Australian Government
Department of Agriculture and Water Resources
ABARES

# Lessons from the water market

## The southern Murray–Darling Basin water allocation market 2000–01 to 2015–16

Neal Hughes, Mihir Gupta, Keerthanan Rathakumar

Research by the Australian Bureau of Agricultural and Resource Economics and Sciences

Research report 16.12
December 2016



**Cataloguing data**

Hughes, N, Gupta, M & Rathakumar, K 2016, *Lessons from the water market: the southern Murray–Darling Basin water allocation market 2000–01 to 2015–16*, ABARES research report 16.12, Canberra, December. CC BY 3.0.

ISSN 1447-8358
ISBN 978-1-74323-311-5
ABARES project 43578

**Internet**

*Lessons from the water market: the southern Murray–Darling Basin water allocation market 2000–01 to 2015–16* is available at agriculture.gov.au/abares/publications.

**Contact**

Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)

Postal address: GPO Box 858 Canberra ACT 2601
Switchboard: +61 2 6272 3933
Email: info.abares@agriculture.gov.au
Web: agriculture.gov.au/abares



Helpful comments on drafts of this report were received from staff at the Murray–Darling Basin Authority, the Commonwealth Environmental Water Office, and the Australian Government Department of Agriculture and Water Resources. Within ABARES, comments and suggestions were provided by Orion Sanders, David Galeano, Dale Ashton, Peter Gooday and Tim Goesch. In constructing the dataset underlying this report (see Appendix A), help was provided by staff at Water NSW and Goulburn–Murray Water. Much of the analysis in this report (including the model in Appendix C) was inspired by the work of Donna Brennan. The title of this report is a reference to the Brennan (2006) paper 'Water policy reform in Australia: lessons from the Victorian seasonal water market'.

# Contents

## Figures

## Tables



## Boxes

# Summary

## Purpose

This study examines trends in the southern Murray–Darling Basin (sMDB) water market between 2000–01 and 2015–16. Since the 1980s, the sMDB water market has grown rapidly and now plays a vital role for the irrigation sector, allowing water to be efficiently reallocated between farms in response to changes in supply and demand.

Since 2000–01, the sMDB market has been subject to several significant policy changes. The *Water Act 2007* (Cwlth) and related Murray–Darling Basin Plan set new limits on water use and reallocated large volumes of water from irrigation to the environment. At the same time, state governments have implemented a range of important reforms to water property rights and market trading rules.

The period has also seen dramatic fluctuations in water supply and market prices. During the peak of the millennium drought (2006–07 to 2008–09), water allocation prices jumped from around $50–100 per ML to more than $1 000 per ML, before dropping to near zero during the flood years of 2010–11 and 2011–12. Between 2011–12 and 2015–16, water storages steadily declined and prices steadily increased, generating renewed interest in water market trends. Since then, water prices have eased considerably following strong rain and storage inflow in 2016-17.

This report analyses the major demand and supply side drivers of water allocation market prices in the sMDB, drawing on historical data for 2000–01 to 2015–16. The study disentangles the effects of climate variability (rainfall, water storage and allocation volumes) from the key policy changes and irrigation sector changes that have occurred during the period.

## Key findings

### Higher water prices in recent years

Recent higher water prices in the sMDB can be explained by a range of factors.

#### Allocation volumes and rainfall

Variation in rainfall and allocation volumes remains the dominant driver of water prices in the sMDB. This study found a strong correlation between allocation volumes, farm rainfall and water market prices, consistent with previous studies. However, lower allocations and rainfall since 2011–12 do not fully explain the higher prices observed in recent years (in particular, 2014–15 and 2015–16). After controlling for these factors, prices were still significantly higher than expected during 2014–15 and 2015–16.

## Environmental entitlement purchases

Entitlements purchased by the Commonwealth since 2007–08 accounted for around 14 per cent of water allocations available in the sMDB by 2015–16. These entitlement purchases reduce the supply of water for irrigation which—all else held constant—will increase water prices. At the same time, government infrastructure projects increase water supply, partially offsetting these effects. However, even if infrastructure projects are ignored, environmental purchases offer only a partial explanation for the recent increase in prices. After controlling for allocation volumes, rainfall and entitlement purchases, prices were still higher than expected during 2014–15 and 2015–16.

## Carryover rule changes

Since 2007–08, there have been some important changes to carryover rules by state governments. These rule changes have seen large increases in the proportion of water allocations being carried over between seasons. Between 2012–13 and 2015–16, an average of 30 per cent of available water was carried over to the next year, compared with just 8 per cent between 2000–01 and 2005–06.

The increased use of carryover has important implications for the water allocation market. In general, carryover will lead to slightly higher prices in years when carryover reserves are being accumulated (typically average or wetter years), and lower prices in years when carryover reserves are drawn down (typically drought years). The increase in carryover volumes since 2008 helps to explain the recent high water market prices. The combination of drier conditions, environmental purchases and increased carryover volume explains most of the recent price increase.

These changes to carryover rules also mean that the water allocation market is more forward looking, in the sense that market prices are increasingly dependent on expectations about water availability in future seasons. For example, allocation prices rose significantly in the last few weeks of 2014–15, following El Niño warnings and forecasts of low allocation in 2015–16.

## Trade restrictions

Within the sMDB there are a range of constraints on trade between regions designed to reflect physical constraints on water delivery. In recent years, a number of these constraints have been binding. For example, in 2015–16, trade was restricted out of the Murrumbidgee region into the Murray because of inter-valley transfer account limits. After trade was stopped in August 2015, prices in the Murray rose well above those in the Murrumbidgee, reaching around $270 per ML in October (compared with around $200 in the Murrumbidgee). In general, trading constraints in recent years have limited trade into the main Murray (downstream of Barmah) trading zones, leading to higher prices here relative to tributaries.

## Changes in water demand from the irrigation sector

Between 2000–01 and 2015–16, there have been many structural changes in the irrigation sector affecting the demand for water and therefore market prices. In particular, there has been a steady decline in wine grape areas, an expansion in other horticultural crops, (including nuts) and a slight shift from rice to cotton. Overall, the most significant change has been an increase in demand for water from horticulture within the lower Victorian Murray region. While further research is required to confirm the effect of these changes on water prices, increased horticultural demand is likely to have an upward effect on water allocation prices, at least in dry years.

## Opportunities for market reform

Water market reforms in the sMDB since the 1980s have been an overwhelming success. Compared with other Australian and international water markets, the sMDB market involves large numbers of transactions, large numbers of buyers and sellers, low transaction costs, and few constraints on trade. The water market proved vital during the millennium drought, allowing the irrigation sector to adapt to unprecedented levels of water scarcity.

Although the sMDB market is highly efficient by international standards, the process of reforming water property rights and market rules is ongoing. This report identifies a few opportunities for future reform in the sMDB, including:

- using more sophisticated carryover systems, similar to those used in northern New South Wales and southern Queensland
- continuing to review trade limits and river operations, to find ways to alleviate trade restrictions while minimising third-party effects
- using more flexible treatment of environmental flows, including separating the accounting of interregional environmental transfers from market trades.

# Introduction

## Background

The water allocation market in the southern Murray–Darling Basin (sMDB) is routinely described as the best in the world. Compared with other Australian and international water markets, the sMDB market involves large numbers of transactions, large numbers of buyers and sellers, low transaction costs, and few constraints on trade (see, for example, Grafton et al. 2011). Each year, the market allows large volumes of water to be reallocated between users and across regions in response to changes in supply and demand.

The sMDB water market played a vital role during the millennium drought, helping irrigation farmers cope with extreme water scarcity. During the worst of the drought (from 2006 to 2009), large volumes of water were traded across region and state boundaries, typically from lower marginal value activities like annual cropping to perennial horticulture (NWC 2011). The drought saw water allocation prices rise to unprecedented levels, from an average of around $50–100 per ML before the drought to more than $1 000 per ML in 2007.

The sMDB water market is the product of a long and gradual process of reform that began as early as the 1980s (NWC 2011). The market is underpinned by sophisticated water property rights and trading rules established and enforced by government agencies. Subject to these rules, market participants can freely trade water through private transactions, brokers and electronic exchanges.

Although much progress has been made, the process of water market reform in the sMDB is ongoing. With government policies (including the Murray–Darling Basin Plan) seeking to increase environmental flows, and climate change potentially decreasing inflows (CSIRO 2008), water scarcity remains a pressing issue in the region. As such, there is continuing interest in finding ways to further improve the efficiency of the market. This interest was heightened by a return to drier conditions and higher water prices during 2014-15 and 2015-16.

## This study

This report analyses the sMDB water allocation market from 2000 to 2016. This period has been one of great change for the market, with continued reform of water property right systems, market rules and the entry of large environmental water holders. At the same time, market activity, in terms of the volumes of trade and numbers of transactions, has grown dramatically.

This report presents a comprehensive dataset on water prices, allocation, carryover, and storage and trade volumes for each of the major sMDB regions for 2000–01 to 2015–16. The report seeks to explain trends in water prices from 2000 to 2016 by considering variations in water supply (that is, storage and allocation volumes), water demand (that is, irrigation and environmental) and policy changes (including environmental reforms, and changes to carryover rights and trading rules). Although the focus is backwards looking, the study aims to provide insights to guide future market reforms.

The study employs a combination of data analysis and econometric modelling. In particular, the report presents some simple regression models of water prices in the sMDB similar to those used by Aither (2016a) and Brennan (2006). In addition, the paper presents an econometric model of interregional water trading in the sMDB similar to that of Brennan (2010).

This report is structured as follows. Section 2 provides background on the sMDB water market and an overview of historical trends. Section 3 provides some analysis of major supply and demand drivers, and policy changes in the water market during 2000-01 to 2015–16. Section 4 provides conclusions. Finally, the report's data sources are detailed in Appendix A, regression analysis is described in Appendix B, and Appendix C outlines an economic model of water trade in the sMDB.

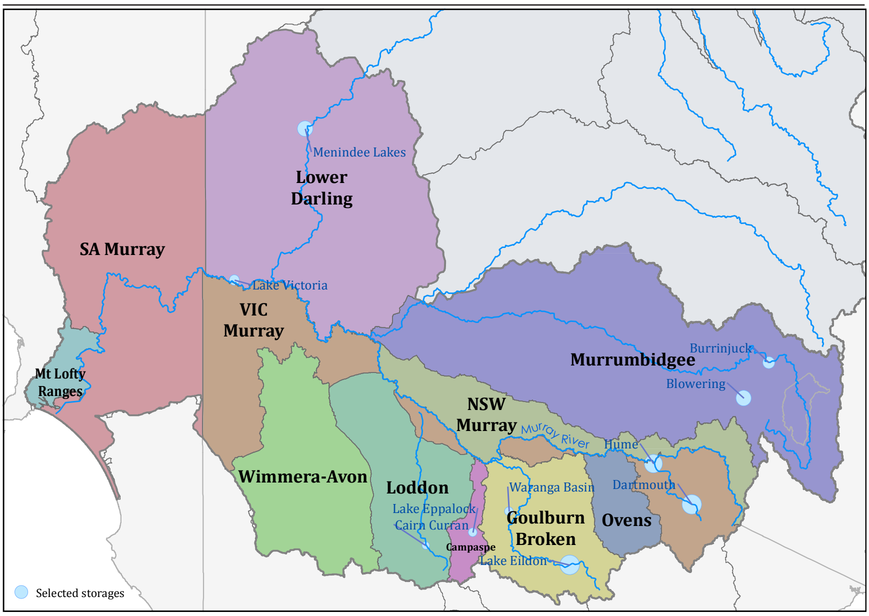
# The southern Murray–Darling Basin water market

## The southern Murray–Darling Basin region

The sMDB refers to a group of connected river systems in south-eastern Australia that includes the Murray River and its tributaries (Figure 1). For the purposes of this report, the sMDB includes the Murray River, the Murrumbidgee and Lower Darling systems in southern New South Wales (NSW); and the Goulburn, Broken, Loddon and Campaspe systems in northern Victoria.

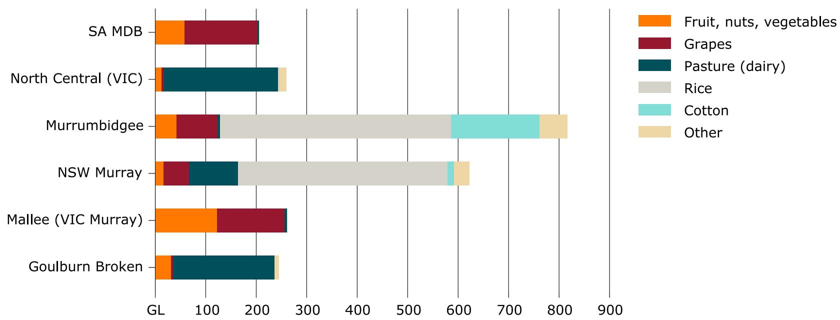
Most of the water supply in the sMDB is provided by storage controlled rivers (that is, regulated surface water) with smaller amounts of groundwater and unregulated surface water. Major dams in the sMDB include Dartmouth, Hume, Blowering, Burrinjuck and Lake Eildon (Figure 1), with total storage capacity (excluding the Snowy Mountains Hydro-electric Scheme) around 16 000 GL.

FIGURE 1 Southern Murray–Darling Basin water systems and major storages



Most of the water use in the sMDB is for irrigated agriculture, with significant broadacre cropping in southern NSW (including rice), dairying in northern Victoria (Vic.), and horticulture in northern Victoria and South Australia (SA) (Figure 2). The gross value of irrigated agricultural production in the sMDB was more than $4 billion in 2013–14 (ABS 2015).

FIGURE 2 Water use on irrigation farms, selected southern MDB natural resource management regions, 2014–15

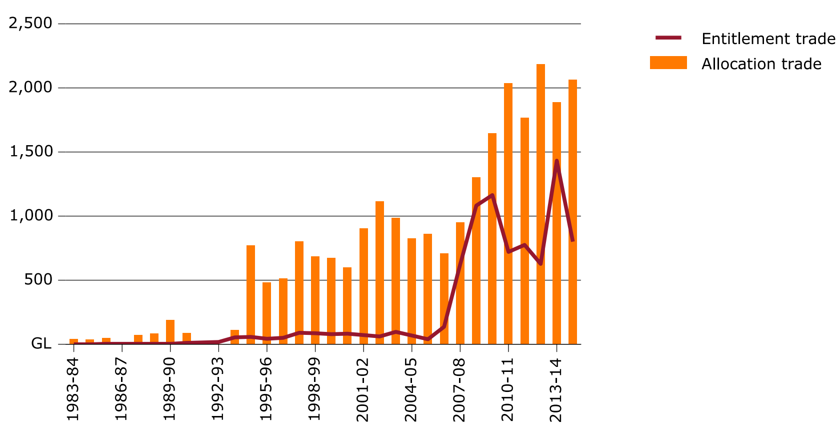



Source: ABS (2016)

## Water market activity

The evolution of the market in the sMDB has been a gradual process (NWC 2011). Government reforms permitting limited trading of water allocations and entitlements began during the 1980s. The pace of reform picked up during the 1990s and early 2000s with two Council of Australian Governments (COAG) agreements. Over time, market activity has gradually increased (Figure 3) in line with improvements in water property rights, trading rules and market information; reductions in transaction costs; and increases in water scarcity. Strong growth in trade volumes occurred during the drought years of 2002–03 and 2006–07 to 2008–09 (Figure 3).

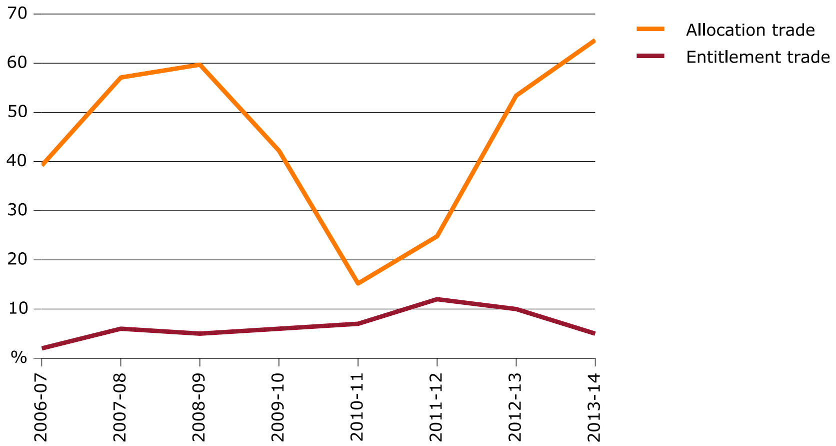
FIGURE 3 Annual volume of water trade in the southern MDB, 1983–84 to 2014–15




Source: 1983–84 to 2009–10 taken from NWC (2011). Allocation trade data for 2010–11 to 2014–15 is provided by the Murray–Darling Basin Authority and excludes environmental transfers. Environmental transfers are assumed to be zero before 2010–11. Entitlement trade volumes 2010–11 to 2014–15 are taken from ABARES (2016).

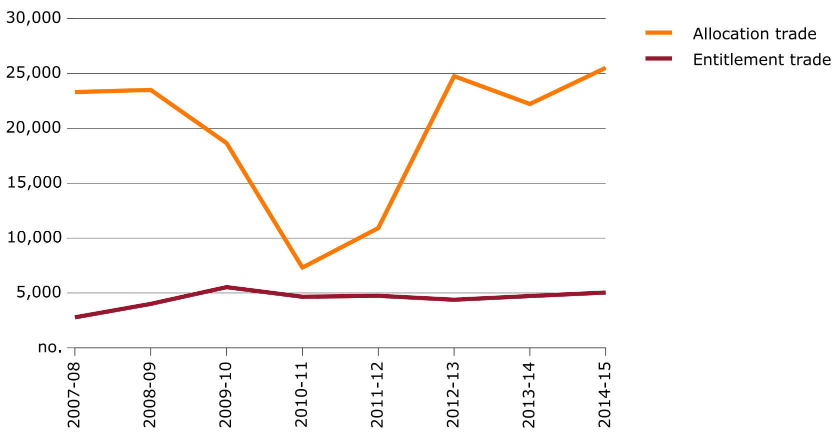
Separate markets exist for water entitlements (long-term shares in available water supply) and water allocations (volumes of water for use in the current year). This report looks exclusively at the water allocation market, which remains much larger in terms of user participation (Figure 4), numbers of transactions (Figure 5) and volumes of water traded (Figure 3).

FIGURE 4 Percentage of MDB irrigators participating in water markets, 2006–07 to 2013–14




Source: ABARES survey of irrigation farms in the MDB

FIGURE 5 Annual number of surface water trades in the southern MDB, 2007–08 to 2014–15



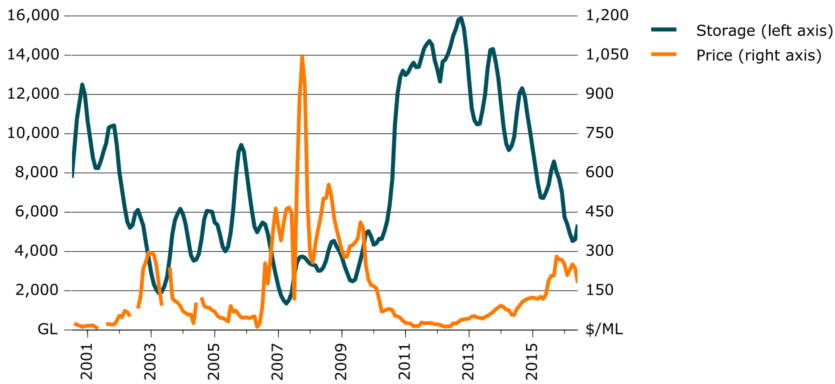

Source: ABARES Australian water markets report database

In 2014–15, around 25 500 surface water allocation transactions were recorded in the sMDB (Figure 5). Market activity decreased during the flood years of 2010–11 and 2011–12, before picking up again in recent years (Figures 4 and 5).

