiency of water use in response to water market incentives eroding environmental flow is discussed.

The essence of the unresolved challenge in Australia, and indeed anywhere that water markets are introduced, is a classic dilemma in the water trade literature: (a) define water rights to protect third parties but with high transaction costs that limit potential benefits of water trades, or (b) choose a simpler definition that facilitates low transaction costs with less concern for third-party water rights. The conclusions outline institutional design principles from the Australian experience that might go some distance toward resolving this dilemma and allow for both realizing efficiency benefits and avoiding adverse environmental impacts when introducing water trade.

20.2 Water Trade as an Institutional Approach to Sharing Water in Drought

In many basins, the sharing of water is governed by administrative rules dictating who receives how much, depending on overall supply. In the Western United States, for example, sharing is typically by the prior appropriations doctrine. This system, often referred to as a “first in time, first in right,” involves attaching a date of issue to each right to take water from a dam. Water is then released to rights holders in the order of the seniority of rights issued. In times of scarcity, when there is insufficient water to satisfy all claims, water is released to rights holders in the order of the water rights issue dates. In times of scarcity, senior water rights holders receive all of their water right, while junior rights holders receive less than their full allocation.

Australia also has administrative rules for sharing water in times of scarcity. Each water rights holder is issued with water access entitlements, defined as “a perpetual or ongoing entitlement to exclusive access to a share of water from a specified consumptive pool as defined in the relevant water plan” (NWC 2008). Then in any given year, depending on resource availability, all water access entitlement holders are issued water allocations, defined as “specific volumes of water allocated to water access entitlements in a given season, defined according to rules established in the relevant water plan.” Allocation levels are expressed as a percentage of entitlements. This percentage varies by year with allocations; a lesser percentage of entitlements in drought and a greater percentage in years of plentiful water availability.

A number of water-sharing plans exist within larger basins, such as the MDB, with separate plans for areas delineated by major catchment and state boundaries. The water released to rights holders as seasonal allocations under rules defined in plans varies across plans with water rights. In some plans, rights to a more reliable supply are referred to as high-security entitlements, while rights to a less reliable (more variable) supply are referred to as general security entitlement. The reliability of water rights “pools” in this system vary with the degree of inflow variability and the degrees of conservatism with respect to leaving reserves in dams to mitigate against potential risk of future low-inflow years. For example, New South Wales plans tend to release a greater proportion of water held in dams in a given year, while Victorian plans tend to hold more water over as contingency for protracted drought.

Administrative rules specifying water-sharing arrangements, including how reductions in water availability are shared among rights-holders, represent a fundamental underpinning of any effective definition of water property rights. However, such approaches often fail to allocate water efficiently to highest-value uses without complementary institutional arrangements. What is needed as a complement are arrangements to allow for flexible re-allocation of water among rights holders, depending not only on the evolution of scarcity but also the evolution of technology, prices, and preferences.

One approach to allowing flexible adaptive changes in how water is shared involves negotiated arrangements among water rights holders and parties with stakes in the outcomes of water-sharing arrangements. The basin water resource planning approach implemented in the Júcair Basin in Spain exemplifies how such an approach can work effectively. In the Júcair basin during a recent operative drought, water flows to a significant wetland were enhanced through reductions in river water diversion for irrigation negotiated in a deal involving compensation for reduced supply and source substitution from river flow to recycled water. Albiac et al. (2013) suggest that the success of this approach can best be realized through a well-documented and broadly accepted common understanding of basin water resources, their interdependence, and multiple-use values. A challenge with this approach is that rather substantial technical and stakeholder engagement efforts are required. Another challenge, reflected in the Spanish experience, is that often the only effective way to claw back water in drought involves expensive compensation (Albiac et al. 2013).

Allowing water to be traded is another way to introduce flexibility and adaptive capacity into water property rights systems. Economists suggest that developing capacity to allow low-transaction costs trades among water rights holders should allow flexible and continuous water reallocation as market conditions, social preferences, and technology evolve. The approach has the potential to allow a set of decentralized individual water rights holders to reallocate water in ways that increase social benefit. The informational advantage of a market is that it tends to lead to efficient social outcomes through individual water rights holders acting on specialized individual information about the productive value of water in their enterprise (Vaux and Howitt 1984).

However, as noted by authors such as Easter and Dinar (1999), realizing the full potential of water trade as a mechanism to efficiently re-allocate water would require:

- Fully defined, monitored and tradable volumetric water rights;
- Low transaction costs market places (e.g., eBay-type Web trading facilities) for annual allocation and permanent entitlement trade, including fast and secure transaction clearance processes;

- Opportunity for environmental water holders representing public environmental, municipal, industrial, and irrigation interests to fully participate in markets;
- Mechanisms to protect against strategic manipulation of market power;
- Mechanisms to calculate and appropriately prorate volumes of tradable water, based on return flow and evaporation impacts of trades;
- Mechanisms to calculate and introduce accountability for third-party water quantity and quality impacts of trades.

Despite the decades of economists' rhetoric advocating water markets, the reality in most basins to date has been quite limited water trade. In the United States, where the preponderance of economic arguments for such markets arises, relatively little trade has actually taken place. Some trade takes place among irrigators within districts with the Colorado Big Thompson district being a widely discussed example. Several examples of environmental trusts exist related to buying irrigated farms and retiring water rights in environmentally strategic regions such as headwaters where returning flows can enhance fish breeding (Landry 1998). In California offers have been made to temporarily lease water from farmers in years of drought (Howitt 1994). Yet highly active water markets similar to purchase and rental markets for real estate are not a reality in most of the United States, nor is there reporting of highly active water markets elsewhere internationally.

20.3 Institutional Set-Up for Murray Darling Basin Water Trade

An important antecedent to water trade in the MDB was a major process of microeconomic reform in Australia over the past 20 years, in particular the Water Reform Agenda of 1994. This included establishing a National Competition Council with a Water Reform Agenda. The agenda has many similar goals to the now widely discussed European Union Water Framework Directive. Goals include full cost-recovery pricing, elimination of cross-subsidies, and separation of water resource management from service provision. The Water Reform Agenda involved establishing water plans for water resources throughout the MDB. As noted above, these water plans defined water entitlements—perpetual rights to a share of a consumptive pool defined in a water plan, and water allocations, annually varying water volumes granted to entitlement holder in a specific season, defined according to rules established in the relevant water plan.

One of the most significant water policy reforms that gave rise to widespread water trade was separation of water property rights from land. Previously, many irrigation property rights were a right to water access associated with land ownership. In some cases, this involved a right to use water attached to a land title but without a volumetric water right. In other instances, an annually variable allocation per hectare of land with an irrigation right was assigned. Such rights could be exchanged in a package with the land to which they were attached but could not be sold separately from the land. Once the Water Reform Agenda was enacted, states progressively established water plans for water resources throughout the MDB.

Another significant reform was development of the capacity to monitor and enforce volumetrically defined water rights across the MDB. Nearly all water rights in the MDB are now measured with meters. This reform, along with the establishment of a cap on issue of any additional water diversion entitlements for nearly all surface water bodies in the MDB, formerly instituted in 1995, led to the emergence of an active water market. An important outcome, as outlined in Sect. 6, has been significantly enhanced capacity to adaptively re-allocate water in times of drought, since water rights are no longer linked to a specific geographic location and water land use ratios are no longer administratively set. In Sect. 7, a conflict is described between a need to facilitate efficient, low transaction costs trade, and a need to protect environmental flows, that has not yet been fully resolved in the Australian water market. The last two sections present some ideas regarding institutional design that advance progress in design of water trade policy to protect environmental flows without introducing significant additional transaction costs.

20.4 The Murray Basin Water Market History

20.4.1 Permanent Water Rights Trade

The dynamics of the market for permanent water entitlements has been consistent with economic theory—water has traded out of districts with a predominance of low-value pasture lands (e.g., Goulburn, Loddon and Campaspe districts) and into areas with a comparative advantage in the production of high-value irrigated horticultural and viticultural production (Victorian and South Australian Murray). Over the decade (1997–2007), water entitlements have seen a 10 % decline in the Goulburn, and 5 and 6 % growth in the South Australian and Victorian Murray, respectively, as a result of trade in permanent water entitlements.[2] This is reflected in a shift in the use of irrigation water over the past decade. Between 2000 and 2001, and 2005 and 2006, total irrigated land in the Murray Darling Basin decreased by 9 %, but the area of grapevines increased by 35 % over this time period (ABS 2008).