## Water prices and storage volumes

Figure 6 shows monthly water allocation market prices and total storage volumes for the sMDB. The primary driver of water market prices in the sMDB is the supply of water allocations, which is largely a function of the volume of water in storage. Water allocation prices rose to unprecedented highs during the peak of the millennium drought, before declining to near zero during the floods of 2011 and 2012.

FIGURE 6 Monthly allocation prices and storage volume in the southern MDB, July 2000 to June 2016

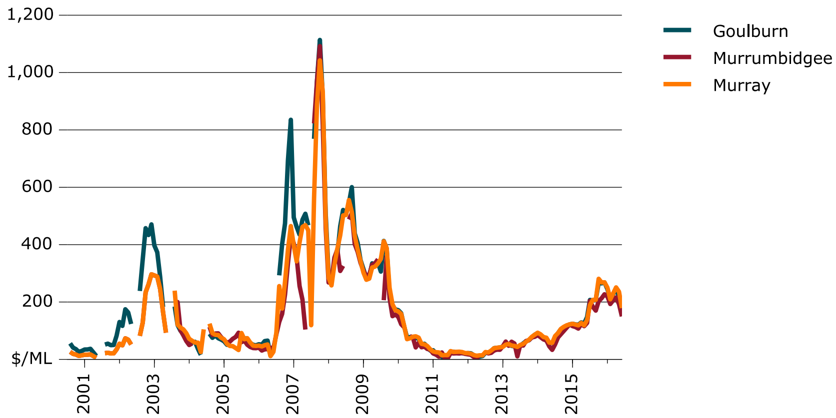



Note: sMDB storage volumes exclude the Snowy Mountains Hydro-electric Scheme and Lake Victoria. Water allocation prices are for the Murray trading zones (see Appendix A).
Source: sMDB dataset (see Appendix A)

A high degree of connectivity exists between the sMDB river systems, enabling relatively open interregional water trading. Although some constraints on trading exist (trading rules are discussed in more detail in the next section), the sMDB can be viewed as a single market, in the sense that water prices across the different regions tend to be similar.

Figure 7 shows water prices in three major regions: the Goulburn, Murrumbidgee and the Murray. In some cases, trading constraints have led to temporary differences in prices between regions (these differences are considered in detail in Section 3).

FIGURE 7 Water allocation prices for major regions in the southern MDB

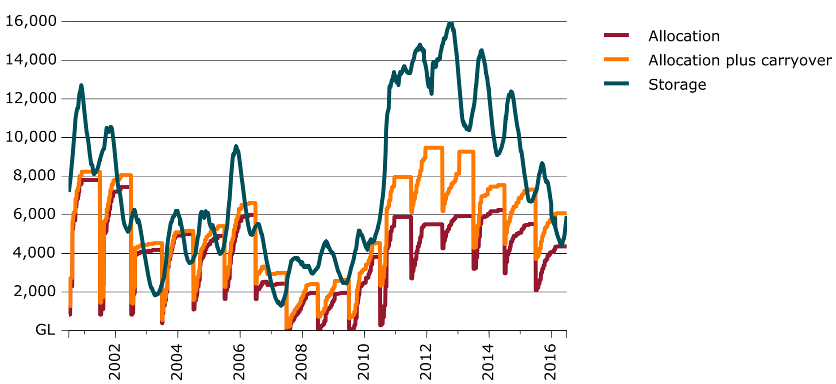



Source: sMDB dataset (see Appendix A)

## Water entitlements, allocations and carryover

State government agencies determine annual water allocation volumes in accordance with regional water sharing plans. These allocations are a function of the volumes of water in each region's storages (but can also be affected by other variables, including expected future inflows and environmental flow rules). Figure 8 shows the total volume of water allocations in the sMDB (to regulated surface water entitlements) and unused allocations carried over from previous years. Restrictions on carryover have progressively been relaxed in the sMDB during the 2000s, leading to a general increase in the volumes of water being carried over between years (carryover rules are considered further in Section 3).

FIGURE 8 Southern MDB water allocation, carryover and storage volumes, July 2000 to June 2016




Note: Allocation plus carryover includes allocations carried over from the previous financial year. Includes only regulated surface water entitlements in the sMDB. Annual allocations differ from storage volumes because allocations exclude year to date usage, whereas storage volumes include additional urban and environmental water, and operational (e.g. conveyance loss) reserves.
Source: sMDB dataset (see Appendix A).

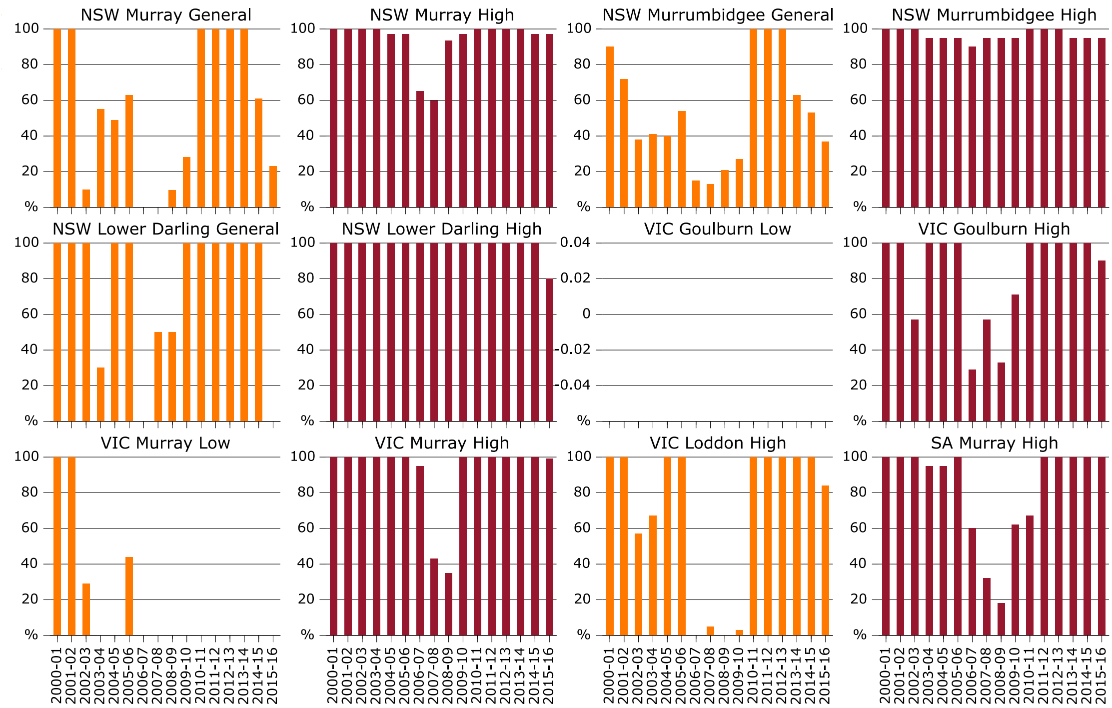
Within the sMDB, a total of around 7 900 GL of regulated surface water entitlements are defined (Table 1). From 2000 to 2016, these entitlements yielded an average end-of-year water allocation of around 67 per cent. Most regions define two entitlement classes (that is, high and low reliability). The reliability levels of these entitlements (as measured by the average allocations received) vary significantly across regions (Table 1, Figure 9).

TABLE 1 Southern MDB regulated surface water entitlement volumes and average allocations, 2000–01 to 2015–16

| Entitlement type | Volume | Allocation percentage | | |
|---|---|---|---|---|
| | (GL) | Min. | Average | Max. |
| NSW Lower Darling General | 78 | 0 | 77 | 100 |
| NSW Lower Darling High | 8 | 80 | 99 | 100 |
| NSW Murray General | 1 672 | 0 | 57 | 105 |
| NSW Murray High | 192 | 60 | 94 | 100 |
| NSW Murrumbidgee General | 1 892 | 13 | 54 | 100 |
| NSW Murrumbidgee High | 381 | 90 | 97 | 100 |
| Vic. Broken High | 18 | 0 | 70 | 100 |
| Vic. Broken Low | 3 | 0 | 0 | 0 |
| Vic. Campaspe High | 23 | 0 | 66 | 100 |
| Vic. Campaspe Low | 19 | 0 | 13 | 120 |
| Vic. Goulburn High | 1 009 | 29 | 84 | 100 |
| Vic. Goulburn Low | 444 | 0 | 0 | 0 |
| Vic. Loddon High | 21 | 0 | 70 | 100 |
| Vic. Loddon Low | 8 | 0 | 0 | 0 |
| Vic. Murray High | 1 245 | 35 | 92 | 100 |
| Vic. Murray Low | 305 | 0 | 17 | 100 |
| SA Murray High | 564 | 18 | 83 | 100 |
| **Total** | **7 882** | **25** | **59** | **86** |

Note: Allocation percentages for Vic. Low reliability water rights include sales water allocations before unbundling. Entitlement volumes are for 2015–16.

FIGURE 9 End-of-year allocations for selected water entitlement types, 2000–01 to 2015–16

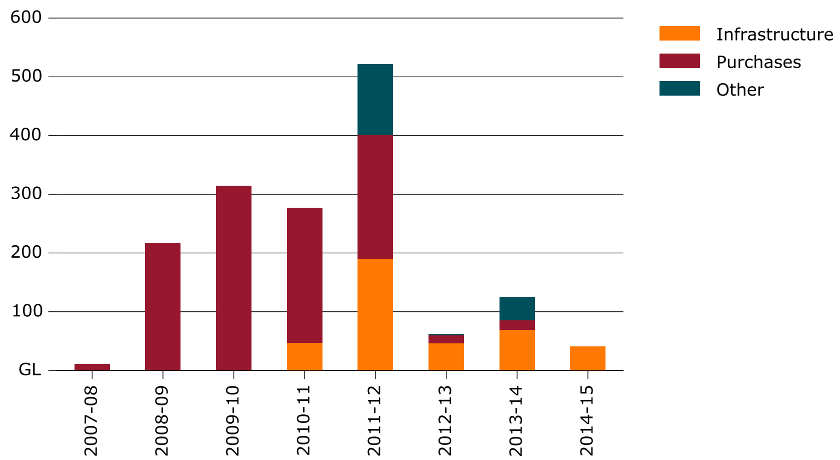



Note: Allocation percentages for Vic. Low reliability water rights include sales water allocations before unbundling.
Source: sMDB dataset (see Appendix A)

# Environmental water

In recent times, environmental water holders (such as the Commonwealth Environmental Water Holder; CEWH) have become increasingly significant players in the water market. This has occurred mostly through the entitlement market, as governments have purchased water from irrigators for environmental purposes (particularly to meet the requirements of the Murray–Darling Basin plan). The Commonwealth was heavily involved in the water entitlement market during 2008–09 to 2011–12, but has greatly reduced this activity in recent years (Figure 10), as the focus of water recovery has shifted toward infrastructure investments (see ABARES 2016).

FIGURE 10 Water entitlements secured by the Commonwealth in the southern MDB (regulated surface water only), 2007–08 to 2014–15



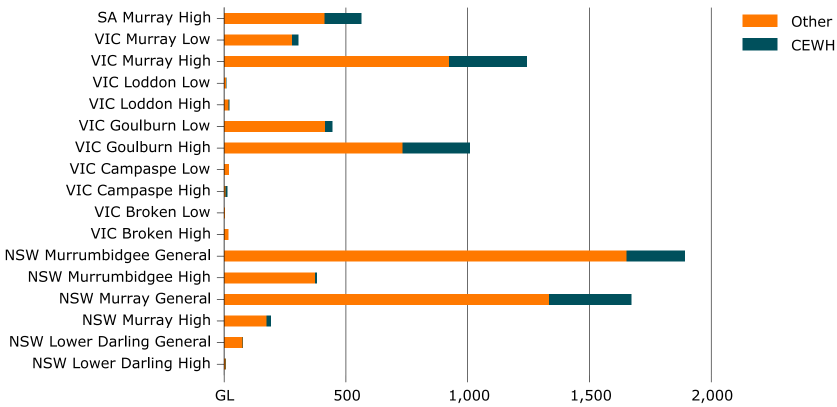

Note: Includes Lower Darling, Murrumbidgee, Murray (NSW, Vic. and SA) Goulburn, Broken, Loddon and Campaspe regions only. Excludes unregulated, supplementary, conveyance and groundwater entitlements.
Source: sMDB dataset (see Appendix A)

Up until 2016, the Commonwealth has had limited involvement in the water allocation market in the sMDB (that is, selling allocations back to irrigators). The only transaction recorded in the sMDB was a sale of 22 864 ML in the Goulburn region in November 2015 (although other transactions occurred in the northern MDB during 2014).

However, environmental water holders (including the CEWH and other state agencies) do transfer large volumes of their water allocations between sMDB regions to deliver water to specific environmental assets (Morey, Grinlinton and Hughes 2015). These interregion environmental transfers have no financial component (no money changes hands), but they are still officially recorded as allocation trades on state government registers.

As of June 2016, the CEWH held around 1 418 GL of regulated surface water entitlements in the sMDB (around 18 per cent), which were obtained through a combination of entitlement purchase and infrastructure upgrade projects (Figure 11).

FIGURE 11 Proportion of water entitlements held by the Commonwealth Environmental Water Holder in the southern MDB, as of June 2016




Note: Includes Lower Darling, Murrumbidgee, Murray (NSW, Vic. and SA) Goulburn, Broken, Loddon and Campaspe regions only. Excludes unregulated, supplementary, conveyance and groundwater entitlements.
Source: sMDB dataset (see Appendix A)

# Industry and regional trade flows

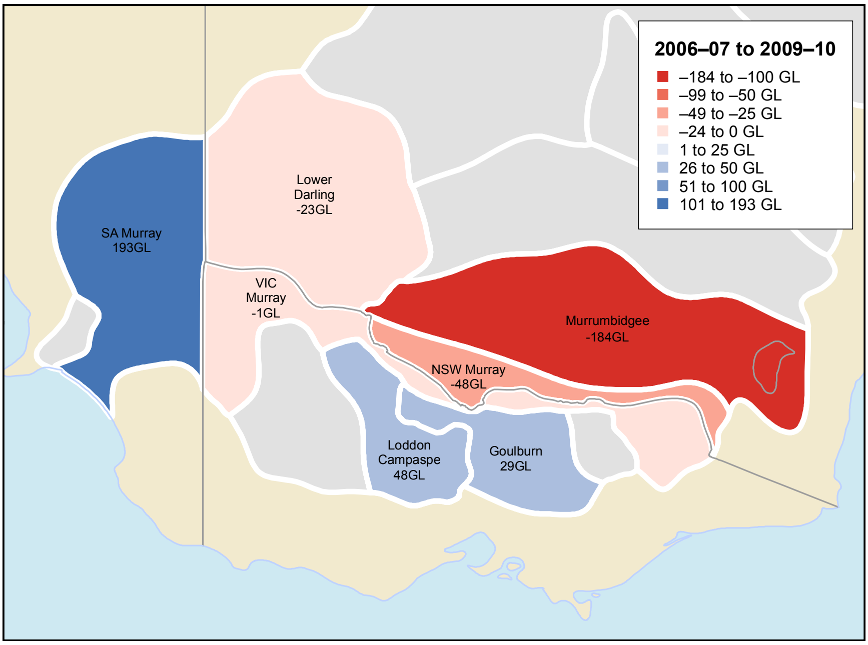
The market played a key role during the 2000s, reallocating water between irrigation industries and regions during periods of drought. Figure 12 shows the average interregional trade flows in the sMDB during 2006–07 to 2009–10, relative to 2011–12 to 2014–15 (Figure 13).

In general, the drought saw large volumes of water being sold by broadacre farmers in southern New South Wales (rice growers) to horticultural farms (grapes and fruit trees) in northern Victoria and South Australia (NWC 2011). The high water prices during this period reflected the willingness of horticulture farms to pay to avoid tree water stress.

Irrigation survey data from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) confirm this pattern of water being traded from broadacre farms to horticulture farms during the drought (Figure 14). On average, rice farms in the sMDB were net sellers from 2008 to 2010, and horticulture farms net buyers. This pattern changed during the wetter years that followed, with rice farmers becoming net buyers on average (Figure 14).

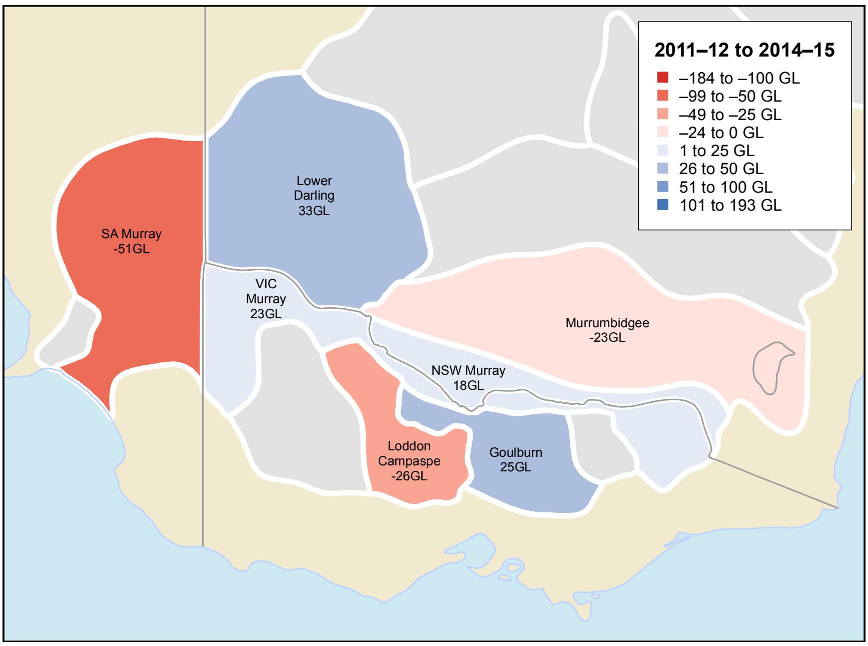
In recent years, dairy farms in the MDB have become large net buyers of allocations (Figure 14). This is partly because of dairy farms reducing their holdings of water entitlements following the drought (Figure 15) and adopting a strategy of purchasing water allocations on the market each year or else purchasing fodder as a substitute for irrigated pasture (Ashton & Oliver 2015a).