Conjectures have been made that permanent water entitlement trade volume over this period would have been considerably greater in absence of several trade restrictions that still inhibit permanent entitlement water trade (Waterfind 2008). Until recently, trade of permanent entitlements out of New South Wales catchments was precluded, and total volumes per annum of permanent water entitlement trade out of Victorian catchments is limited. Additionally, to sell permanent

[2] Calculations by the author are based on figures in Kaczan et al. (2011), Tables 2 and 7.

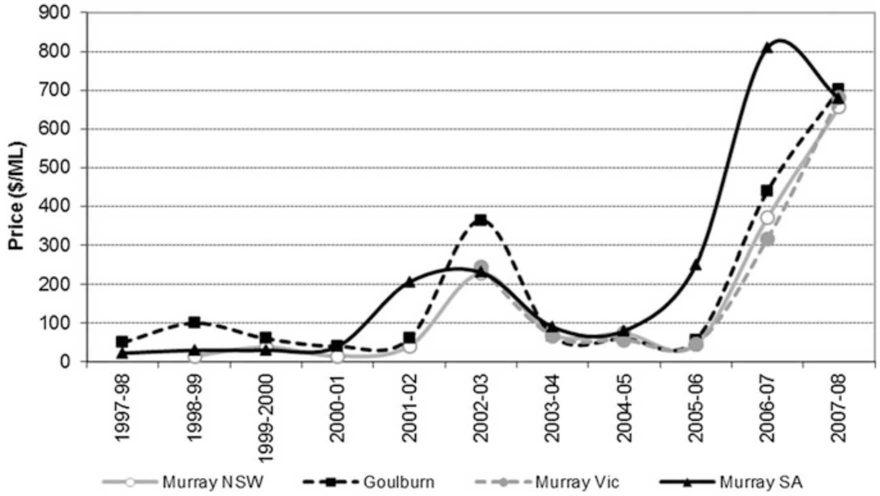

Fig. 20.4 Approximate prices for temporary water (allocations) averaged over the water season for four major trading areas in the southern Murray Darling Basin. *Source* (Kaczan et al. 2011)

entitlements in some districts, the water conveyance provider must be paid a significant termination fee associated with the costs of delivery system operations.

Several surveys suggest another reason for the paucity of permanent entitlement trades: a perception among irrigators that selling permanent water entitlements represents a loss of the opportunity to continue to hold an asset that is increasing in capital value (Bjornlund 2003); permanent water entitlements have displayed an increasing price trend over time, rising nearly five fold over the last decade (Fig. 20.4). This increasing price trend would appear to represent an expectation of increasing scarcity. Such expectation is in line with the projections for future water scarcity outlined by CSIRO (2008) and further analyzed by Kirby et al. (2013). However, part of the recent price rise is likely attributable to the Commonwealth government entering the market to acquire significant volumes of entitlement with the objective of restoring flows to maintain and enhance the environmental health of ecologically significant river floodplain and wetland and estuary assets. "The Living Murray" program was established in 2002 and was completed in 2009. Nearly 343 GL of permanent water entitlements were purchased over this period with an additional 163 GL planned before the end of 2009 (MDBA 2009). A further AU$ 3.1 billion in purchases, through the Commonwealth Government under the "Restoring the Balance" program, has also been underway since 2007 and is scheduled to continue through 2011. A result is that, the State and Federal Governments together are estimated to currently hold approximately 1200 GL of water entitlements (Wentworth Group, 2010).

20.4.2 Annual Water Rights Lease Market

The dominant form of water trade in the MDB is the annual lease of water allocations. In 2007–2008, an unprecedented one-half of all water allocations were traded: 82 % of trades were within catchments and 18 % were between catchments (NWC 2008). The volume of this trade is a clear indication that water can easily be traded on an annual lease basis with low transaction costs. Large volumes of trade took place through Internet trading sites that allow low transaction fees, nearly immediate (daily) transaction clearance and the water traded, generally available within a month.

Figure 20.5 shows the patterns of across catchment annual allocation trade and Fig. 20.6 shows the annual water allocation price dynamics. Regression analysis by Brennan (2006) estimates that two factors explain nearly 90 % of the variation

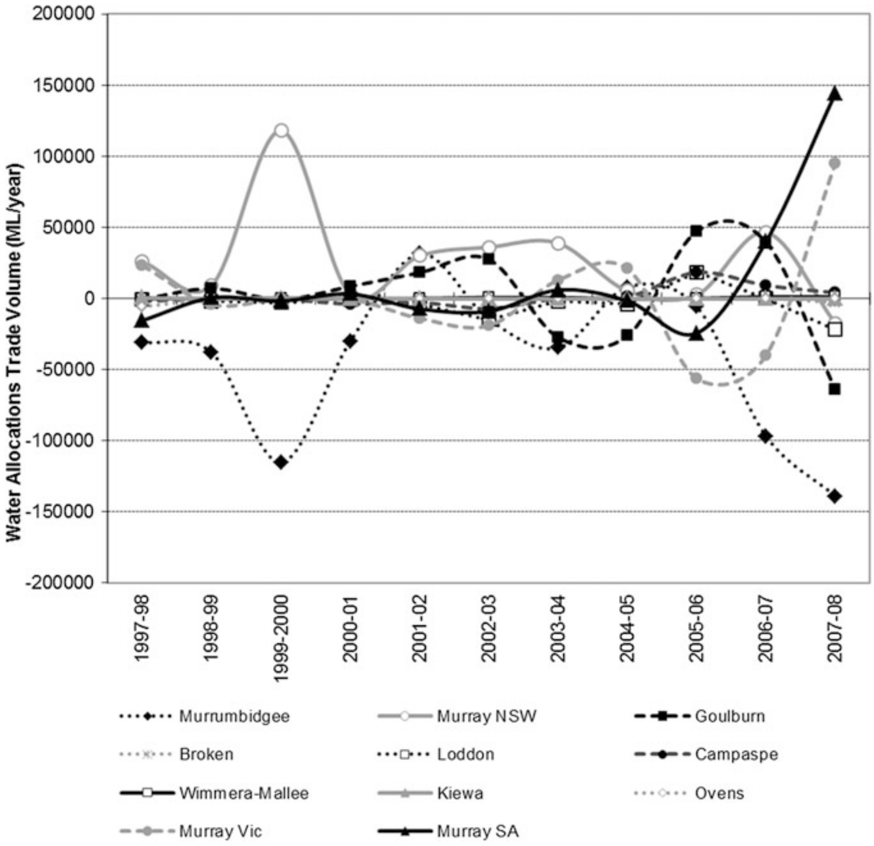

Fig. 20.5 Approximate annual trade volume of temporary water allocations in 11 major trading areas in the southern Murray Darling Basin. A negative trade volume indicates trade out of a region; a positive trade volume indicates trade into a region. *Source* (Kaczan et al. 2011)

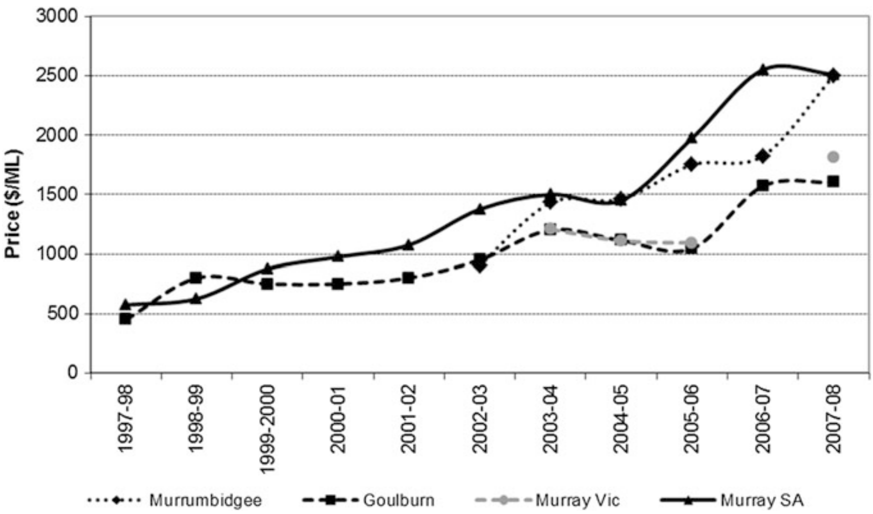

Fig. 20.6 Approximate prices for permanent, high security water (entitlements) averaged over the water season for four major trading areas in the southern Murray Darling Basin. *Source* (Kaczan et al. 2011)

in annual entitlement prices and trade patterns: the annual level of allocation (an indicator of the expected water scarcity level at the growing season outset) and growing season rainfall (an indicator of the divergence from initial expectation regarding the extent to which water requirements are likely to be met by rainfall).