FIGURE 12 Average annual net trade for major southern MDB regions, 2006–07 to 2009–10



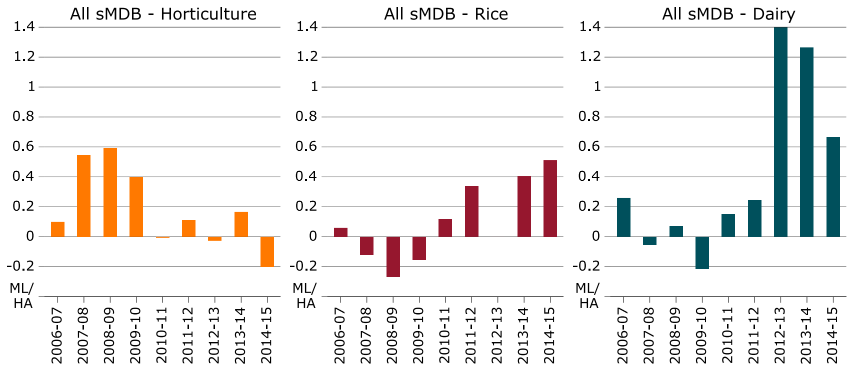

Note: Excludes all environmental transfers. Source: sMDB dataset (see Appendix A)

FIGURE 13 Average annual net trade for major southern MDB regions, 2011–12 to 2014–15



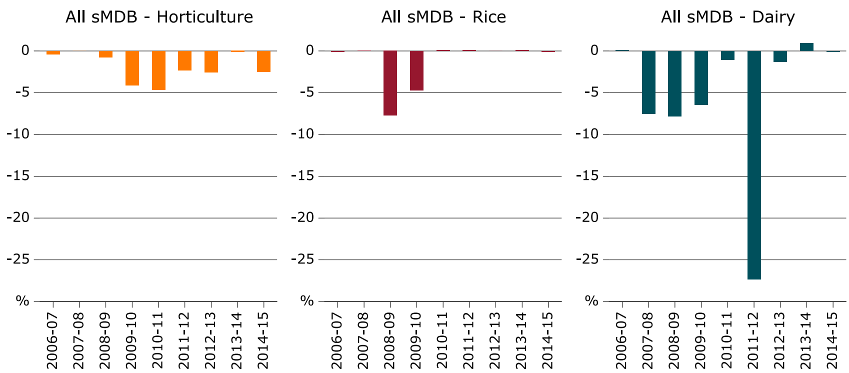

Note: Excludes environmental transfers. Source: sMDB dataset (see Appendix A)

FIGURE 14 Average net water allocation trade (per hectare) for farms in the southern MDB, 2006–07 to 2014–15




Note: No data for rice farms were available for 2012–13.
Source: ABARES survey of irrigation farms in the MDB

FIGURE 15 Average net water entitlement trade as percentage of entitlements held for farms in the southern MDB, 2006–07 to 2014–15




Note: No data for rice farms were available for 2012–13.
Source: ABARES survey of irrigation farms in the MDB

# Water market drivers

As with any competitive market, water market prices are a function of demand and supply. At any point in time, the demand for, and supply of, water allocations will depend on the following range of variables:

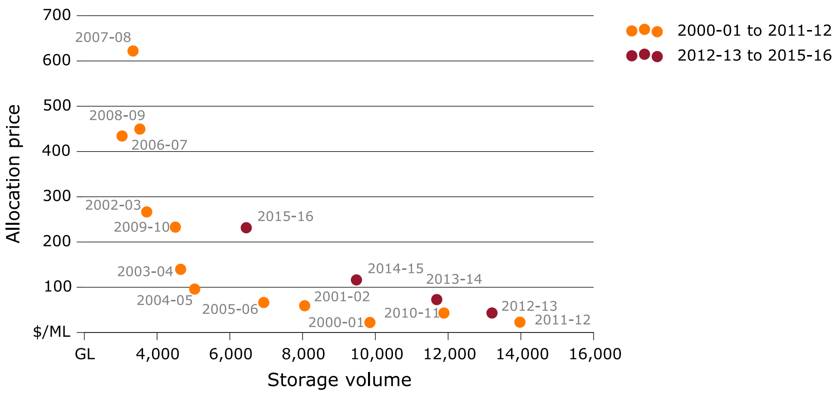
- Supply
  - Water allocation percentages, which, in turn, are a function of storage volumes and state water sharing plans.
  - Environmental water—water rights transferred to environmental agencies effectively reduce the supply of water allocations for irrigation users.
  - User carryover decisions—decisions by individual water right holders to hold water allocations in storage within or between years (rather than using or selling).
  - Water trading rules—any binding constraints on trade can lead to differences in prices between regions.
  - Infrastructure investment—government on and off-farm infrastructure programmes can increase the effective supply of water by decreasing losses.
- Demand
  - Rainfall and soil moisture—rainfall is a substitute for irrigation water. When rainfall is high over irrigation areas, farm demand for irrigation water will be lower.
  - Commodity prices and input prices—market prices of major irrigation commodities (for example, milk, cotton, rice) influence irrigation water demand.
  - On-farm infrastructure investment (public or private)—expansion or rationalisation of irrigation areas, changes in the mix of irrigation activities or investments in on-farm water use efficiency all influence the demand for water allocations.

In this section, each of these factors and how they have varied in the sMDB between 2000 and 2016 are considered, as well as the potential implications for water market prices. In particular, how these factors have combined to produce higher market prices for water allocations in recent years is outlined.

## Storage volumes

Figure 16 compares average storage volumes in the sMDB against water market prices (in the Murray region) from 2000–01 to 2015–16. As expected, market prices are negatively related to storage; prices are higher in dry years. However, the data also suggest that, for a given level of water in storage, market prices have been higher in recent years.

FIGURE 16 Average annual water prices against storage volumes in the southern MDB, 2000–01 to 2015–16

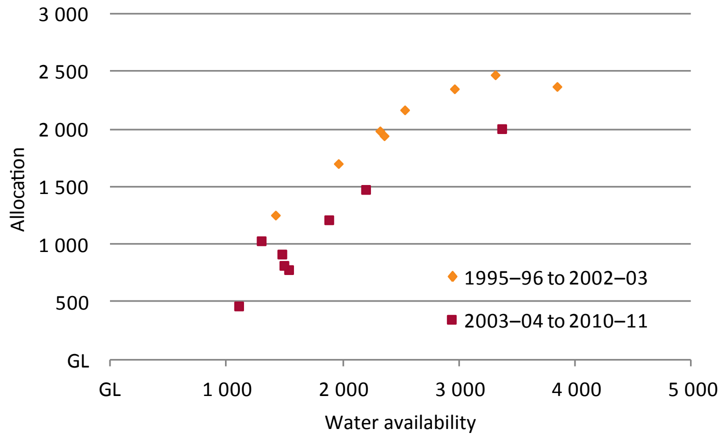



Note: Allocation prices are for the Murray region and have been adjusted for inflation (see Appendix A).
Source: sMDB dataset (see Appendix A)

The trend shown in Figure 16 can be partly explained by changes in the way water allocations are determined. From 2000–01 to 2015–16, significant changes have been made to water sharing plans within the sMDB (Hughes et al. 2013). Together these changes mean that, for a given volume of water in storage, there is generally less available for allocation to entitlement holders.

Key changes have included increases in 'rules-based' environmental flows, new storage reserve policies and more conservative forecasts of future inflows (Hughes et al. 2013). Figure 17 provides an example of the effect of rule changes in the Murrumbidgee system (for more detail, see Hughes et al. 2013). Note that some of these rules changes did not apply during drought years when water sharing plans (WSPs) were suspended (for example, the Murrumbidgee WSP was suspended in 2006–07 and reinstated in 2010–11).

FIGURE 17 Murrumbidgee water allocations against water available (storage plus inflow) on 1 December 1995–96 to 2010–11



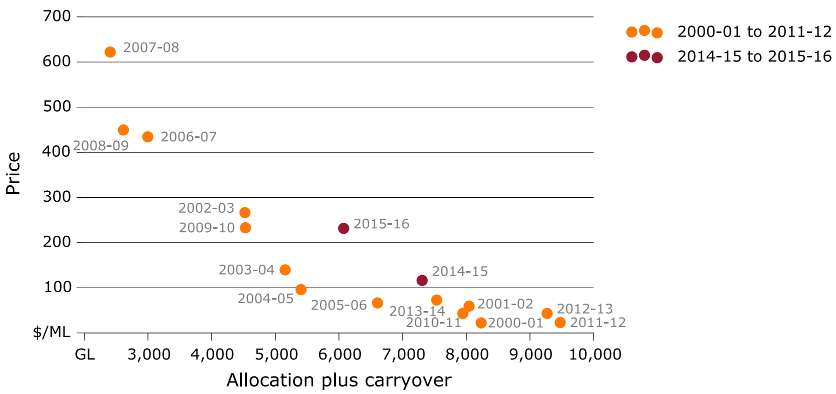

Source: Hughes et al. (2013)

# Water allocations

The supply of water allocations in the sMDB market can be defined as the sum of current water allocations in each system plus allocations carried over from the previous year. To be precise, the supply at any point within the water year is the volume of allocation and carryover, less year-to-date usage. However, data on the usage of allocations within the year are typically not available.

Figure 18 compares end-of year water allocations for the sMDB (plus carryover) from the previous year with average annual prices (in the Murray region). As expected, prices are higher in low allocation years. Although not as pronounced as seen in Figure 16, there is still evidence that, for a given level of water allocations, market prices have been higher in recent years.

FIGURE 18 Average annual water prices against end-of-year allocations and carryover, 2000–01 to 2015–16




Note: Allocation prices are for the Murray region and have been adjusted for inflation (see Appendix A).
Source: sMDB dataset (see Appendix A)

Many changes have occurred in the sMDB during 2000–16 that have contributed to this result, including environmental entitlement purchases, changes in demand for irrigation water, and changes in carryover and trading rules. Each of these factors is considered in detail below.

# Environmental purchases

Between 2007–08 and 2014–15, the Australian Government recovered around 1 400 GL of regulated surface water entitlements in the sMDB (excluding unregulated and groundwater entitlements) through a combination of market purchase and infrastructure projects.

The effects on the allocation market of entitlement purchases differ from those of infrastructure upgrades. Entitlements that are purchased by the government reduce the supply of allocations available for irrigation users (assuming allocations are used for environmental flows and not traded back to irrigators). All else held constant, this reduction in supply will lead to an increase in market prices for allocations.

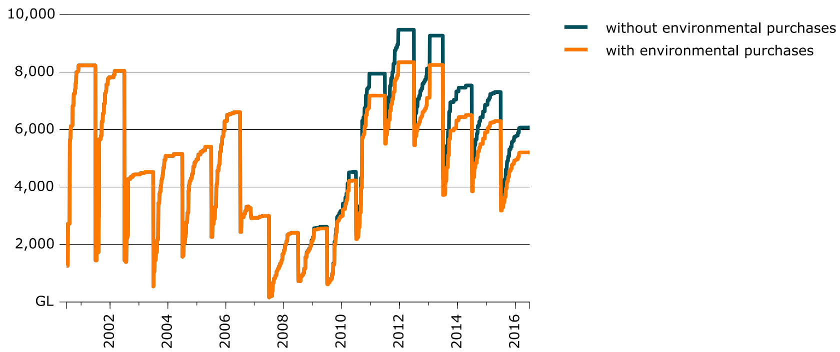
The story is more complicated in the case of infrastructure upgrades. Investments in on- or off-farm infrastructure reduce losses (to evaporation, seepage and so on). Under the Murray–Darling Basin Plan programmes, at least 50 per cent of these water savings are returned to the Commonwealth, with the remainder returned to entitlement holders. As such, the net effect of infrastructure projects should be to increase the volume of water available for use and/or to improve farm water use efficiency (by an amount greater than any environmental water recovery)—both of which would lead to lower water prices.

However, infrastructure projects can also help farmers achieve improvements in productivity. General improvements in irrigation farm productivity and profitability may result in increased demand for water. Thus, the precise effect of infrastructure projects on the water allocation price is difficult to measure, although the overall effect on the allocation price is likely to be downward because of the water savings achieved.

## Commonwealth purchases

Figure 19 shows the proportion of sMDB water allocations, associated with entitlements purchased by the Commonwealth (and therefore not available for consumptive use). This includes allocations against the CEWH's purchased entitlements, less any allocations sold back to irrigators, plus any carryover volumes held by the CEWH. In 2015–16, this environmental water amounted to a reduction in allocations available for consumptive use of around 14 per cent.

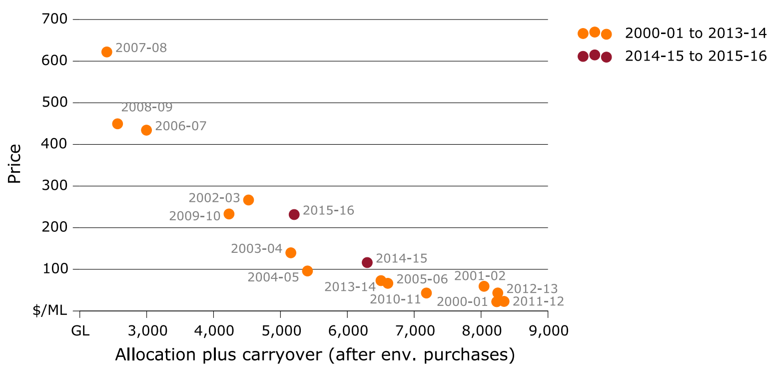
FIGURE 19 Allocations plus carryover, with and without Commonwealth purchases




Note: Includes regulated surface water entitlements only. Water entitlements held by the CEWH maintain the same characteristics as those held by irrigation users (that is, receive the same allocations and are subject to the same carryover rules) for a given reliability class.
Source: sMDB dataset (see Appendix A)

Figure 20 shows the volume of consumptive allocations available to market prices. The data suggest that environmental purchases offer a partial explanation for the higher water allocation prices observed in recent years. However, even after taking these reductions in supply into account (and ignoring any offsetting water savings from infrastructure), prices in recent years (2014–15 and 2015–16) still appear higher than other comparable years (2003–04, 2004–05, 2005–06). These data suggest that other factors (beyond allocation volumes and environmental water recovery) have contributed to the recent increase in prices.

FIGURE 20 Allocations plus carryover after environmental purchases against average annual water prices, 2000–01 to 2015–16




Note: Allocation prices are for the Murray region and have been adjusted for inflation (see Appendix A).
Source: sMDB dataset (see Appendix A)

The relationship between allocations and prices was also studied using regression analysis. Appendix B presents regression models of water allocation prices against farm rainfall and allocations (after accounting for environmental purchases). This analysis obtains a similar result to that shown in Figure 20: the combination of lower allocations and environmental purchases in 2014–15 and 2015–16 can explain some, but not all, of the increase in prices. Overall, the results suggest that some factors beyond allocation volumes, environmental purchases and rainfall have contributed to the recent high prices.

Finally, an economic model of the sMDB water market (detailed in Appendix C) was used to estimate the effects of Commonwealth entitlement purchases since 2007–08 on allocation prices. Entitlement purchases are estimated to have increased annual water allocation prices by an average of around $25 per ML (or 39 per cent) between 2012-13 and 2014–15. This estimate is comparable to that obtained by Aither (2016a) of around $22 per ML (or 32 per cent) for the same period. Note that these studies may overstate the actual effect of environmental water recovery in the sMDB, because both exclude offsetting water savings from infrastructure projects (see Appendix C for more detail).

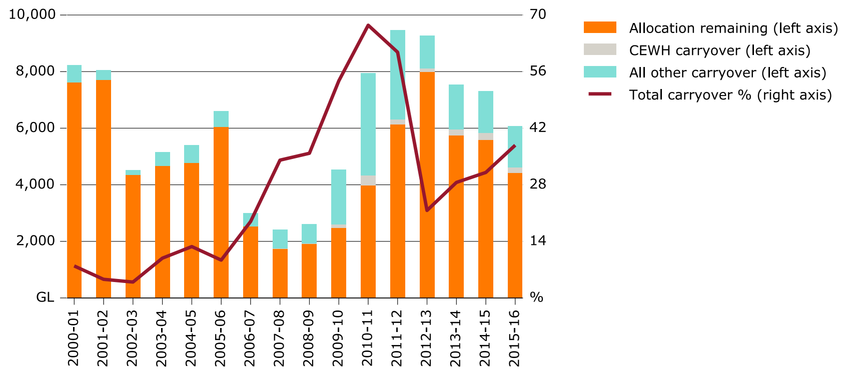
## Carryover rules

Since 2000, there have been significant changes to carryover rules in the sMDB. During the millennium drought, temporary carryover arrangements were introduced for the first time in South Australia and Victoria, while carryover limits in some NSW regions were temporarily increased. Since then, both South Australia and Victoria have introduced permanent carryover arrangements. Carryover rules remain different across states and water systems (for a detailed description, see Hughes et al. 2013). Key rule changes since 2007–08 include:

- 2007–08: South Australia and Victoria introduce temporary carryover arrangements
- 2008–09: Victorian annual carryover limit increased from 30 to 50 per cent
- 2009–10: Murrumbidgee annual carryover limit increased from 15 to 30 per cent
- 2010–11: South Australia removes carryover, while Victoria introduces permanent carryover arrangement in the form of spillable water accounts, with no limit on annual carryover volumes (see Box 1)
- 2011–12: Review of Victorian carryover rules (see Box 1)
- 2012–13: South Australia adopts a permanent carryover arrangement
- 2013–14: Changes to Victorian carryover rules introduced, including a 100 per cent annual limit.

These rule changes amount to a significant relaxation of constraints on carryover in the sMDB, resulting in a significant increase in the volumes of water being carried over by entitlement holders (Figure 21).

FIGURE 21 Allocation available after carryover into the next year, 2000–01 to 2015–16




Note: Total allocation remaining includes total allocation plus carryover from the previous year, less carryover to the next year. All other carryover into next year is total carryover less CEWH carryover. Carryover percentage is total carryover into next year as a percentage of allocation plus carryover from previous year.
Source: sMDB dataset (see Appendix A)

Figure 21 shows total sMDB allocations and carryover volumes into the next year between 2000–01 and 2015–16. Despite the drought conditions, carryover increased in 2008 following the introduction of carryover rules in Victoria and South Australia. In 2010–11, carryover volumes increased dramatically, because of a combination of wetter conditions and changes to Victorian carryover rules (see Box 1). Although drier conditions (and a tightening of carryover rules in Victoria) have led to some reduction in carryover since then, carryover percentages remain well above their pre-drought levels (37 per cent in 2015-16 compared with 4 per cent during 2000–01 to 2002–03).

This relaxation of carryover rules and the resulting increase in carryover volumes has important implications for water prices. The next section considers the effect of carryover rule changes on both inter-year and intra-year price variation.

### Box 1 **Victorian carryover rule failure during 2010–11 and 2011–12**

In 2010–11, Victoria implemented a new spillable water account (SWA) carryover system (for more detail, see Hughes et al. 2013). Its first year in operation revealed several system flaws. Specifically, the system allowed unlimited user carryover in the Vic. Murray region in 2010–11 despite binding storage capacity constraints (that is, Victoria's share of the Hume Dam was full).

Various limitations in storage rights and trading rules contributed to this situation (Hughes et al. 2013):

- The Victorian resource manager incorrectly predicted a low risk of storage spill at the beginning of the 2010–11 water year. Once this declaration had been made, all water in the SWA was available for use, and spill forfeit rules could not be applied to carryover volumes.
- Although Victoria lost water through an 'internal spill' to NSW, this event did not constitute a spill for the purposes of user carryover rules. Under the rules that prevailed at the time, only a spill from Dartmouth storage triggered spill forfeit rules.

Interregional allocation trade during 2010–11 exacerbated the situation. In 2010-11 irrigators in the NSW Murray region faced binding limits on carryover and were at risk of forfeiting allocations. As such, NSW Murray irrigators had an incentive to trade water into the Vic. Murray where carryover limits were not binding. However, such trade had significant external effects, since it could not be matched by an increase in Vic. Murray water holdings (given the Victorian share of Hume Dam was full).

The Victorian Government imposed a temporary ban on water allocation trade from New South Wales into the region from April 2011. However, water effectively traded around this ban, with allocations moving from New South Wales to South Australia, and then from South Australia back into the Vic. Murray (see Hughes et al. 2013). In March 2012, storages again filled after a low risk of spill declaration in December 2011. Victoria again moved to suspend interregional water trading with New South Wales, but this time trading bans also extended to South Australia.

Several rule changes were made following a review of carryover in Victoria in 2012.

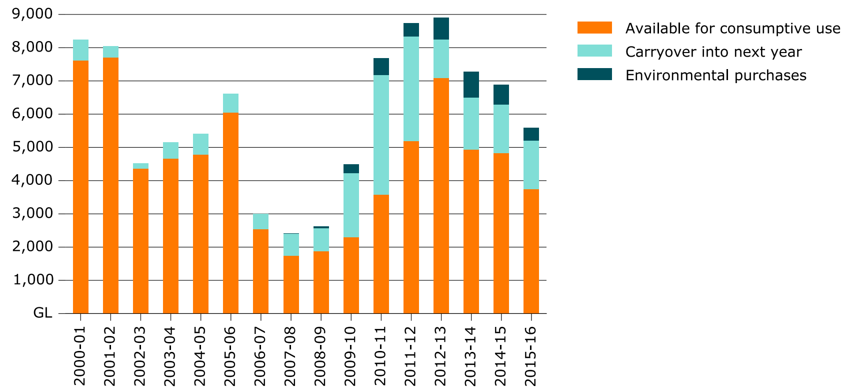
- The spill rules were amended so that a Hume Dam spill event triggers user SWA deductions.
- New trade restrictions were imposed, including an annual limit on trade from New South Wales to Victoria of 200 GL or 'a volume that keeps the risk of spill in Victoria's share of the Murray system below 50 per cent' (Victorian Water Register 2016).
- An annual limit on carryover of 100 per cent of entitlement volume was imposed.