The inverse relationship between price and allocation level can be seen by comparing Figs. 20.6 and 20.7. The price pre-season scarcity relationship is particularly evident in especially low water allocation years (2003–2004 and 2007–2008). The inverse relationship between volume traded and allocation level can be seen by comparing Figs. 20.5 and 20.7. Trade in low-allocation years is generally to high-value horticulture and viticulture (note the large volumes of trade into the Victorian and South Australian Murray where high-value wine and horticultural crops dominated in 2007–2008). The trends in the Goulbourn, a predominantly dairy region, exemplifies how dairy and livestock operations tend to grow pasture and forage in years of low-priced water and buy-in feed and trade away their water allocation in low-allocation, high-priced water years.

Volume traded and market price variation also can be related to within season patterns of rainfall and evapotranspiration. Irrigators with annual crops plant early in the season and sometimes trade based on their expectation of the deficit or surplus relationship between crop water requirements and their allocation. Those with perennial horticultural and wine plantings in contrast have less opportunity to adjust planted area annually. As the year progresses, if rainfall exceeds expectation, some irrigators end up holding allocations in excess of requirements, resulting in a drop in the price of water due to water surpluses. In years when rainfall is below expectations, prices tend to rise as a result of a relative shortage of water for critical mid-to late-season irrigations (Brooks and Harris 2008).

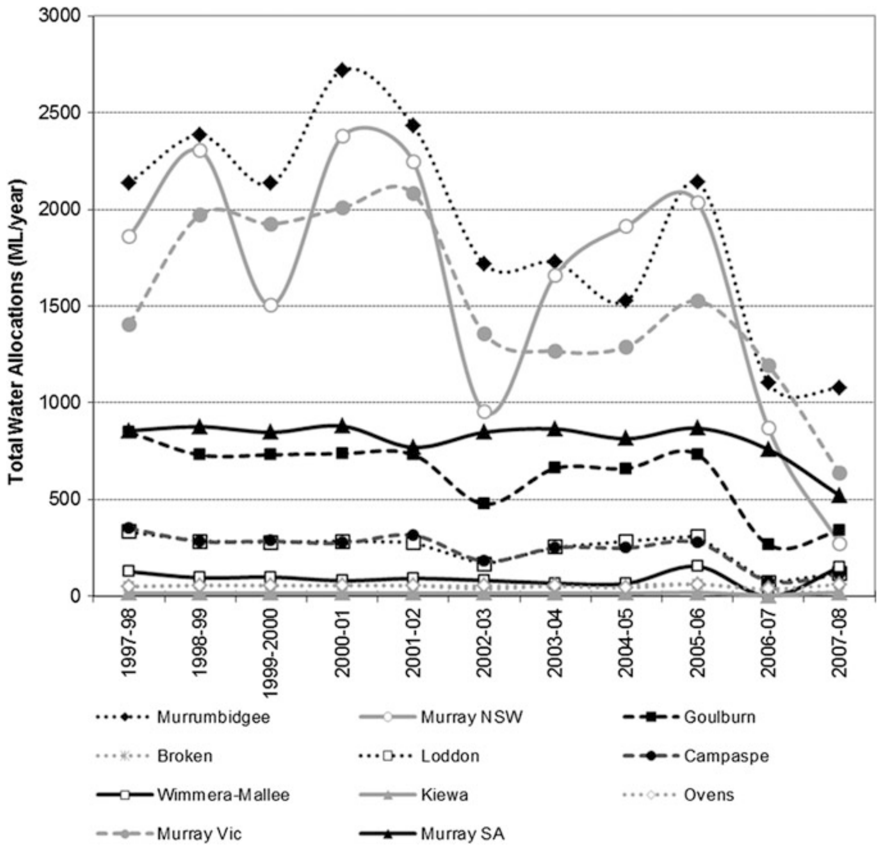

Fig. 20.7 Approximate annual allocation volumes in 11 major trading areas in the southern Murray Darling Basin. *Source* (Kaczan et al. 2011)