## Effect of carryover on annual allocation prices

In general, greater access to carryover will tend to smooth annual variation in water allocation prices (see Box 2). During wet to average years, users are expected to increase their carryover balances, reducing the supply of water in that year and increasing the price. In dry years, users can drawdown on these carryover reserves and help limit allocation price rises. The economic motivation behind carryover is that the benefits of lower prices in drought years will, in the long run, outweigh the costs of slightly higher prices in other years.

The increase in carryover in the sMDB helps to further reconcile the higher allocation prices observed in recent years. Although total allocations available in 2014–15 and 2015–16 were relatively high, a large proportion of this water (23 and 37 per cent, respectively) was carried over into the next year and therefore not used. After accounting for carryover and allocations to purchased Commonwealth environmental entitlements, the volume of allocation available for use in 2015–16 was lower than during the 2002–03 drought year (Figure 22).

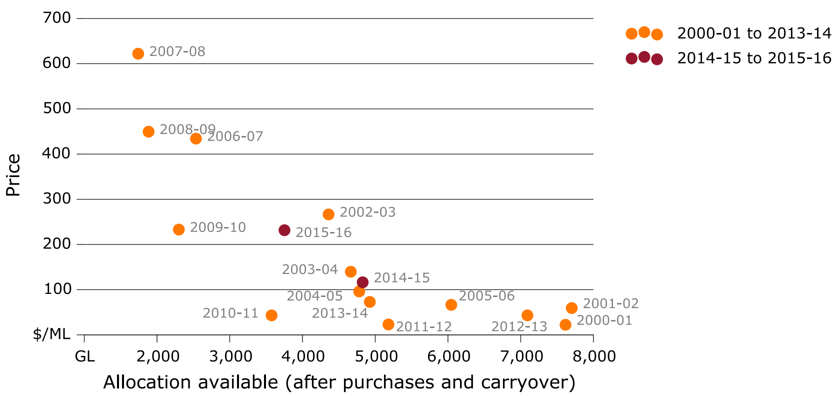
FIGURE 22 Allocation available after environmental purchases and carryover into the next year, 2000–01 to 2015–16




Note: 'Allocation used within year' includes total allocation plus carryover from the previous year, less allocations and carryover against purchased Commonwealth entitlements, and less carryover to the next year.
Source: sMDB dataset (see Appendix A)

Figure 23 shows the allocations available within each year (after removing both Commonwealth purchases and carryover into the next year) with average water prices. These data suggest that the combination of lower allocations, environmental water purchases and greater carryover volumes go a long way in explaining the recent higher prices. Much of the remaining variation in water prices in Figure 23 (including the low prices in 2010–11 and higher prices of 2002–03) can be explained by shifts in irrigation demand in response to annual rainfall variation (discussed in detail later in this section).

FIGURE 23 Allocations less environmental water and less water carried over to the next year, against average annual water prices, 2000–01 to 2015–16




Note: Allocation prices are for the Murray region and have been adjusted for inflation (see Appendix A).
Source: sMDB dataset (see Appendix A)

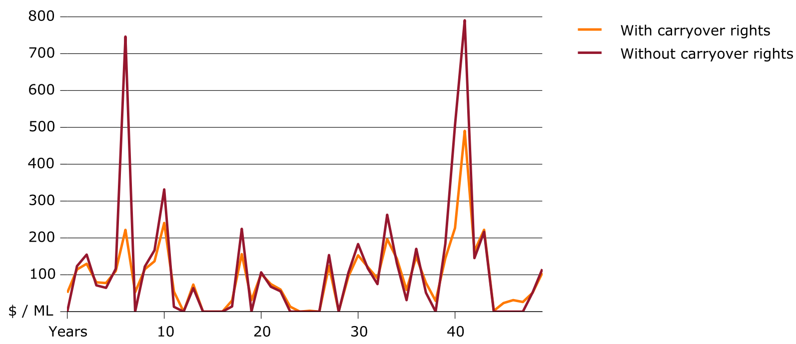
## Box 2 **Modelling the effect of carryover on water prices**

The effect of carryover rights on water market prices has been recently considered by Hughes (2015). This study involved the development of an economic model of a river system, in which many water users make storage decisions subject to carryover rules while also engaging in water allocation trade. Although this research remains somewhat theoretical, the model is calibrated using data from the MDB, and is broadly representative of the water demand and supply conditions in the sMDB.

Results from this modelling are summarised below (for more detail, see chapter 5 of Hughes 2015). These results compare a 'Without carryover rights scenario' ('no storage rights' or NS; see Hughes 2015) with a 'With carryover rights scenario' (capacity sharing or CS; see Hughes 2015), and demonstrate the effect of complete adoption of carryover rights from a starting point of no carryover rights. In practice, the transition in the sMDB has been gradual, with carryover rules being progressively introduced across regions over several decades.

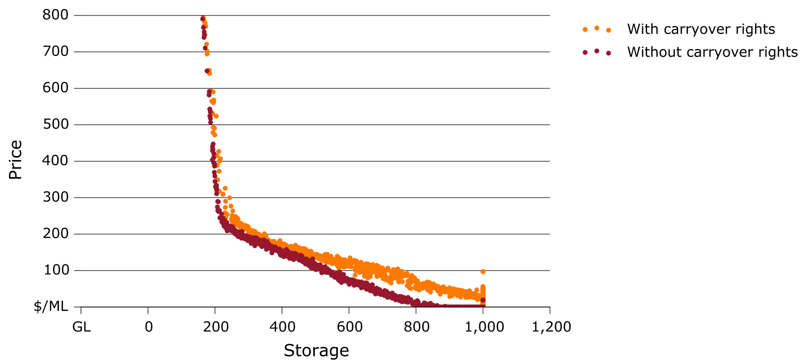
Figure 24 compares simulated water prices under the two scenarios (for a hypothetical 50-year climate sequence). With carryover rights, water prices tend to be significantly lower in drought years and slightly higher in wetter years. For a given volume of water in storage, prices are higher with carryover rights, reflecting the additional 'option value' of storing water for future years (Figure 25). However, water prices are lower on average with carryover rights, because of higher storage reserves, and less frequent and severe drought shortages. Overall, carryover rights lead to a gain in average irrigation profits of 2 per cent and a larger 25 per cent reduction in the variance of profit.

FIGURE 24 Simulated water prices, with and without carryover rights




Source: Hughes (2015)

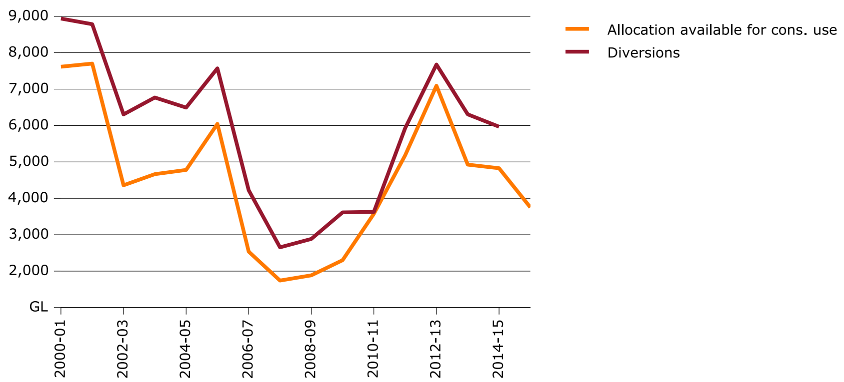
FIGURE 25 Simulated water prices against storage volumes




Source: Hughes (2015)

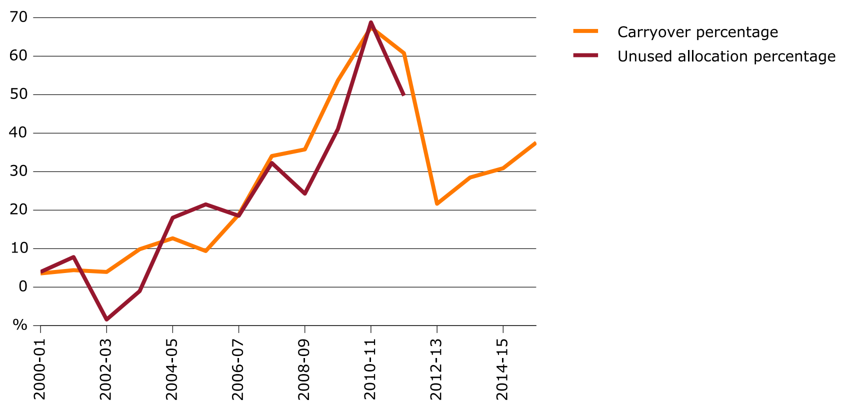
One limitation of the analysis (including Figure 23) is that it doesn't account for unused (forfeited) allocation (unused water that is forfeited to the 'consumptive pool' rather than carried over by entitlement holders). Although unused water is effectively carried over from one year to the next (because it is reallocated to users in the next year), it is excluded from carryover statistics. However, available data on actual sMDB diversions (Figure 26) and allocation usage (Figure 27) both correlate closely with the estimates presented above, suggesting a limited role for forfeited allocation effects. Note that the diversion numbers presented in Figure 26 include use against all water entitlements (including conveyance, stock and domestic and unregulated) and are therefore consistently higher than the allocation estimates which include only regulated surface water.

FIGURE 26 Allocations available (after purchases and carryover) and actual southern MDB diversions, 2000–01 to 2015–16




Note: Diversions include conveyance, stock and domestic, and unregulated water use. Source: sMDB dataset (see Appendix A) and MDBA. Annual diversions provided by the MDBA and include the NSW and Vic. Murray, Goulburn, Campaspe, Murrumbidgee, SA MDB, and Lower Darling regions.

FIGURE 27 Total carryover percentage versus actual allocation usage, 2000–01 to 2015–16



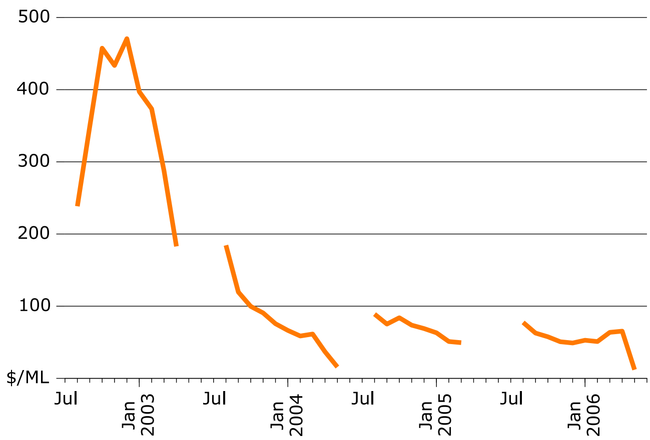

Source: sMDB dataset (see Appendix A) and MDBA. Total unused allocation percentage is calculated as 1 – 'use as percentage of authorised valley use' as reported in MDBA Water Audit Monitoring Reports 2000–01 to 2011–12, and includes both carryover and forfeited allocation. MDBA data include the NSW and Vic. Murray, Goulburn, Loddon, Campaspe, Murrumbidgee, SA MDB, and Lower Darling regions.

## Effect of carryover on end-of year prices

Brennan (2006) observed that, before the introduction of carryover rights in Victoria, allocation prices tended to decline late in the water year (as any water allocations unused by the end of the year were forfeited) (Figure 28). This situation has clearly changed in recent times. For example, in 2014–15, water allocation prices increased significantly late in the year (Figure 29).

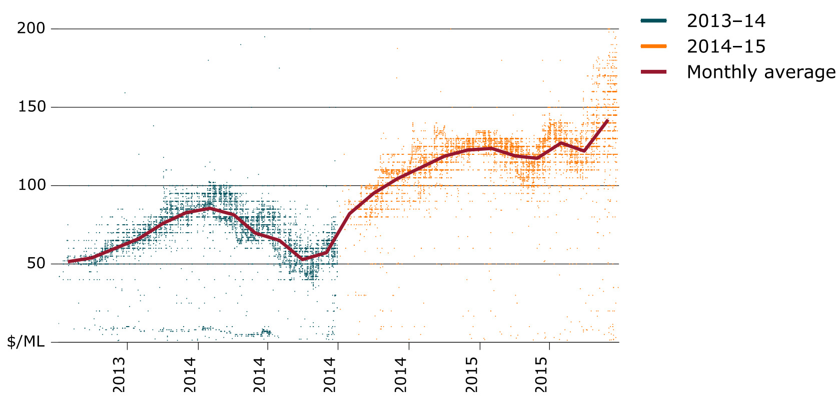
The relaxation of carryover limits also generally encourages market participants to be more forward looking. When making trade decisions, users will pay more attention to forecasts of water availability in subsequent seasons. For example, the 2014–15 end-of-year price rise could be partially attributed to a market expectation of poor conditions in 2015–16 (driven by strong El Niño observations and predictions of lower future allocations made around that time).

FIGURE 28 Goulburn region monthly allocation prices, 2002–03 to 2004–05




Source: sMDB dataset (see Appendix A)

FIGURE 29 Prices of allocation trades in the southern MDB, 2013–14 to 2014–15



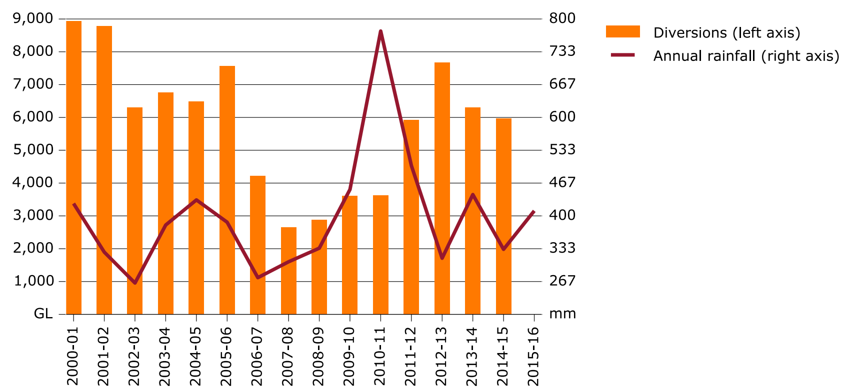

Source: ABARES (2016)

## Farm rainfall

The preceding discussion has ignored any variation in the demand for irrigation water. In practice, demand for irrigation water largely depends on annual farm rainfall. In high rainfall years, natural soil moisture is high and demand for irrigation water is lower.

Figure 30 shows average farm rainfall as well as annual diversions (that is, water use) for the sMDB between 2000 and 2016. In terms of farm rainfall, 2010–11 was an extremely wet year; thus, irrigation water use remained low—in fact, significantly lower than for 2006–07, which was during the height of the millennium drought. The driest year in terms of farm rainfall was 2002–03, which helps to explain why water prices were so high despite relatively average allocation and diversion levels.

FIGURE 30 Annual southern MDB diversions and average rainfall, 2000–01 to 2014–15

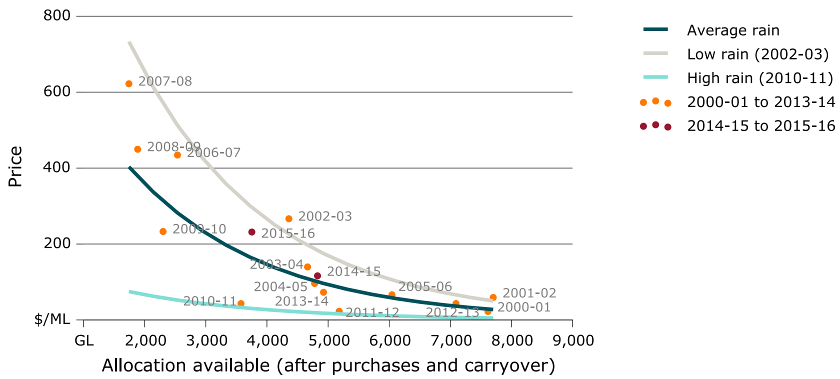



Note: Farm rainfall can vary significantly across the sMDB.
Source: Rainfall data from the sMDB dataset (see Appendix A); diversions data from the MDBA, and include the NSW and Vic. Murray, Goulburn, Campaspe, Murrumbidgee, SA MDB, and Lower Darling regions.

A regression model for annual water prices is presented in Appendix B. This model controls for all of the factors discussed above, including variation in allocations and farm rainfall, entitlement purchases and carryover volumes, and explains the vast majority of variation in prices during the period. The relationship between allocation volumes, rainfall and prices estimated by the model is shown in Figure 31 (see Appendix B for detail). Low farm rainfall helps to explain the higher prices observed during 2002–03, whereas high rainfall explains the lower prices of 2010–11 and 2011–12.

After controlling for allocations available for use (after environmental purchases and carryover into the next year) and farm rainfall, the model still under-predicts prices during 2015–16 (given near average rainfall in that year). The Murrumbidgee trade restriction and changes in irrigation land use (discussed below) are two potential explanations for the higher prices observed during 2015–16.

FIGURE 31 Estimated relationship between water allocations, rainfall and price in the southern MDB (model 2)




Source: sMDB dataset (see Appendix A) and ABARES model estimate

# Trade restrictions

The sMDB water market is governed by a complex set of trading restrictions. Key trade restrictions are specified in the MDB Agreement, which defines at least 13 major trading zones and various rules for when water allocations can be traded between each zone. Other trading rules are specified by the Murray–Darling Basin Authority (MDBA) in the Basin Plan trading rules, by state governments (in water sharing plans) (see Box 3) and by irrigation infrastructure operators.

The basic principles of water trading (under the Murray–Darling Basin Plan trading rules) are that trade should be allowed wherever it is physically possible. As such, trade restrictions are intended to only reflect actual hydrological constraints on the water network (for example, transmission losses and capacity constraints).

The development of interregional trading rules involves a difficult trade-off between maximising trading opportunities and minimising third-party effects (that is, externalities). Third-party effects can occur where water trading violates physical constraints (if, for example, transmission losses are not considered). In these cases, water trade can reduce water availability for other water users.

In many cases, trade restrictions are non-binding, so that market prices are not affected (that is, trade limits are greater than market trade volumes). However, there are some important constraints that have the potential to restrict trade and lead to differences in prices between zones at certain times. Significantly, these trading restrictions apply to all allocation transfers, including market-based irrigation trades and environmental transfers. That is, environmental transfers can also count towards volumetric trade limits and can therefore influence whether a constraint is imposed on all users.

The development of interregional trading rules in water markets is complex. Section 4 considers whether scope remains to improve trading rules in the sMDB. For now, the focus is on key trading constraints in the Murrumbidgee and Goulburn regions, and their effect on market prices between 2000–01 and 2015–16.

### Box 3 **Inter-valley transfer accounts and trade limits in the southern MDB**

The states and the MDBA maintain inter-valley transfer (IVT) accounts, to keep track of net allocation trade between regions. The IVT accounts record how much water needs to be physically transferred between systems to satisfy regional water demands.

The water allocation market allows individual users to trade allocations between regions subject to prevailing limits. Once traded, these allocations are available for use as soon as the trade is approved (typically within 1–2 days). However, water is not physically transferred to support each individual trade. Instead, net trade balances are recorded for each region in the IVT accounts.

Over time, the MDBA adjusts these accounts via river operation decisions (that is, by physically releasing water from different storages). However, given other river operation objectives (such as the need to minimise evaporation and storage losses), the balancing of IVT accounts can take some time. In some cases, regional IVT accounts may not be balanced within the water year, in which case they carryover to the next.

In New South Wales and Victoria, trading constraints are imposed when these IVT accounts reach certain thresholds (outlined below). As the IVT account balances depend on river operation decisions, the actual volumes of trade that are permitted in any given month or year can vary significantly.

**Murrumbidgee (–100–0 GL):** net interregional trade is allowed only when the IVT balance is from -100 to 0 GL (no net trade in and a maximum of 100 GL net trade out). These rules are intended to reflect hydrological constraints—water cannot be transferred upstream into the Murrumbidgee, whereas large downstream transfers are subject to high transmission losses (WaterNSW 2016).