20.5 The Economic Benefits of Water Trade in Drought

Economists argue that water markets are efficient at allocating water during drought periods. The informational advantage of a market is that it can achieve efficient sharing with decentralized decision making. With water rights holders making individual decisions based on knowledge of water productivity in their own enterprises and observable price signals arising from collective market responses, a well-functioning market leads to an equilibrium market price and trade pattern. Those suffering the greatest marginal value loss as a result of reduced water allocation tend to buy additional water, as price tends to be less than the value of water in their production. Those suffering relatively little marginal value loss from reduced allocation sell water for an equilibrium price per unit greater than the potential value of a marginal unit of water in their enterprise.

Water market experience during the recent MDB drought is consistent with economic theory. The very high volumes of water trade are evidence that transaction costs involved are not high enough to be a significant trade barrier. For example, one-quarter of all irrigated farms participated in water trade in 2006–2007 (Ashton et al. 2009). Trade from low to high marginal value uses is also evident. The largest source of cross catchment water market supply was the Murrumbidgee catchment in New South Wales where water use is predominantly for comparatively low-value rice, pasture, and grain crops. Here, water trade led to the reduced diversion of 150 GL or 30 % of the total allocation to the catchment. The largest net demand in trade across catchments was the South Australian Murray, a region with greater than 70 % of irrigated area with relatively high-value permanent horticultural and viticultural plantings. Nearly 150 GL of water were traded into this region, thereby increasing the level of allocation by 35 %.

Several economics studies have estimated the benefits of water trade during drought conditions. Mallawaarachchi and Foster (2009) focused on 2007–2008 and estimated benefits to South Australia, the catchment with the largest net import of water, and the Murrumbidgee catchment in New South Wales, the catchment source of the largest net export. They estimated that the benefits of trade to South Australia were approximately $31 million while the benefits to upstream sellers in the Murrumbidgee were $4 million. This is likely an underestimate of the overall benefits of water trade given the focus on only two catchments, precluding benefits for about half of the volume of trade across catchments and the benefits from the 82 % of total trade that was within catchments. Further, the study assumed marginal value of water is likely low as it is based on a dated empirical study from a time of relatively more plentiful (and thus less valuable at the margin) water.

Peterson et al. (2004, 2005) estimated a AU$ 550 million benefit of water trade in the MDB in a dry year, considering benefits from both within and across catchment trade. Most of the benefit is estimated to result from trade within catchments and only about a quarter of the benefit (AU$ 138 million) is estimated to arise from trade across catchments. Connor et al. (2009) assess the economic impacts of the ability to trade water in mild, moderate, and severe climate change scenarios for the high-value irrigated horticultural and vineyard plantings in the Lower Murray region. They find that in a moderate climate change scenario (with a 38 % reduction in available water), net returns in Victorian and South Australian agriculture decline 19 and 54 %, respectively, in the absence of water trade but by only 5 and 11 %, respectively, with the possibility of water trade.

Using computable general equilibrium modeling, Dixon et al. (2008) estimated that the 2006–2007 drought reduced Australian GDP by 1.45 %. The value of completely free water trade within and across catchments in the MDB under 2006–2007 water scarcity conditions was estimated at AU$ 1.3 billion, including regional economy follow-on impacts. This may well be an overestimate of the level of benefits actually realized, as the assumed level of trade may overstate actual trade given several impediments to trade and with market transaction costs not fully accounted for in the model.

A limitation of all of the above-cited studies is that none includes estimates of the potential value of urban to rural water trading. Considering that major cities that could source water from the Murray and Tributaries (Adelaide, Melbourne, and Canberra) through water trade are considering major new urban water infrastructure, such as desalinization plants, to meet growing demand and as a contingency for drought, the benefits of such trade could be considerable. In any case, it seems reasonable to conclude that the benefits of water trade during recent MDB droughts have been considerable, likely in the range of several hundred million to over $1 billion annually during the last two to three years of operative drought. This is in comparison to a gross farm gate value of MDB irrigation of AU$ 4 billion in 2006–2007 (Ashton et al. 2009).

20.6 Adverse Environmental Flow Impacts of Water Trade

One incentive introduced with water trade has been for increased utilization of surface water that was previously left in-stream. Prior to water trade, water rights were attached to land and defined as an annually varying quantity of allowable water use per hectare of land. Bjornlund (2003) noted that 60 % of the irrigators responded to the separation of land and water rights by utilizing water previously left in stream in years of high allocation. With the introduction of water markets, many water allocations that had previously been unused (sometimes called sleeper or dozer rights) were traded from non-users to users, thus increasing overall water diversions (Lee and Ancev 2009). Prior to trade, some water rights tended to be left unutilized in relatively wet years: essentially this was a risk management strategy against shortage in dry years. After trade, the previously unutilized "sleeper" and "dozer" water became activated to place greater land areas of flexible annual crops under irrigation in wet years or to trade.

The advent of the cap on water allocation and water rights separate from land also introduced incentives to increase irrigation efficiency, as water saving could be used to expand irrigated area or sold on water markets. Available statistics show a dramatic decline in the rate of irrigation water application per hectare for Australia since introduction of water markets (and by inference, the MDB as the location of more than half of all Australian irrigation). Water use per hectare declined from 8.7 ml per hectare in 1996 to 4.2 ml per hectare in 2005 (OECD). As noted by Young (2008), this is a greater increase in irrigation efficiency than is reported for any other OECD country over these years. The extent of water "spreading"—increasing irrigation area through greater or more efficient utilization of water was evaluated by Bryan et al. (2009). They concluded that despite the cap on granting additional water rights, set in place in 1995, the amount of land irrigated in the MDB expanded by 20 % between 1995–1996 and 2000–2001. As the area irrigated contracted between 2001 and 2006 as the result of a reductions in allocations, the drive to increase efficiency (reduce water use per hectare) continued. This is evident in the less-than-proportionate 9 % decrease in irrigated land area for a 16 % decline in irrigation diversions over this period.

Another incentive established through introduction of a cap on surface water use and allowing trade in this resource was increased utilization of groundwater. It is estimated that groundwater extraction levels increased by 415 GL between the 1999–2000 and 2004–2005 cropping years in the basin. This represents a marked acceleration in previous historical rate of growth in groundwater extraction which grew by only 180 GL between the 1983–1984 and 1999–2000 cropping years (MDBC 2008).

A consequence of the increased efficiency and trade is that less flow was left in stream than when irrigation water rights were attached to land and not tradable. Several case studies estimated the impacts of reduced stream flow for parts of the basin. Qureshi et al. (2010) estimated that in the Murrumbidgee catchment, the opportunity to trade water introduced incentives to save 177 GL (8 % of diversions) through efficiency practices and to sell or "spread" the water savings. They concluded that most of the increased efficiency would have reduced drainage and return flows to the environment. Connor et al. (2009) estimated that the incentive created by the introduction of water markets in the Lower Murray region would have been sufficient to induce efficiency savings of 113 GL (11 % of regional irrigation diversions) and reduce irrigation drainage and return flows by 50 %.

20.7 Principles for Efficient and Environmentally Sustainable Water Markets: What Have We Learned from the Australian Experience?

The story of the Murray Basin summarized above is that reforms in the 1990s resulted in defined, enforced and monitored water rights tradable independently of land. This led to very active water markets that during the recent severe drought, very effectively re-allocated water from lower- to higher-value uses and significantly reduced the drought's economic consequences. The significant incentives to utilize water that had previously been left in-stream and to irrigate more efficiently, however, led to reductions in water available for the environment.

One nuance of Australian water policy is that the quantity of water defined as tradable is the allowable diversion, consisting of both a portion that is consumptively used and a portion that returns to ground or surface water as drainage or runoff. This is very likely an important reason that water markets arose so quickly in the MDB and also a reason that these markets led to an erosion of flow available for the environment. The interdependence among water rights that arises because return flow from upstream diversions form the basis for downstream rights has long been understood (e.g., Hartman and Seastone 1965).

To avoid the adverse environmental flow consequences of water trade that can arise as they have in Australia, tradable water rights in some other parts of the world are described as the consumptively used portion of diversions. This avoids erosion of return flows that form part of downstream water rights. In places like the western United States there is, at least in principle, a requirement that water trades do not diminish return flows and thus avoid erosion of downstream consumptive or environmental water rights.