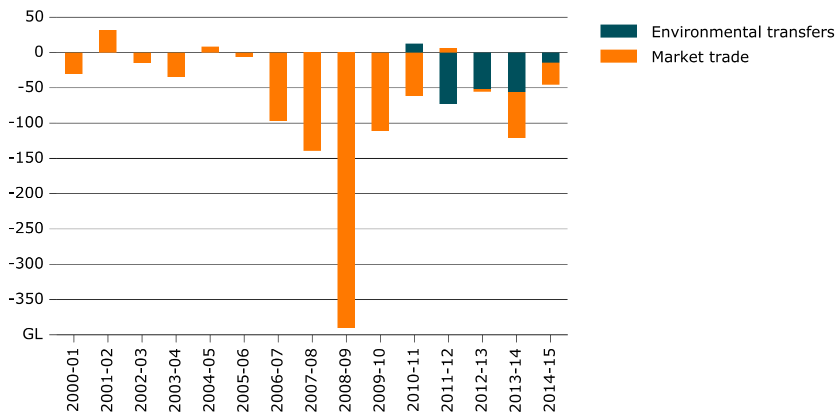
**Goulburn (–200–0 GL):** net interregional trade is allowed only when the IVT balance is from –200 to 0 GL (no net trade in and a maximum of 200 GL net trade out). The Goulburn 200 GL restriction is motivated by concern about storage spills, following the Murray spill events of 2010–11 (Victorian Water Register 2016).

## The Murrumbidgee

Historically, the Murrumbidgee region has been a net exporter of water allocation (Figure 32). During the millennium drought, regional water sharing plans and trading rules were suspended, allowing unrestricted trading, with as much as 390 GL of water being traded out in 2008–09 (the Murrumbidgee WSP was suspended between 2006–07 and 2009–10). However, in 2015-16, allocation trade out of the Murrumbidgee into the Murray has been constrained by the region's export trade limit.

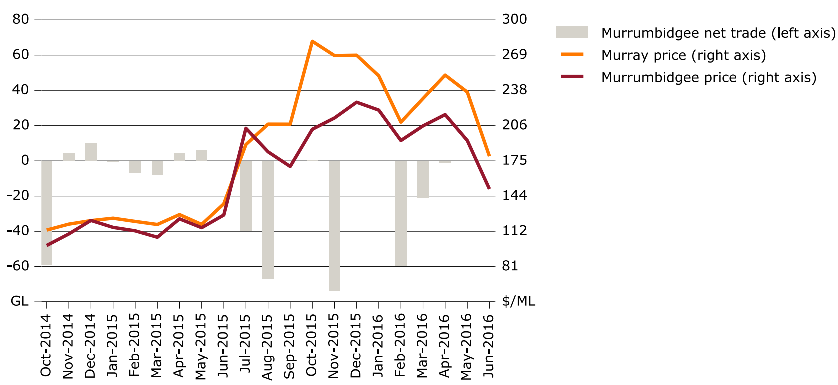
In August 2015, the Murrumbidgee 100 GL IVT limit was reached, preventing trade out of the region, and resulting in a divergence in allocation prices between the Murrumbidgee and Murray zones (Figure 33). When the trading constraint was briefly relaxed in November 2015, a rush of trade out of the Murrumbidgee helped to reduce this price differential. This divergence further explains the perception of higher prices in recent years - at least when the reference point is the Murray trading zone as it was in the preceding analysis (Figures 18, 20 and 23).

FIGURE 32 Annual net allocation trade, Murrumbidgee region, 2000–01 to 2014–15




Source: sMDB dataset (see Appendix A)

FIGURE 33 Monthly allocation prices, Murrumbidgee and Murray, October 2014 to June 2016




Note: Trade data only available until April 2016.
Source: Price data from sMDB dataset (see Appendix A) and monthly trade data from the MDBA.

In Appendix C, an economic model of the sMDB water market simulates the effects on water market prices of limits on trade out of the Murrumbidgee. In particular, a scenario with no Murrumbidgee export limits is compared with a scenario with a 100 GL annual export limit in all years. The results suggest that, if a Murrumbidgee export limit had been applied during the millennium drought, it would have increased prices in the Murray trading zone (by around $65 per ML in 2008–09) and lowered prices in the Murrumbidgee (by around $130 per ML in 2008–09).

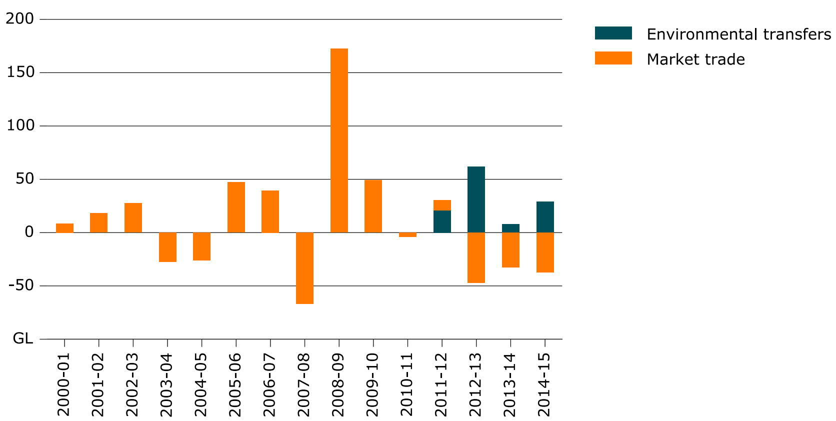
These results do not necessarily imply that removing the restriction would benefit water users. In the case where trade out of the Murrumbidgee is subject to high transmission losses and/or capacity constraints, trade will result in negative third-party effects, which may more than offset any gains from trade. The design of interregional water trading rules is considered further in Section 4.

Up until 2016, environmental agencies have been net exporters of water from the Murrumbidgee (Figure 32). These environmental transfers consume a portion of the region's trade limit, potentially reducing the capacity of irrigation users to trade water out. However, it is important to recognise that the CEWH accounts for only a portion of these environmental transfers. In 2013–14, the CEWH transferred only 4.5 GL of allocation out of the Murrumbidgee into the Murray compared with a total net environmental transfer of 55.8 GL. In 2014–15, the CEWH transferred 20 GL of water out (ABARES2016), compared with a total net environmental transfer of 14.5 GL (suggesting that other environmental agencies transferred water into the Murrumbidgee). Other environmental entities in the sMDB include The Living Murray Initiative, the Victorian Environmental Water Holder and the NSW Office of Environment and Heritage.

## The Goulburn

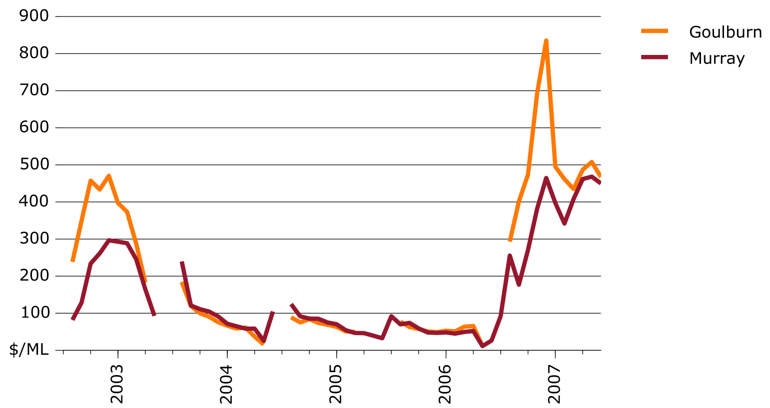
The Goulburn's net trade position has varied from year to year (Figure 34). Historically, the limit on net trade into the region from the Murray has been the major constraint. During both 2002–03 and 2006–07, Goulburn import limits were binding, leading to substantially higher prices in the Goulburn relative to the Murray (Figure 35). In recent years, the Goulburn has been a net exporter of water allocations (at least excluding environmental transfers). From August to November 2014, the region's IVT export limit was binding, leading to slightly lower prices in the Goulburn region relative to the Murray (Figure 36). In the Goulburn, up until 2016, environmental agencies have been small net importers of water (Figure 34).

FIGURE 34 Annual net allocation trade, Goulburn and Broken regions, 2000–01 to 2014–15



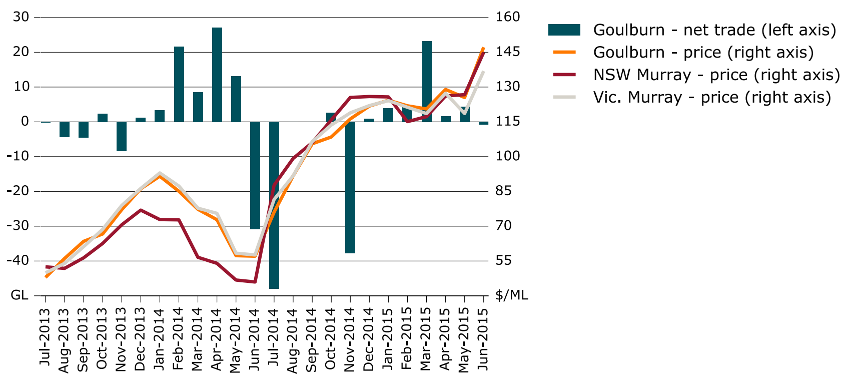

Source: sMDB dataset (see Appendix A)

FIGURE 35 Monthly allocation prices, Goulburn and Murray regions, 2002–03 to 2006–07




Source: sMDB dataset (see Appendix A)

FIGURE 36 Monthly allocation prices, Goulburn and Murray regions, 2013–14 to 2014 –15




Source: ABARES (2016)

## Commodity prices and land-use change

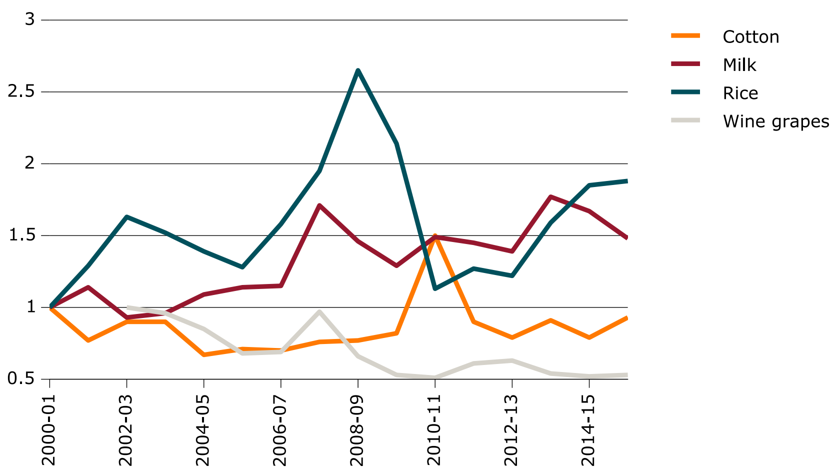
Short-run variation in output and input prices can alter the relative profitability of irrigation activities and, in turn, affect the demand for water. In the longer term, changes in relative profitability can alter investment patterns, leading to more substantial shifts in irrigation land use.

Prices of major irrigated commodities in the sMDB have varied widely from 2000–01 to 2015–16 (Figure 37) and show some key trends.

- Since 2000–01, the price of wine grapes has declined significantly, leading to a gradual contraction in wine grape plantings in the sMDB.
- Since 2006–07, the financial performance of cotton farms has exceeded that of rice farms in the MDB. Thus, there has been a slight shift towards cotton and away from rice in the sMDB.
- Between 2000-01 and 2004-05, almond prices more than doubled, leading to a large increase in almond plantings in the sMDB. The area planted almost doubled, from around 15 000 hectares to 29 000 hectares in the space of a few years (ABA 2016).

Some of these industry trends are documented further in recent ABARES reports (Ashton and Oliver 2015a, 2015b).

FIGURE 37 Selected commodity price indexes, 2000–01 to 2015–16



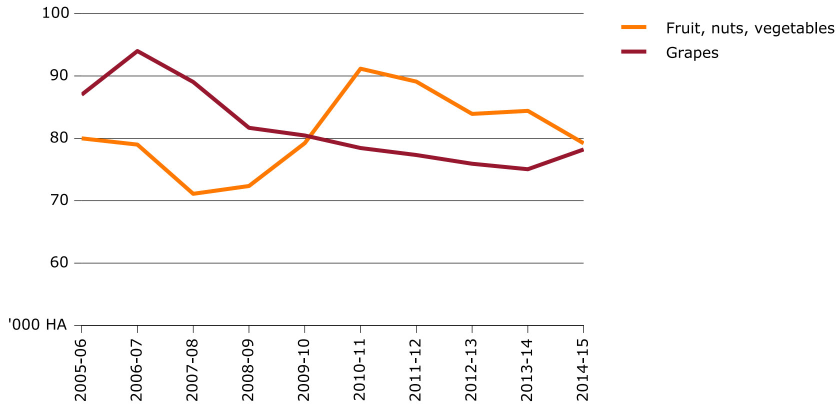

Note: Wine grapes (warm climate) price data not available before 2002–03.
Source: ABARES Agricultural commodity statistics (2015) ABARES Agricultural commodities (2016)

The total land area set up for irrigation has been subject to opposing drivers during 2000–16. Government environmental water recovery and related irrigation network rationalisation has seen some irrigation land being converted to dryland production. More recently, some new irrigation areas have been established on greenfield sites largely to support nut production (particularly almonds). Aither (2016b) documents the recent expansion in nuts and cotton in the sMDB, and predicts these new investments will increase water demand in the coming years.

Data from the Australian Bureau of Statistics (ABS) on irrigated land use in the southern MDB are shown in Figure 38 and Figure 39. Since 2005–06, grape areas have gradually decreased, although a slight increase was recorded in 2015. Fruit and nut areas increased between 2008 and 2011, although they have declined since then.

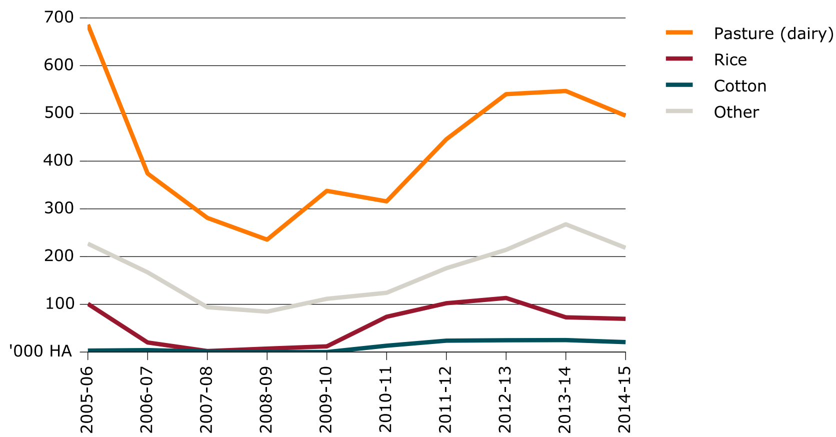
Broadacre areas planted all decreased during the drought, with most broadacre crops returning to near their pre-drought levels during the higher allocation years of 2012-13 and 2014-15. Two exceptions include: irrigated pasture (dairy) areas – which have remained somewhat below their pre-drought (2005-06) levels and cotton – which expanded in the sMDB in 2010–11 and 2011–12.

FIGURE 38 Southern MDB area, irrigated horticulture, 2005–06 to 2014–15




Note: Includes the Vic. Goulburn, North East, North Central, SA MDB, NSW Murray, Mallee, Wimmera and Murrumbidgee regions.
Source: ABS (2016)

FIGURE 39 Southern MDB area, irrigated broadacre, 2005–06 to 2014–15

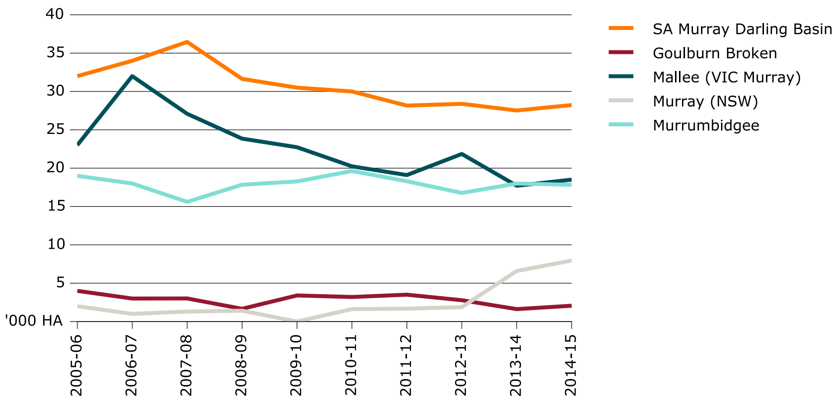



Note: Includes Vic. Goulburn, North East and North Central, SA MDB, NSW Murray, Mallee, Wimmera and Murrumbidgee regions. Other includes 'other cereals for grain or seed' and 'other broadacre crops'. Pasture includes 'pastures and cereal for grazing/hay/silage'.
Source: ABS (2016)

At a regional level, the declines in grape areas have been largest in the SA Murray and Mallee (Sunraysia) regions (Figure 40). In recent years, increases in fruit, nut and grape plantings have been observed in the Goulburn, Murrumbidgee and NSW Murray regions while decreases have occurred in the SA Murray region (Figures 40 and 41).

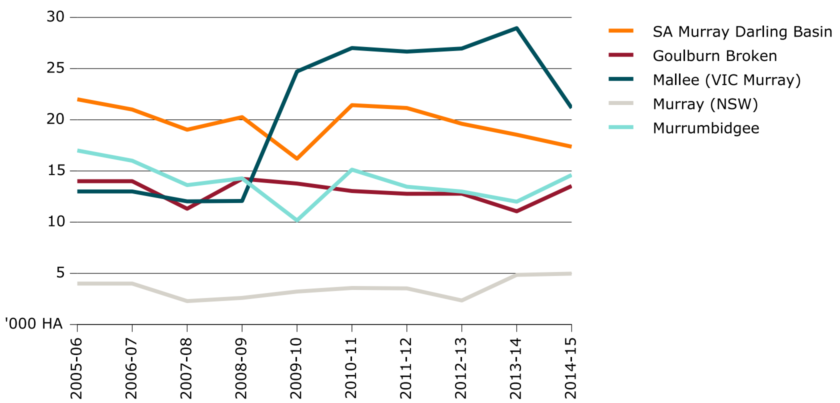
By far the largest increases in horticultural areas since 2005–06 have occurred in the Victorian Mallee region. There has also been a large rise in the water application rate for horticulture in the Victorian Mallee, potentially driven by the expansion of almonds (Figure 42). Overall these changes appear to have increased horticultural water demand in the sMDB (Figure 42). While further research is required to confirm the effect of these structural changes on water prices, increased horticultural demand is likely to have an upward effect on water allocation prices, at least in dry years.

FIGURE 40 Grape area irrigated, by region, 2005–06 to 2014–15



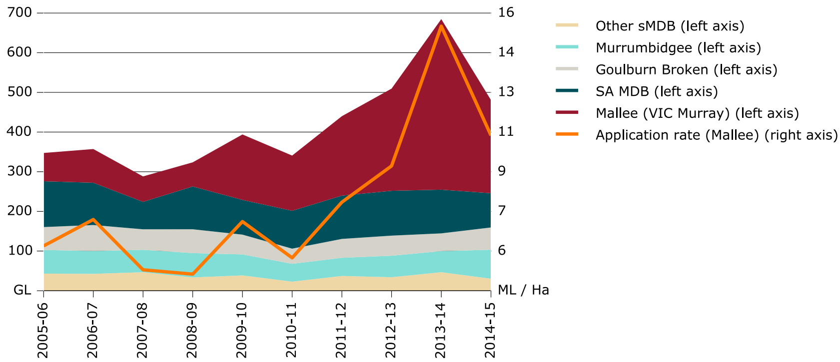

Source: ABS (2016)

FIGURE 41 Fruit, nut and vegetables area irrigated, by region, 2005–06 to 2014–15




Source: ABS (2016)

FIGURE 42 Fruit and nuts water use by region, 2005–06 to 2014–15




Source: ABS (2016)

# Conclusions

Since 2000–01, the sMDB water allocation market has grown dramatically in terms of user participation and trading activity. The market has become a vital tool for the irrigation sector—particularly during drought—allowing large volumes of water to be quickly reallocated in response to farm demands. Overall, the sMDB market has been an overwhelming success, and is rightly viewed as one of the best examples of its kind in the world.

Some dramatic fluctuations in water market prices have been seen from 2000–01 to 2015–16. Much of this variation can be easily explained by climate variability and its influence on water supply and demand. During the height of the millennium drought, water storage volumes and water allocations reached record lows and prices reached record highs. When storages filled in the subsequent flood years, water prices quickly dropped to near zero.

## High water prices in recent years

Between 2011–12 and 2015–16, water market prices have steadily increased. Although these price rises have coincided with a general decline in allocations, recent prices still appear to be high, given past experience. Based on an analysis of market data from 2000–01 to 2015–16, this study concludes that the high market prices in recent seasons are best explained by a combination of factors: allocation percentages and rainfall, Commonwealth entitlement purchases for environmental flows, carryover rule changes, trade restrictions, and commodity price fluctuations and land-use changes.

### Allocation percentages and rainfall

Data presented in this report demonstrate a strong correlation between allocation volumes, farm rainfall and water market prices, consistent with that observed in previous studies. However, lower allocations and rainfall since 2011–12 can explain only part of the recent increase in prices. After controlling for these factors, prices were still significantly higher than expected during 2014–15 and 2015–16.

### Commonwealth entitlement purchases for environmental flows

Between 2007–08 and 2014–15, the Commonwealth has purchased around 1 000 GL of water entitlement for environmental flows, and acquired around 840 GL through infrastructure investments in the sMDB. Environmental entitlement purchases reduce the supply of allocations for irrigation, which—all else held constant—will increase water prices. At the same time, infrastructure projects increase the supply of water, which may offset these effects.

Environmental purchases resulted in a 14 per cent reduction in allocations available for consumptive use in 2015–16. Even if water savings from infrastructure projects are ignored, environmental purchases offer only a partial explanation for the recent increase in prices. After controlling for the reduction in allocations available for use since 2007–08, prices were still higher than expected during 2014–15 and 2015–16.

### Carryover rule changes

Since 2000–01, there have been several important changes to carryover rules, including the introduction of carryover in Victoria in 2007–08. These rule changes have seen large increases in the proportion of water allocations being carried over. Between 2012–13 and 2015–16, an average of 30 per cent of available water was carried over into the next year, compared with just 8 per cent between 2000–01 and 2005–06.

The increased use of carryover has important implications for the water allocation market. In general, carryover will lead to higher prices in some years (typically during average or wetter years) in turn for lower prices in others (typically drier years). The increase in carryover volumes since 2010–11 helps to explain the recent high water market prices. In 2015–16, around 37 per cent of water available was carried over into 2016–17, reducing the available supply in 2015–16 to less than what was available during the 2002–03 drought year. The combination of dry conditions, environmental purchases and increased carryover explains most of the recent price increases.

### Trade restrictions

In recent years, several interregional constraints on allocation trade have been binding. In general, these constraints have limited trade into the Murray, leading to higher prices in the Murray trading zones. For example, in 2015–16, trade was restricted out of the Murrumbidgee region into the Murray because of IVT account limits. After trade was stopped in August 2015, prices in the Murray rose well above those in the Murrumbidgee, reaching around $270 per ML in October (compared with around $200 in the Murrumbidgee).

### Commodity price fluctuations and land-use changes

Between 2000–01 and 2015–16, there have been many structural changes in the irrigation sector, all of which have implications for the demand for water and therefore market prices. Wine grape areas have steadily decreased, whereas other horticultural crops—including nuts—have expanded. Overall, the most significant change has been an increase in demand for water from horticulture within the lower Victorian Murray region. While further research is required to confirm the effect of these changes on water prices, increased horticultural demand is likely to have an upward effect on water allocation prices at least in dry years.

## Policy implications

Although water market prices have been higher than expected in recent years, this does not necessarily indicate a market failure. Higher market prices can be explained by changes in supply and demand including: changes in water allocation volumes, the purchase of water rights for environmental purposes, changes in the way water is managed and used by irrigators and changes in trading rules.

At the same time, it is important to realise that fluctuations in prices can have welfare effects on individual market participants. These welfare effects will depend largely on the types of water entitlements held. For example, some entitlement holders will benefit from higher allocation (and in turn entitlement) prices, because they represent an increase in the value of their assets. Others may be adversely affected, particularly irrigation farms that have sold entitlements and are now more reliant on purchasing allocations.

From an efficiency perspective, the key question is whether there remain any opportunities to further improve the market. Although the sMDB market is highly efficient by international standards, the process of reforming water property rights and market rules is an ongoing one. Given the complexities involved, water property rights and market rules are always an approximation of hydrological reality. Over time, changes in market conditions, increases in scarcity or new technologies may warrant changes to existing rules. Three areas where there may exist some scope for reform include carryover rules, trading rules and environmental water transfers.

## Carryover rules

The expansion of carryover within the sMDB is a positive development that helps water users to better manage annual variability in water supply. Fully realising the gains from carryover requires well-defined carryover rules that reflect physical storage constraints. The design of carryover rules has been considered in detail in previous reports (Hughes 2015; Hughes et al. 2013).

Past research suggests that, although existing rules in the sMDB are effective, there may be gains from adopting more sophisticated carryover arrangements (such as continuous accounting), similar to those used in northern New South Wales and southern Queensland.  Broadly, this approach would involve the removal of annual limits on carryover, in place of limits on the volume of unused allocation that can be held at any time, reflective of storage capacity constraints (Hughes et al. 2013).

## Trading rules

The Murrumbidgee trading ban during 2015–16 raised questions about the design of interregional trading rules. The first question is whether there is any scope to relax existing trading rules, particularly volumetric IVT limits. Although the potential for third-party effects requires attention, some review of trading limits is warranted, given the frequency with which they have been binding in recent years.

A second question is whether there are any options for more substantial property right reform to improve the efficiency of interregional allocation trade. There are several proposals that have been advanced, including ‘source tagging’ (such as applying delivery loss factors to trades), computerised ‘smart markets’ or American-style centralised ‘water banks’. However, each are subject to their own practical limitations and more work remains to be done before these can be considered anything but long-term propositions (for more detail, see Hughes 2010).

In the short term, it may be easier to alleviate trade limits by altering river operation decisions, where circumstance allow. For example, in the case of the Murrumbidgee, it might be possible to export more water into the Murray through the Snowy Mountains Hydro-electric Scheme to lower the IVT account balance. Such changes need to take into account other operational objectives, including scheduling of hydro-power generation. While subject to some complexity, these types of operations have been undertaken in the past and continue to be considered by the MDBA.

## Environmental water transfers

Typically, environmental water holders (EWHs) in the sMDB are subject to the same water property rights and trading rules as irrigation users. For some aspects of water rights and some forms of environmental use, this approach appears appropriate. However, for other aspects, particularly those related to the delivery of in-stream environmental water, there may be a case for developing more specific rules.

Some environmental water demands, such as delivering water to specific wetland sites, are similar to 'consumptive' demands and can be easily achieved using standard water rights. However, in other cases environmental flows are designed to remain in-stream, for example to benefit native fish or improve water quality. In these cases, a high proportion of environmental water released in a region may continue on and flow into downstream regions. This type of this inter-regional movement of environmental water is not always easily accommodated within traditional water right and trading rule systems.

Currently, to support inter-region environmental transfers, EWHs are required to formally trade water allocations between regions subject to market trading rules. In recent years, large volumes of environmental water 'trades' have been recorded in the sMDB typically from up-stream catchments into the SA Murray. In 2015-16 these environmental water transfers accounted for more than half of the total allocation 'trade' volume in the sMDB.

One alternative would be to provide EWHs with some form of return flow right, where environmental releases that flow to the end of a river reach, are automatically re-credited to the environment for use downstream. Such arrangements have been developed in northern Victoria (VDEPI 2016), but have not yet been implemented in New South Wales beyond trials in limited areas. Establishing an equivalent rule across New South Wales catchments could provide benefits to other users, such as helping to reduce pressure on the Murrumbidgee inter-valley trade (IVT) export limit – which is used by environmental water holders in the absence of return flow arrangements.

For example, under this approach, an environmental release in the Murrumbidgee, would trigger an environmental allocation credit in the Murray, based on the estimated return flow (that is, the initial release less all river / wetland losses incurred through the Murrumbidgee system). This would allow environmental water transfers between the Murrumbidgee and the Murray to occur without adding to the region's IVT account and potentially constraining trade for irrigation users.

The more general question is whether environmental managers should have to formally trade water allocations at all when moving environmental water between zones. Beyond the potential effects on trade limits, this requirement creates an additional transaction cost for EHWs and complicates water market reporting. Maintaining a separate accounting system for environmental flows of water between regions could be considered.

# Appendix A: The southern MDB dataset

For this study, a dataset covering July 2000 to June 2016 was constructed. Within the report, this data are referred to as the 'sMDB dataset'. The data set involves five tables:

- allocations.csv (allocation/entitlement volumes, carryover, environmental purchases)
- prices.csv (market prices for water allocations)
- trade.csv (interregional water trade volumes)
- storage.csv (storage volumes for major sMDB dams)
- rainfall.csv (rainfall on irrigation farms in the sMDB).

## Allocations

The allocations dataset contains the following variables, each on a daily time step for 1 July 2000 to 30 June 2016.

TABLE 2 Southern MDB allocation data, variables

| Name | Description | Units | Time scale |
|---|---|---|---|
| ALLOC | Total volume of water allocated to entitlement | ML | Daily |
| ALLOC_perc | Percentage allocation to entitlement | ML | Daily |
| ENTITLE | Entitlement volume | ML | Annual |
| CARRY | Total volume of allocation carried over from the previous year | ML | Daily |
| CARRY_perc | Carryover volume as percentage of entitlement | ML | Daily |
| SWA | Volumes quarantined in Spillable Water Accounts | ML | Daily |
| ENV_PURCH_ENTITLE | Volume of purchased entitlements held by the commonwealth | ML | Annual |
| ENV_PURCH_ALLOC | Volume of water allocated to purchased CEWH entitlements | ML | Daily |
| ENV_CARRY | Volume of allocation carried over from previous year on Commonwealth entitlements | ML | Daily |
| ENV_CARRY_PURCH | Volume of allocation carried over from previous year on purchased commonwealth entitlements | ML | Daily |

Each variable is available for the following regions and entitlement types.

TABLE 3 Southern MDB water market data, regions

| Name | Reliability types | |
|---|---|---|
| NSW Lower Darling | General | High |
| NSW Murrumbidgee | General | High |
| NSW Murray | General | High |
| SA Murray | - | High |
| Vic. Murray | Low | High |
| Vic. Goulburn | Low | High |
| Vic. Broken | Low | High |
| Vic. Loddon | Low | High |
| Vic. Campaspe | Low | High |

These entitlement types represent the major regulated surface water products for the sMDB water allocation market, and exclude some of the smaller and less frequently traded types (such as conveyance, supplementary, stock and domestic, bulk entitlements) and regions (the Ovens and Eastern Mt Lofty). SA High refers to Class 3 irrigation entitlements.

## Sources

### *Entitlements, allocations and carryover*

- NSW Office of Water 2016, Water accounting, available at water.nsw.gov.au/water-management/water-availability/water-accounting
- Dan Berry, NSW Office of Water, 2016, pers. comm.
- WaterNSW 2016, Water availability reports, available at waternsw.com.au/supply/regional-nsw/availability
- Victorian Water Register (2016)
- Northern Victorian Resource Manager 2016, available at nvrm.net.au
- Guy Ortlipp, Goulburn-Murray Water, 2016, pers. comm.
- South Australian Department of Environment, Water and Natural Resources 2016, Water allocations, available at environment.sa.gov.au/managing-natural-resources/river-murray/water-allocations
- ABARES (2016) *Australian Water Markets Report 2014–15*.

### *Environmental water*

- CEWO, Annual carryover reports and website, available at environment.gov.au/water/cewo/publications and environment.gov.au/water/cewo/portfolio-mgt
- Department of Agriculture and Water Resources, Volumes of water entitlements secured by the Commonwealth in the MDB

## Assumptions

- Where unavailable, historical entitlement volumes are based on the most recently available data.
- Daily allocation volumes were obtained by multiplying assumed entitlement volumes by daily allocation percentages. These figures reflect total allocations available against these entitlements, regardless of whether they are held by irrigator's or environmental water holders.

- In some limited cases, allocation percentage data could not be obtained: in the Victoria Loddon region 2000–01 to 2002–03 and Victoria Broken 2000–01 to 2006–07. In this case, allocation percentages were assumed to be the same as those in the Goulburn region.
- In New South Wales, carryover percentages (carryover volumes available from the previous year) were multiplied by entitlement percentages. Only carryover water currently available for use is included, so any volumes suspended during droughts were excluded.
- New South Wales allocation percentages were taken from NSW Department of Primary Industries historical spreadsheets and differ from those reported in the register for several reasons, including drought allocation suspensions (decreases) and the 100 per cent rule (limit on allocation and carryover of 100 per cent).
- To avoid double counting New South Wales allocation percentages, ALLOC_perc excludes carryover volumes in years and regions where the 100 per cent rule was binding: NSW Murrumbidgee General (2010–11 to 2012–13), NSW Murrumbidgee High (2011), NSW Murray General (2000–01, 2001–02, and 2010–11 to 2013–14), NSW Murray High (2010–11 to 2012–13), NSW Lower Darling General (2010–11 to 2012–13).
- In Victoria, carryover volumes include volumes carried over in allocation bank accounts (ABAs). Volumes held in SWAs are only included once returned to the ABA—after a low-spill risk declaration has been made and any spill deductions have been applied.
- Volumes of environmental water entitlements secured by the Commonwealth were provided by the Department of Agriculture and Water Resources, by region, entitlement type and recovery method (purchases, infrastructure and other).
  - Only regulated surface water rights (of the types listed in Table 3) are included in environmental recovery estimates.
  - Entitlement volumes are multiplied by allocation percentages to obtain daily allocation volumes for ENV_ALLOC.
  - Note that water recovery is reported at the point at which water savings or purchase have been received, estimated or agreed in signed contracts. Until water transfer contracts have been exchanged, however, these figures are subject to change.
- Environmental carryover data for 2012–16 were obtained from the Commonwealth Environmental Water Office. Before 2012, carryover data were imputed assuming CEWO carryover percentages equal to 75 per cent of the annual average (by region and entitlement type).
- CEWH carryover (ENV_CARRY) includes volumes held against both purchased entitlements and those obtained from infrastructure upgrades. The carryover volume held against purchased entitlements (ENV_CARRY_PURCH) is imputed, by multiplying ENV_CARRY by the proportion of entitlements obtained through purchases.

## Water prices

Monthly water prices were obtained from three major trading regions (the Murray, Goulburn and Murrumbidgee) for July 2000 to June 2016. Data were obtained from a variety of water exchanges, including:

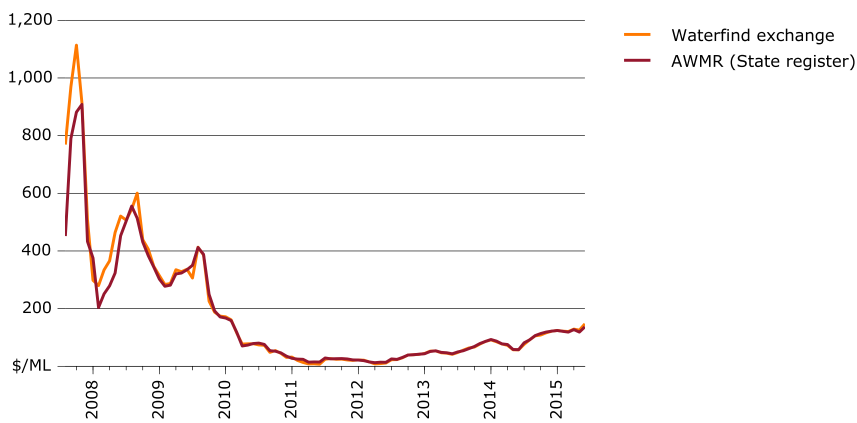
- ABARES (2016) *Australian Water Markets Report 2014–15*
- Waterfind, available at www.waterfind.com.au
- the former Waterexchange (now RuralCo Water)
- Brennan (2006) (reporting data from the former Watermove exchange)
- Murray Irrigation, available at murrayirrigation.com.au/water/water-trade/water-exchange-history.

### Assumptions

- Monthly price data for the Goulburn region during 2000–01 to 2002–03 is taken from Brennan (2006), which in turn was sourced from the old Vic. Watermove exchange.
- Monthly data for the Murray and Murrumbidgee were not available before 2002–03, but annual data were available for the Murray from Murray Irrigation. Monthly Murray prices before 2002–03 were imputed by scaling Goulburn monthly prices to match the annual average for the Murray.
- From 2000–01 to 2002–03, Murrumbidgee prices were assumed to be identical to the Murray region.
- Data for 2003–04 to 2006–07 are taken primarily from the former Waterexchange (now RuralCo Water).
- Data for 2007–08 and 2015–16 were obtained from the Waterfind exchange.
- Data for 2008–09 to 2014–15 were obtained primarily from ABARES (2016).

Water exchange data (from Waterfind) was validated for 2007–08 to 2014–15 against data from the *Australian water markets report 2014–15* ABARES (2016), which are sourced primarily from state government registers. The two series are mostly identical post-2009. During 2007–09, the register-based prices appear to lag exchange prices (which likely reflects longer trade processing times during that period).

FIGURE 43 Monthly allocation prices for the Goulburn region, 2007–08 to 2014–15




Source: sMDB dataset

## Trade

Net interregional water trade data were obtained each year from 2000–01 to 2014–15. Data for 2000–01 to 2009–10 were obtained from previous Australian water markets reports.

Data for 2010–11 to 2014–15 were sourced from the MDBA (as part of ABARES 2016). Data provided by the MDBA record both environmental and non-environmental trade volumes separately. Where recorded, environmental transfers were excluded from the trade dataset.

## Storage

Storage volume data were provided by the Bureau of Meteorology on a daily time step from 1 July 2000 to 30 June 2016. The dataset includes the following sMDB dams:

- Murray: Hume, Dartmouth, Yarrawonga Weir, Lake Victoria
- Lower Darling: Menindee, Wetherell, Pamaroo, Cawndilla
- Murrumbidgee: Blowering, Burrinjuck
- Goulburn: Lake Eildon, Warranga Basin
- Campaspe: Lake Eppalock
- Loddon: Cairn Curran, Laanecoorie.

Data for Lake Victoria are not available before 2007–08, so this dam is excluded when calculating total sMDB storage volumes.

## Rainfall

Monthly rainfall data were obtained from July 1999 to June 2016 for the following regions: NSW Murray, Vic. Murray, SA Murray, Goulburn, Loddon and Murrumbidgee. These data reflect average rainfall on irrigation farms within each region.

Rainfall data from the CSIRO Australian Water Availability Project (csiro.au/awap) were mapped to farms in an ABARES survey of irrigation farms in the MDB. Catchment and sMDB averages were obtained by averaging across the farm-level observations.