While such a water rights definition avoids the problem of water trade diminishing the value of downstream water rights, the way that such approaches are typically implemented tends also to involve resolution of conflicts in the courts, which tends to increase water trade transaction costs and reduce the potential economic benefits. This is because consumptive use and return flow are much more difficult to monitor than diversions, and thus typically much more highly contestable. A classic water allocation dilemma thus arises (Howe et al. 1986): (a) define water rights to protect third parties but in a high-transaction costs way that reduces benefits of water trade, or (b) choose a simpler definition that facilitates low-transaction cost trade without as much concern for third-party water rights. It can be argued that in implementing tradable water rights, Australia has essentially chosen path b.

Going forward, one alternative to insure against reduced environmental flows as a consequence of future water trade in the MDB is the approach used in the western United States described above. Young and McColl (2002) suggest an alternative approach involving periodically reviewing the overall impact of water trade on in-stream flows and adjusting allocation rules in water plans, reducing allowable diversions so as to preserve environmental flow.

The advantage with this approach is that it maintains the benefits of the efficient water market that are possible with trade in easily monitored and not easily contested water diversions. Yet, it also addresses the issue that defining tradable water rights as diversions can tend to erode environmental flows. The highly contested environmental flow issue is addressed for an accumulated result of many individual trades in an occasional periodic process (once every 5 years in the Australian case). All of the expensive science and public processes in reaching decisions about periodic revisions of allocations is concentrated and addressed primarily by bureaucracies with specialized technical capacity. Thus, the impasse and stifling of water trade created by individually contestable water transfers, a feature of some other systems, is avoided.

20.8 Summary and Conclusions

Institutional reforms in Australia over the 1990s resulted in volumetrically defined and metered water rights independent of land that are tradable. These water rights are fully defined in all states of water availability through the inclusion of two elements in their definition: (1) a water access entitlement—"a perpetual or ongoing entitlement to exclusive access to a share of water from a specified consumptive pool as defined in the relevant water plan"; and (2) an annual water allocations, defined as a "specific volume of water allocated to water access entitlements in a given season, defined according to rules established in the relevant water plan."

The result of these well-defined water rights, tradable independently of land, has been the emergence of efficiently functioning markets, especially for the annual lease of water allocations. An astounding one-half of all water allocations were traded in the extreme drought year of 2007–2008, primarily from low-value annual crops and pasture to high-value horticultural and wine crops. Estimates of the benefits of the re-allocation that these transactions afford are as high as $A 1.3 billion, including regional multiplier impacts in the context of an irrigated agricultural sector gross regional product of $A 4 billion.

On the downside, the introduction of water markets has led to a decrease of instream flow, due to increased utilization of previously unutilized water and increased irrigation efficiency; more area is under irrigation with more efficient irrigation, thereby leading to less irrigation drainage return flow back into the river and for the environment. While the extent of reduced environmental flow has not been assessed comprehensively at the basin scale, there is significant evidence consistent with the hypothesis. The evidence includes surveys showing a halving of water application rates, a 20 % expansion of irrigated areas, despite a cap on growth in irrigation diversions, and case studies suggesting in the order of 60 % of diversions saved through efficiency measures used to more extensively irrigate.

Striking a balance in institutional arrangements to allow the benefits of low transaction costs trade, but avoiding the adverse environmental flow consequences poses a classic dilemma: (a) define water rights to protect third parties but in a high transaction costs way that reduces benefits of water trade, or (b) choose a simpler definition that facilitates low transaction costs trade without as much concern for third-party water rights. It can be argued that in implementing tradable water rights, Australia has essentially chosen path b.

Going forward, the issue for Australia and other countries that are contemplating the introduction of water trade is how to resolve this dilemma. One alternative might involve periodically reviewing the overall impact of water trade on in-stream flows and adjusting allocations to preserve environmental flow. This could maintain the benefits of the efficient water market enabled by trade in easily monitored and not easily contested water diversions. Yet, if this approach is taken, one should be cognizant of the issue that defining tradable water rights as diversions can tend to erode environmental flows. The alternative, it seems, is to define water rights in terms of consumptive use, but that would seem to introduce excessive transaction costs into the market, costs that could stifle trade.

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