# Appendix B: Regression analysis

## Monthly southern MDB water prices

### Model

This section details a model for predicting monthly water allocation prices in the sMDB as a function of allocation available (allocations plus carryover less environmental purchases) and rainfall. The model takes the form:

$$\log PRICE_t \quad = \beta_0(m_t) + \beta_1(m_t)A_t + \beta_2(m_t)RAIN_t + \beta_3(m_t)A_t.RAIN_t$$

where:

$PRICE_t$ is the monthly allocation price in the Murray (adjusted for the consumer price index)

$$A_t = ALLOC_{it} + CARRY_{it} - ENV\_ALLOC_{it} - ENV\_CARRY\_PURCH_{it}$$

(allocation plus carryover from previous year after environmental purchases)

$RAIN_t$ is the average rainfall during the past three months on irrigation farms in the sMDB:

$m_t$ is the 'water year month' (1 = July, 12 = June) of period $t$

$\beta_0, \beta_1, \beta_2, \beta_3$ are parameters which depend on the month $(m_t)$

### Estimation

Since allocations are announced in a cumulative way across the water year, the relationship between *A* and *PRICE* will depend significantly on the month. That is, the relationship at the end of the water year may differ significantly from that at the beginning. To account for this, the model allows the parameters to vary depending on the month within the water year.

Monthly parameters are obtained using a temporally weighted regression method. With this approach, the parameters for each month are based on a weighted ordinary least squares (OLS) regression, where the weights depend on the current month (that is, with lowest weight placed on months furthest away in time). A standard Gaussian weighting function is used:

$$w_t = e^{-\left(\frac{[m_t - \bar{m}]^2}{\theta}\right)}$$

where $w_t$ are the weights and $\overline{m}$ is the chosen month. $\theta$ is a free parameter calibrated using cross-validation. The final model used a $\theta$ value of 5. The parameter results are summarised in Table 4. Most of the parameters are significant at a 5 per cent level. As would be expected, the allocation coefficients are all negative (higher allocations lead to lower prices).

TABLE 4 Monthly southern MDB water price model regression results

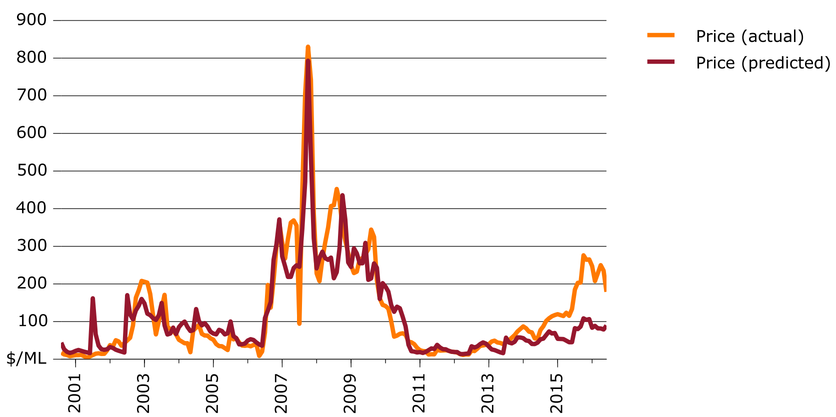
| Parameter | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Constant | 5.93* | 6.77* | 7.40* | 7.70* | 7.75* | 7.68* | 7.428 | 7.00* | 6.67* | 6.47* | 6.35* | 6.31* |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| A | −3.3E−07* | −4.5E−07* | −5.3E−07* | −5.5E−07* | −5.5E−07* | −5.3E−07* | −4.9E−07* | −4.3E−07* | −3.9E−07* | −3.9E−07* | −4.0E−07* | −4.3E−07* |
| | (0.01) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| RAIN | 0.00 | −0.01* | −0.01* | −0.01* | −0.01* | −0.01* | −0.01* | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 |
| | (0.45) | (0.01) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.19) | (0.98) | (0.41) | (0.18) | (0.15) |
| A*RAIN | −3.4E−10* | 6.1E−10* | 1.2E−09* | 1.3E−09* | 1.1E−09* | 9.3E−10* | 5.9E−10 | 6.8E−11 | −4.3E−10 | −8.0E−10 | −9.8E−10 | −8.6E−10 |
| | (0.76) | (0.46) | (0.05) | (0.01) | (0.01) | (0.02) | (0.16) | (0.88) | (0.42) | (0.20) | (0.16) | (0.27) |

* Significant at 5% level.
Note: P values in parentheses.

## Results

Figure 44 shows actual water prices versus the model predictions. The model performs reasonably well in most years, but underestimates prices during 2014–15 and 2015–16. The results suggest that variation in water availability (accounting for the occurrence of environmental purchases) and rainfall cannot explain all of the recent increase in prices. In particular, the model cannot reconcile recent high prices with the low prices during the pre-drought period. Several explanations for the higher water prices in recent years are discussed in the report, including environmental water recovery and carryover rule changes.

FIGURE 44 Monthly southern MDB water prices actual vs model prediction




Source: sMDB dataset (see Appendix A) and ABARES model estimate

# Annual southern MDB water prices

## The model

This section details a simple model for predicting average annual water allocation prices in the sMDB as a function of end-of-year allocations and rainfall. The model takes the form:

$$\log P_t \quad = \beta_0 + \; \beta_1 A_t + \beta_2 RAIN_t$$

where:

$t$ denotes the water year (all variables are defined as at the end of year – 30 June)

$$A_t = ALLOC_t + CARRY_t - ENV\_ALLOC_t - ENV\_CARRY\_PURCH_t$$

(allocation plus carryover from previous year after environmental purchases)

$P_t$ is the average annual water allocation price (in the Murray zone)

$RAIN_t$ is average annual farm rainfall moisture for the whole sMDB

A second model was also estimated in which the allocation variable $A_t$ was redefined as:

$$A_t = ALLOC_t + CARRY_t - ENV\_ALLOC_t - ENV\_CARRY\_PURCH_t - (CARRY_{t+1} - ENV\_CARRY\_PURCH_{t+1})$$

(allocation plus carryover from the previous year after environmental purchases and after carryover into the next year)

This second model is intended to reflect the effect of changes in carryover rules and volumes over time.

## Estimation

Both models are fit using OLS; results are presented in Table 5.

TABLE 5 Annual southern MDB price models, regression results

| Parameter | Model 1 | Model 2 |
|---|---|---|
| Constant | 7.93** | 8.55** |
| | (0.00) | (0.00) |
| A | –0.0005** | –0.005** |
| | (0.00) | (0.00) |
| RAIN | –0.0013* | –0.0045** |
| | (0.046) | (0.00) |
| $R^2$ | 0.948 | 0.917 |

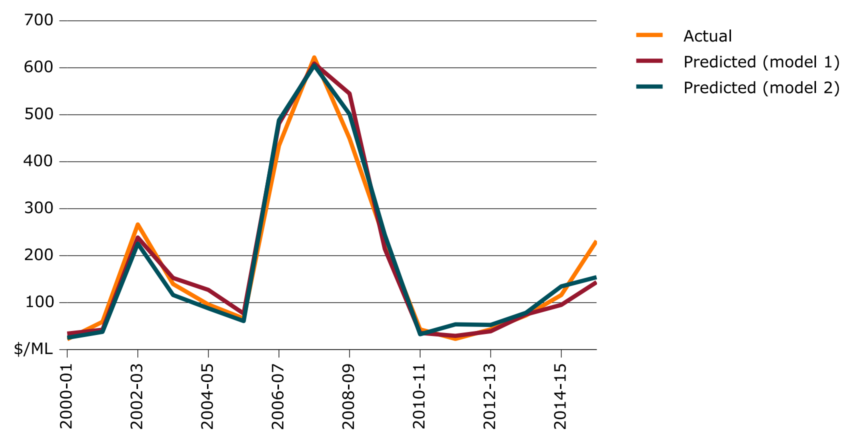
* Significant at 5% level; ** Parameter significant at 1% level.
Note: P values shown in parenthesis.

## Results

Both models explain most of the variation in annual prices (Figure 45). Model 2 (which adjusts allocations for carryover into the next year) better explains the high water prices in 2014 to 2016. The results suggest that water availability, rainfall, environmental purchases and carryover rule changes can explain most of the price increases. However, model 2 still under-predicts water prices slightly during 2015–16. The Murrumbidgee trade restriction and changes in water demand remain potential explanations for the higher prices observed during 2015–16.

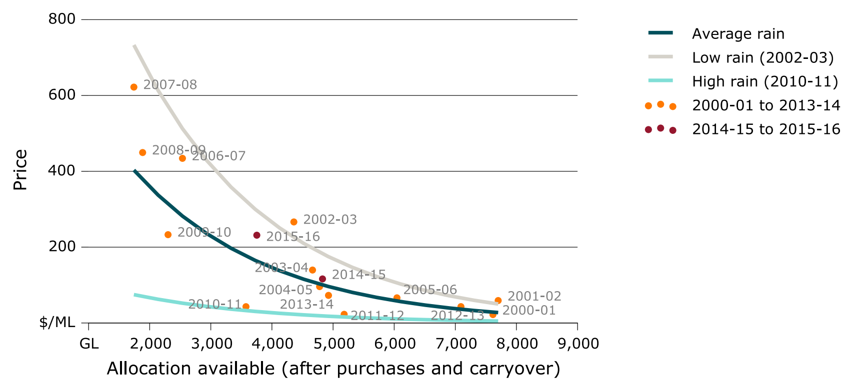
Figure 46 demonstrates the estimated relationship between allocations available and annual water prices (for model 2) and shows how the relationship varies depending on annual rainfall. Rainfall variation helps to explain the high water prices observed in 2002–03 and the low prices of 2010–11.

FIGURE 45 Annual southern MDB water prices versus model predictions




Source: sMDB dataset (see Appendix A) and ABARES model estimate

FIGURE 46 Estimated relationship between water availability, rainfall and price (model 2)




Source: sMDB dataset (see Appendix A) and ABARES model estimate

# Appendix C: A model of the southern MDB water market

This section details an econometric model of the sMDB water market. The model simulates interregional water trading across the sMDB, predicting water market prices and trade volumes, given prevailing allocation volumes and rainfall in each region. The structure of the model closely follows the approach of Brennan (2010).

The model includes seven regions, with Goulburn–Broken and Loddon–Campaspe both combined (because of the availability of historical interregional water trade data):

- NSW Murray
- NSW Murrumbidgee
- NSW Lower Darling
- SA Murray
- Vic. Murray
- Vic. Goulburn–Broken
- Vic. Loddon–Campaspe.

For each region, a historical dataset is constructed for water availability (allocations), rainfall, net trade flows and market prices (adjusted for inflation) each year for 2000–01 to 2014–15. Note that 2015–16 is excluded given trade data were not available. This dataset is then used to estimate water demand curves for each region, linking water availability and rainfall with regional prices.

## Data

The annual dataset used here is derived from the sMDB dataset described in Appendix A. Allocation prices in the NSW, SA and Vic. Murray regions are assumed equal to Murray prices in the sMDB dataset, whereas prices in Goulburn–Broken and Loddon–Campaspe are assumed equal to the Goulburn prices.

Prices in the NSW Lower Darling region are set equal to Murray prices, except during 2006–07 and 2007–08, where average annual prices of $60 and $84 are assumed respectively (based on data presented in NWC 2009 and Waterfind). The lower prices in the Lower Darling region in these years reflect a trade restriction in force during the millennium drought that was lifted in 2008–09.

For each region, annual variables were constructed from the sMDB dataset (Table 6).

TABLE 6 Annual southern MDB water trade model variables

| Name | Description | Units | Time scale |
|---|---|---|---|
| A | Total allocation available for use in the year for that region = $ALLOC_t$ + $CARRY_t$ – $ENV\_ALLOC_t$ - $ENV\_CARRY\_PURCH_t$ + $TRADE_t$ – ($CARRY_{t+1}$ – $ENV\_CARRY\_PURCH_{t+1}$) | ML | Annual |
| R | Annual average farm rainfall for that region | mm | Annual |
| P | Average market price for water allocations in real terms | $/ML | Annual |
| $A^0$ | Allocation available at end of water year before trade = $A_t$ – $TRADE_t$ | ML | Annual |

## Model

Each region *i* has an annual water allocation demand curve, linking prices *P* with allocation volumes *A* and farm rainfall *R*:

$$P_{it} = d_i(A_{it}, R_{it})$$

where *t* indicates the year.

Given these water demand functions, water allocations can be traded between regions, subject to defined trading constraints, until an equilibrium price is realised:

$$\max_{A_{it}} \sum_i \int_0^{A_{it}} d_i\,(A_{it}, M_{it})$$

Subject to:

$$\sum_i A_{it} = \sum_i A^0{}_{it}$$

$$TL_i \leq (A_{it} - A^0{}_{it}) \leq TU_i$$

where $\sum_i A^0{}_{it}$ is the total volume of allocations available, $(A_{it} - A^0{}_{it})$ is the net trade position of region i (positive values indicating imports, negative exports), and $TL_i$ and $TU_i$ are the lower and upper limits on trade, respectively.

### Trade limits

Representing sMDB trade limits within the model is difficult given the annual time scale. In practice, limits can vary across and within years depending on river operation decisions, and changes in trading rules (including the temporary suspension of WSPs). Further, the model only represents irrigation water trade and not environmental water transfers.

Subject to the limitations of the model, the trade restrictions approximate key historical restrictions on trade, including:

- Murrumbidgee import and export limits
- northern Victoria (Goulburn, Broken, Loddon, Campaspe) import and export limits
- Lower Murray–Darling (trade limits enforced under drought conditions).

Note that the model does not represent all possible trade constraints, including, for example, limits on trade through the Barmah Choke and limits on trade from New South Wales into the Vic. Murray (which were imposed in 2011 as a response to carryover rule problems).

The baseline scenario trade restrictions are defined in Table 7. These limits are intended to reflect average annual limits on non-environmental trade—after adjusting for expected environmental transfers (as opposed to limits on accumulated IVT account balances).

During 2013–14 and 2014–15, an average of 83 GL was exported from the Murrumbidgee per year (around 48 GL after excluding environmental transfers). Complete trade data for 2015–16 were not available at the time of publishing, but from July 2015 to April 2016, around 260 GL of water was traded out in total (the volume of environmental transfers was unknown). The selection of the 100-GL limit for the Murrumbidgee remains relatively arbitrary. In practice, actual trade volumes possible in the Murrumbidgee will vary from year to year. The development of more realistic trading limits remains a subject for future research.

TABLE 7 Annual southern MDB water trade model trade limits

| | NSW Murrumbidgee | | Northern Vic. (Goulburn/Broken/ Campaspe/Loddon) | | NSW Lower Murray–Darling | | Other regions | |
|---|---|---|---|---|---|---|---|---|
| Year | *TL* | *TU* | *TL* | *TU* | *TL* | *TU* | *TL* | *TU* |
| 2001 | –100 | 0 | $-\infty$ | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2002 | –100 | 0 | $-\infty$ | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2003 | –100 | 0 | $-\infty$ | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2004 | –100 | 0 | $-\infty$ | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2005 | –100 | 0 | $-\infty$ | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2006 | –100 | 0 | $-\infty$ | 50 | 0 | 0 | $-\infty$ | $+\infty$ |
| 2007 | $-\infty$ | 0 | $-\infty$ | 50 | 0 | 0 | $-\infty$ | $+\infty$ |
| 2008 | $-\infty$ | 0 | $-\infty$ | 50 | 0 | 0 | $-\infty$ | $+\infty$ |
| 2009 | $-\infty$ | 0 | $-\infty$ | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2010 | $-\infty$ | 0 | $-\infty$ | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2011 | –100 | 0 | –150 | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2012 | –100 | 0 | –150 | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2013 | –100 | 0 | –150 | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2014 | –100 | 0 | –150 | 50 | $-\infty$ | $+\infty$ | $-\infty$ | $+\infty$ |
| 2015 | –100 | 0 | –150 | 50 | –0 | 0 | $-\infty$ | $+\infty$ |

***TL*** Lower trade limit; ***TU*** Upper trade limit.

## Estimation

Demand functions for the NSW Lower Darling, NSW Murray, NSW Murrumbidgee, Vic. Murray and Vic. Goulburn–Broken regions take the form:

$$\log P_{it} = \beta_0 + \beta_1 A_{it} + \beta_2 R_{it}$$

The SA Murray and Vic. Loddon–Campaspe regions take the form:

$$P_{it} = \beta_0 + \beta_1 A_{it} + \beta_2 R_{it}$$

The log-linear form is identical to the sMDB wide regression models presented in Appendix B, and broadly reflects the differing water demands of broadacre and horticultural irrigation sectors. That is, at lower allocation levels, the demand for water becomes increasingly unresponsive to price, reflecting the high marginal value of water in horticulture. In the SA Murray and Vic. Loddon–Campaspe regions, linear functions performed better, reflecting the relative homogenous irrigation activity in these regions.

Functions for each region are estimated via OLS using data for 2000–01 to 2014–15. Regression results are presented in Table 8.

TABLE 8 Annual southern MDB water trade model regression results

| Region | Dependent variable | $\beta_0$ | $\beta_1$ | $\beta_2$ | $R^2$ |
|---|---|---|---|---|---|
| NSW Murrumbidgee | log (price) | 7.54* | –1.56E–06* | –2.68E–03* | 0.90 |
| NSW Lower Darling | log (price) | 5.62* | –9.25E–06 | –1.56E–03 | 0.32 |
| NSW Murray | log (price) | 7.78* | –1.58E–06* | –4.69E–03* | 0.91 |
| Vic. Murray | log (price) | 8.36* | –1.28E–06* | –5.41E–03* | 0.76 |
| Vic. Goulburn–Broken | log (price) | 8.99* | –2.68E–06* | –4.57E–03* | 0.83 |
| Vic. Loddon–Campaspe | price | 629.90* | –4.25E–03* | –0.54 | 0.62 |
| SA Murray | price | 1 201.52* | –1.40E–03* | –1.41* | 0.58 |

* Statistically significant at 5% level.

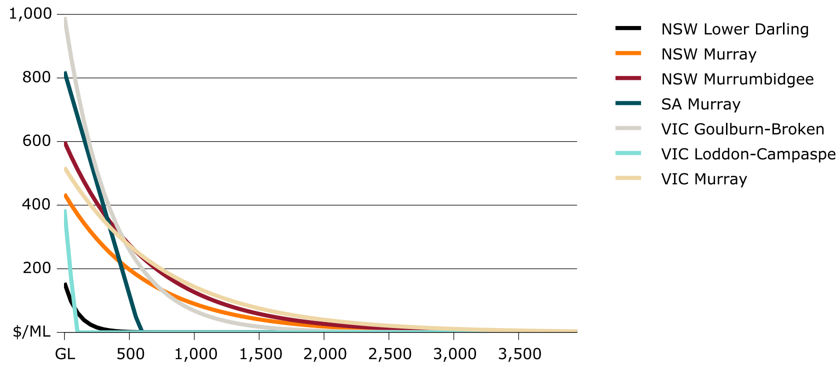
### Market demand curves

Estimated demand curves for each region are shown in Figure 47 (assuming long-run average rainfall). The NSW Murrumbidgee and Vic. Murray regions have a similar response to changes in price. Water allocation demand reaches 0 ML for prices of around $520 per ML or greater (under average rainfall) in the Vic. Murray and around $620 per ML or greater in the Murrumbidgee.

As would be expected, the SA Murray region has an inelastic demand for water compared with most other regions (that is, their water demand is less responsive to price), reflecting their higher proportion of perennial crops. The Vic. Goulburn–Broken demand curve becomes increasingly inelastic at higher price levels.

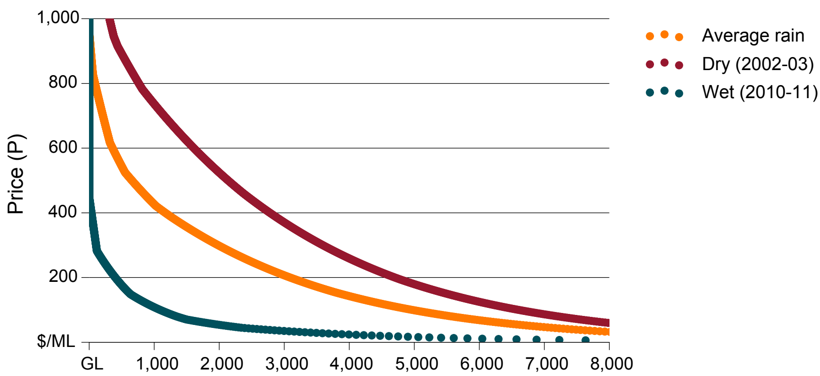
The implied market demand curve is also shown in Figure 48. This shows the expected annual average market price for water in the sMDB as a function of the allocations available and rainfall (assuming unrestricted trade).

FIGURE 47 Estimated regional water demand functions (price as a function of water allocations available)




Note: Demand functions also depend on farm rainfall. These curves are for average rainfall conditions in each region.
Source: ABARES model estimate

FIGURE 48 Estimated market water demand function (assuming unrestricted trade)




Source: ABARES model estimate

# Results

## Baseline scenario

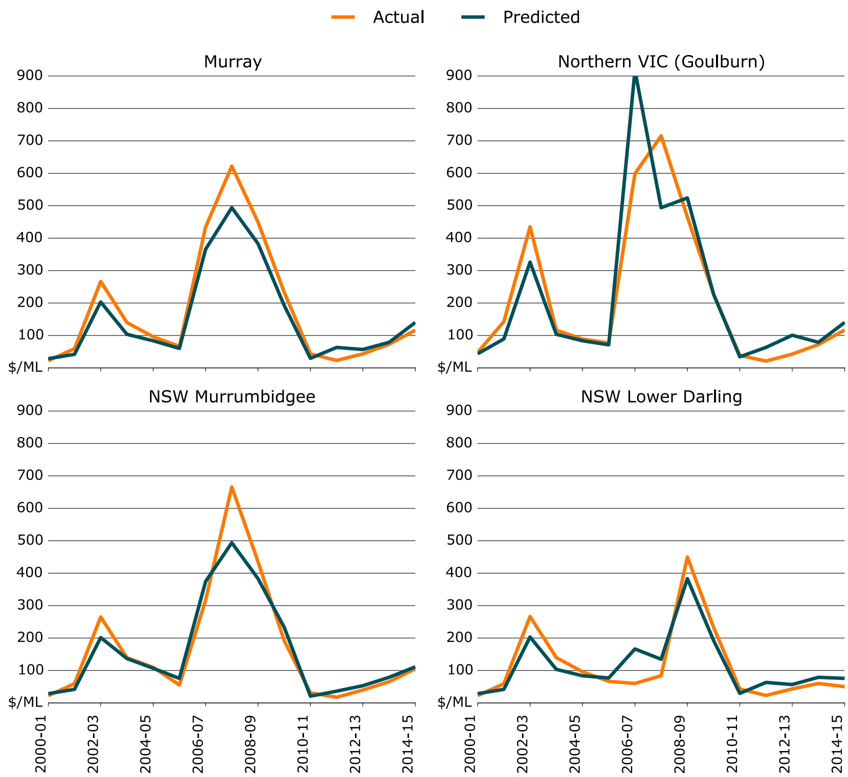
The model baseline scenario assumes historical allocation and rainfall levels for each region between 2000–01 and 2014–15. The model is then solved for the market-clearing price levels and net trade volumes in each year. Model results for the baseline scenario are shown in Figures 49 and 50.

Figure 49 shows modelled market prices in the major trading zones (Murrumbidgee, Murray, Northern Victoria and Lower Murray–Darling) compared with historical values. The model accurately recreates historical variation in prices over time and across regions. For example, the model is able to recreate expected differences in prices between regions caused by trading constraints including higher prices in Northern Victoria and lower prices in the Lower Darling during drought years.

The model performs well in matching historical trading patterns (Figure 50). In particular, the model accurately represents trade flows during the drought, including large net exports from the Murrumbidgee and large net imports into the SA Murray. Post 20011-12, the model consistently overestimates exports from the NSW Murray region and imports into the SA Murray. This result could be partly explained by recent changes in perennial land use (which have been declining in the SA Murray).

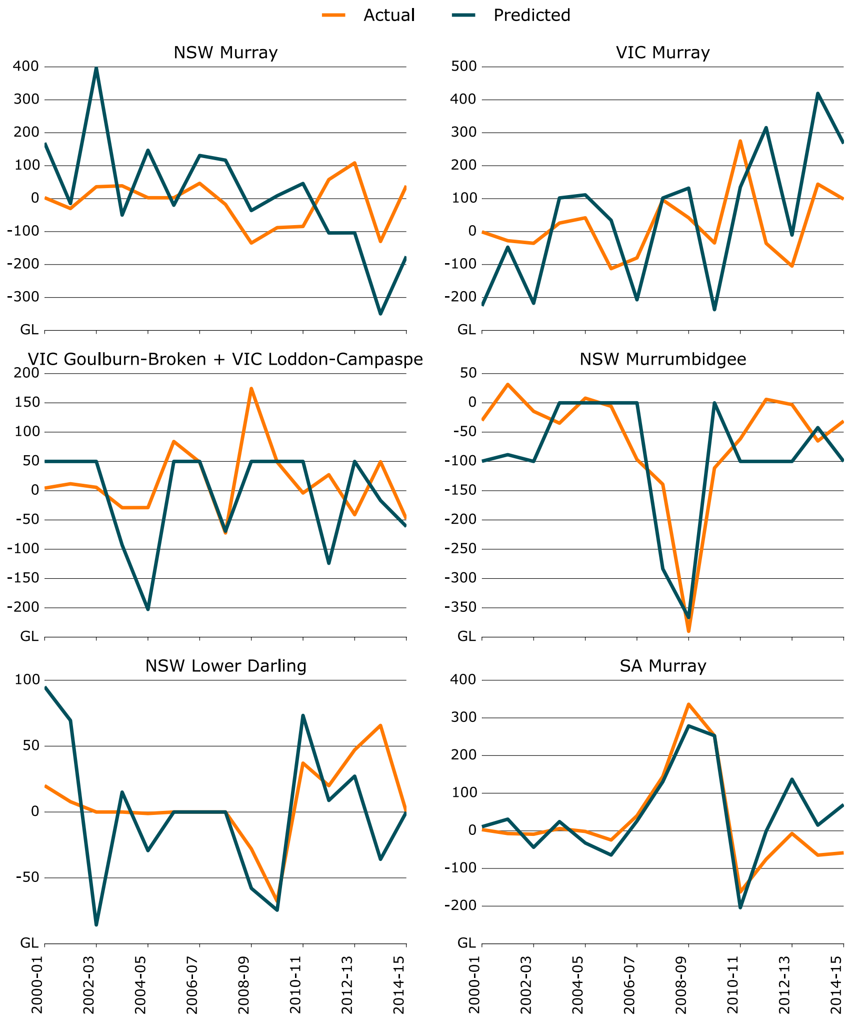
Although the model matches historical prices and trade flows well, it could be extended in several directions. Firstly, future extensions could include moving from an annual to monthly time step (if monthly trade data were available). A monthly time step could also allow a more realistic set of trading restrictions to be implemented. Secondly, the regional definition could be expanded to include other key trade restrictions such as the Barmah Choke. Thirdly, the allocation trade model could be combined with a model of irrigation production to better reflect changes in land-use patterns.

FIGURE 49 Actual and modelled water allocation prices by region, 2000–01 to 2014–15




Source: sMDB dataset (see Appendix A) and ABARES model estimate

FIGURE 50 Actual and modelled net interregional water trade, 2000–01 to 2014–15



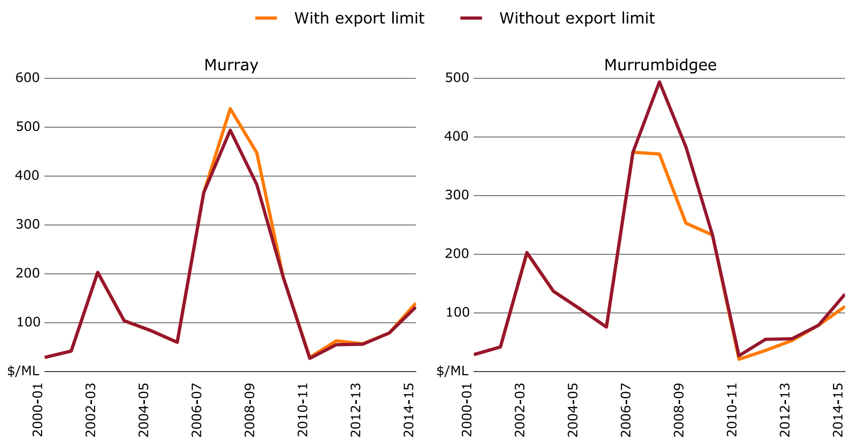

Source: sMDB dataset (see Appendix A) and ABARES model estimate

## Export limits in the NSW Murrumbidgee

This section looks at two additional scenarios: one with no restrictions on exports in the Murrumbidgee and one with a 100 GL per year export restriction (applying in all years). In both cases, baseline trade restrictions were applied to all other regions. Together these scenarios demonstrate the effect of Murrumbidgee export limits on prices and trade flows.

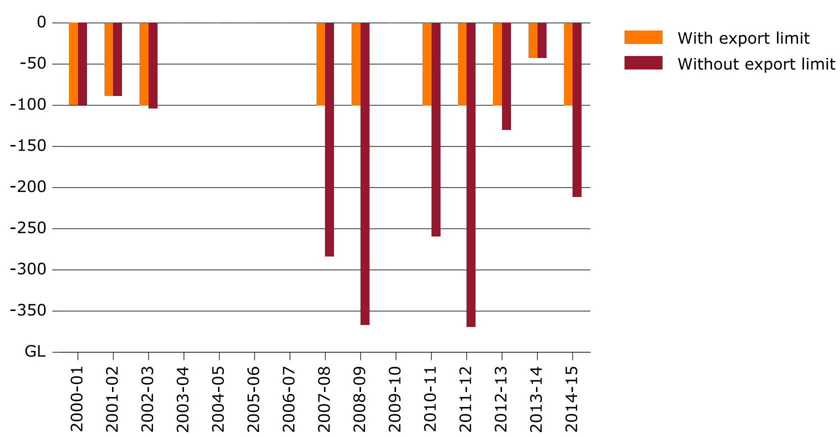
A restriction on exports of 100 GL reduces the price per trade in the Murrumbidgee, particularly in the drought years between 2006–07 and 2009–10 (Figure 51). The trade limit also decreases the available water supply for other regions (including the Murray), which drives the market price up in these trading zones (Figure 50). Figure 52 shows the volume of exports from NSW Murrumbidgee. Murrumbidgee exports are much higher if the restriction is lifted, particularly during the drought years of 2008 and 2009.

FIGURE 51 Modelled water prices, with and without 100 GL Murrumbidgee export restriction, 2000–01 to 2014–15




Source: ABARES model estimate

FIGURE 52 Modelled net trade in the Murrumbidgee region, with and without export restriction, 2000–01 to 2014–15




Source: ABARES model estimate

## Entitlement purchases for the environment

In this section, the model is used to simulate the effects of Commonwealth entitlement purchases on annual allocation prices. Here we refer to the baseline scenario as the 'entitlement purchases' scenario, as it includes the effects on water availability of Commonwealth entitlement purchases since 2007–08.

This scenario is compared with a 'without environmental recovery' scenario where environmental purchases are ignored. Opening allocation volumes A0 under each scenario are defined in Table 9. The 'entitlement purchases' scenario amounts to a reduction in allocations available for consumptive use in 2014–15 of around 14 per cent. Note that, in practice, this reduction would be offset to some extent by water savings from infrastructure projects.

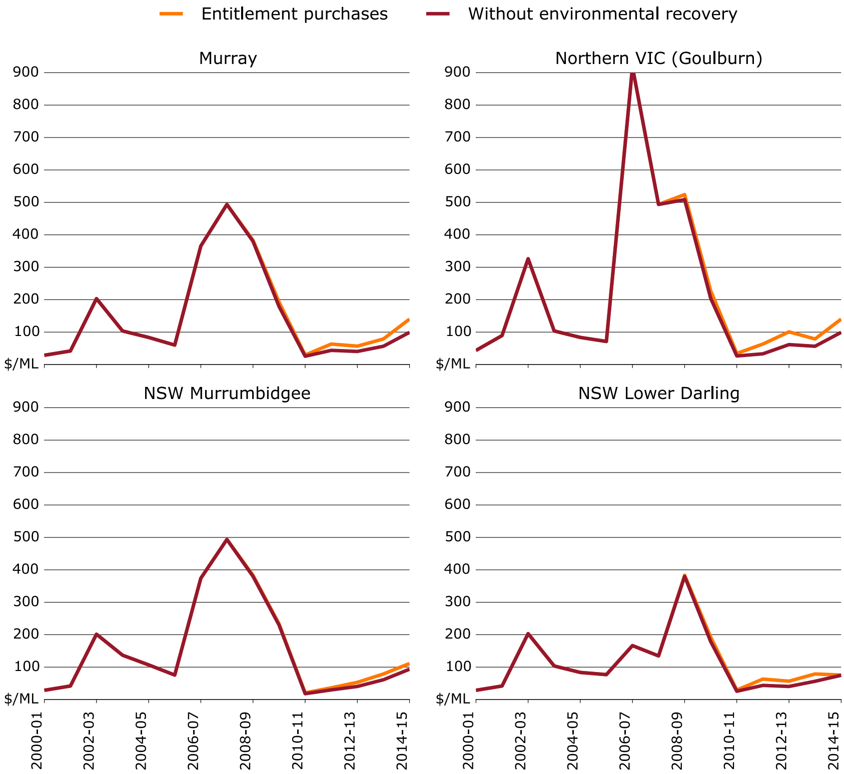
TABLE 9 Opening allocations under environmental recovery scenarios

| Scenario | Opening allocation volume, $A^0$ |
| --- | --- |
| Entitlement purchases (baseline) | $= ALLOC_t + CARRY_t − ENV\_ALLOC_t - ENV\_CARRY\_PURCH_t − (CARRY_{t+1} − ENV\_CARRY\_PURCH_{t+1})$ |
| Without environmental recovery | $= ALLOC_t + CARRY_t − CARRY_{t+1}$ |

The results are summarised in Figures 53 and 54. On average, the 'entitlement purchase' scenario leads to an increase in annual water allocation prices of around $25 per ML (or 39 per cent) between 2012-13 and 2014–15 relative to the 'without' scenario. This estimate is likely to overstate the actual effect of environmental water recovery in the sMDB, given it excludes the offsetting water savings from infrastructure projects.

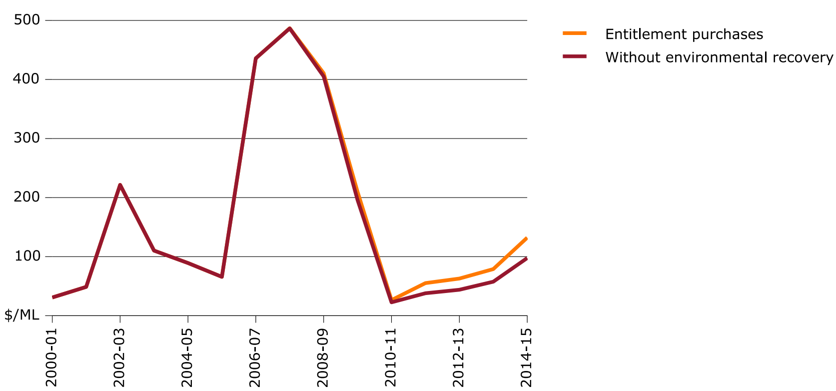
This estimate is comparable to that obtained by Aither (2016a) of around $22 per ML (or 32 per cent) for the same period. Given binding trade restrictions, the simulated price effects vary across regions (Figure 54).

FIGURE 53 Modelled water allocation prices by region, with and without environmental recovery, 2000–01 to 2014–15




Source: ABARES model estimate

FIGURE 54 Modelled water allocation prices, southern MDB weighted average, with and without environmental purchases, 2000–01 to 2014–15




Note: Regional prices are weighted by post-trade water allocation volumes.
Source: ABARES model estimate

# Acronyms and abbreviations

| | |
|---|---|
| **CEWH** | Commonwealth Environmental Water Holder |
| **IVT** | inter-valley transfer |
| **MDB** | Murray–Darling Basin |
| **MDBA** | Murray–Darling Basin Authority |
| **NSW** | New South Wales |
| **OLS** | ordinary least squares |
| **SA** | South Australia |
| **sMDB** | southern Murray–Darling Basin |
| **SWA** | spillable water account |
| **Vic.** | Victoria |
| **WSP** | water sharing plan |

# References


ABA 2016, *Almond insights 2014–15*, Almond Board of Australia, Loxton, SA, growing.australianalmonds.com.au.

ABS 2015, *Gross value of irrigated agricultural production 2013–14*, Australian Bureau of Statistics, Canberra, available at abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4610.0.55.008Main+Features12013-14?OpenDocument.

ABS 2016, *Water use on Australian farms 2014–15*, cat. no. 4618.0, Australian Bureau of Statistics, Canberra, available at abs.gov.au/ausstats/abs@.nsf/mf/4618.0.

ABARES 2016, *Australian Water Markets Report 2014–15*, Australian Bureau of Agricultural and Resources Economics and Sciences, Canberra.

Aither 2016a, *Identifying and modelling supply-side drivers of water allocation prices in the southern Murray–Darling Basin*, Aither, Canberra.

Aither 2016b, *Contemporary trends and drivers of irrigation in the southern Murray–Darling Basin*, report for RIRDC National Rural Issues, Rural Industries Research and Development Corporation, Canberra.

Ashton, D & Oliver, M 2015a, *Dairy farms in the Murray–Darling Basin*, ABARES research report, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

Ashton, D & Oliver, M 2015b, *Wine grape farms in the Murray–Darling Basin*, ABARES research report, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

Brennan, D 2006, 'Water policy reform in Australia: lessons from the Victorian seasonal water market', *Australian Journal of Agricultural and Resource Economics*, vol. 50, no. 3, pp. 403–23.

Brennan, D 2010, Water prices in the lower Murray market: the effect of physical trading constraints, climate change and the spatial pattern of buyback, unpublished manuscript available from the author.

CSIRO 2008, *Murray–Darling Basin Sustainable Yields Project*, Commonwealth Scientific and Industrial Research Organisation, available at csiro.au/en/Research/LWF/Areas/Water-resources/Assessing-water-resources/Sustainable-yields/MurrayDarlingBasin.

Grafton, RQ, Libecap, G, McGlennon, S, Landry, C & O'Brien B 2011, 'An integrated assessment of water markets: a cross-country comparison', *Review of Environmental Economics and Policy*, vol. 5, no. 2, pp. 219–39.

Heaney, A, Dwyer, G, Beare, S, Peterson, D, Pechy, L 2006 'Third party effects of water trading and potential policy responses', *Australian Journal of Agricultural and Resource Economics,* vol. 50, no. 3, pp. 277-293.

Hughes, N 2010, 'Defining property rights to water in complex regulated river systems: generalising the capacity sharing concept', paper presented at 54th AARES Conference, Adelaide, 10–12 February.

Hughes, N 2015, 'Water property rights in rivers with large dams', PhD thesis, Australian National University.

Hughes, N, Gibbs, C Dahl, A, Tregeagle, D & Sanders, O 2013, *Storage rights and water allocation arrangements in the Murray–Darling Basin*, ABARES research report, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

Morey, K, Grinlinton, M & Hughes, N 2015, *Australian water markets report 2013–14*, report to ABARES, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

NWC 2009, *Australian water markets report 2007–2008*, National Water Commission, Canberra.

NWC 2011, *Water markets in Australia: a short history*, National Water Commission, Canberra.

VDEPI 2016, *Northern region sustainable water strategy*, Victorian Department of Environment and Primary Industries, Melbourne, available at depi.vic.gov.au/water/governing-water-resources/sustainable-water-strategies/northern-region-sustainable-water-strategy.

Victorian Water Register 2016, *Victoria refines controls on water allocation trade between valleys*, Victorian Water Register, Melbourne, waterregister.vic.gov.au/images/documents/Victoria%20refines%20controls%20on%20allocation%20trade%20between%20valleys_November2012.pdf

WaterNSW 2016, *Murrumbidgee IVT account status*, WaterNSW, Dubbo, NSW, available at waternsw.com.au/customer-service/trading/murrumbidgee.