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Markets, mis-direction and motives: a factual analysis of hoarding and speculation in southern Murray-Darling Basin water markets

1. Introduction

Speculative bubbles in financial and commodity markets are well studied (e.g., Hong *et al.*, 2006, Gutierrez, 2013, Adämmer and Bohl, 2015). These studies are typically based on Keynes' (1937) view that speculators anticipate what average opinion expects average opinion to be, rather than focusing on market fundamentals. Analysis typically involves identifying how market prices differ from their fundamental values and the drivers behind such indeterminacies. Where current equity price and agents' beliefs about future equity prices begin to act endogenously, deviations away from market fundamental price paths will emerge, leading to price increases (Flood and Hodrick, 1990). Careful specification of the market fundamentals are thus required to ensure valid tests for indeterminacies.

Water markets are subject to speculative price increases, but the study of their drivers is less common. Some studies note that in the United States water rights were bundled with land to prevent speculation, hoarding and increased prices (NWC, 2011). Further, non-landholders were prevented from accessing water to ensure that rights and resources remained largely with consumptive (e.g. irrigation) users (ACIL Tasman, 2003). This suggests different market fundamentals for water assets that may need to be explored further. Evidence for treating water assets differently can be also found in a comparison of its characteristics to that of financial or commodity assets. First, water may not readily convert to cash as transfers can take days/months to finalize and may ultimately be impossible due to regulatory or other market constraints. Second, water's physical form, fungiblity and bulk transfer properties also differentiate it from financial assets. Third, the trade of water by individuals on small-scale platforms—and requirements that a portion of the asset be sacrificed to enable end-delivery—clearly differentiates water from commodity assets; although in other respects they are more closely related (Table 1). Arguably therefore, water asset prices may not adequately reflect the degree of associated risk given that water: retains both private and public good characteristics in the market (Hanemann, 2006), is challenging to match in terms of supply and demand (Brooks and Harris, 2014), can experience unidirectional spill-overs across permanent and temporary markets in respect of prices to volumes (Zuo *et al.*, 2019), and can be prone to significant abnormal price movements without clear signals (de Bonviller *et al.*, 2019). These characteristics make it challenging to analyse the drivers of price increases (e.g. hoarding).

Table 1: Comparison of different criteria for financial, commodity and water assets

Criteria:	**Financial Asset**	**Commodity Asset**	**Water Asset**
Liquid asset	✓	✗	✗
Value derived from contractual or ownership claim	✓	✓	✓
Physical form	✗	✓	✓
Reflects supply and demand within specified markets	✓	✓	✓
Value reflects degree of associated risk	✓	✓	✗
Can be traded in bulk form	✗	✓	✓
Typically traded by individuals	✓	✗	✓
May enjoy fungible status	✗	✓	✓
Large-scale central exchange platforms	✓	✓	✗
A portion of the asset must be allocated to delivery	✗	✗	✓

Common market fundamental assumptions may therefore not hold for water assets, triggering closer examination. Support for this may be found in two recent public inquiries into non-landholder market participant impacts on allocation water (i.e. spot) market prices in southern Murray–Darling Basin (sMDB) water markets. These include federal government (Treasury, 2019) and state government inquiries (DELWP, 2019). Both inquiries have an interest in the effects of speculative behaviour and water hoarding drivers on market prices.

To inform these inquiries we could employ econometric analytical approaches (e.g., rolling and recursive regressions coupled to right- or left-sided unit root tests as discussed by Gutierrez *et al.* (2013) for commodity price bubbles). However, Australian water trade data does not include: i) futures prices even though such trade is possible (Bayer and Loch, 2017), ii) identified trades enabling differentiation between market participants, iii) reliable/timely supply, demand and inventory predictions, or iv) reliably priced assets. This is because central trade is non-existent and significant price differences can occur within daily data or across different markets for the same product (BoM, 2020b) enhancing the probability of speculative gains. Rather, data is provided on transfers of water in to and out of specified regions, and the analyst can only theorize about any application by major commodity type (e.g. annuals v perennials). These limitations induce us to employ Hirshleifer's *speculation theory* as a basis for structuring our exploration of water market fundamentals and rapid price increase drivers using the sMDB, Australia's largest water market, as a case study.

2. Hirshleifer's theory of speculation

While there is no agreed definition (Tirole, 1982), speculation can describe any activity expected to result in capital gains or profit (Harrison and Kreps, 1978). Speculative price increases may occur where sufficient market power/presence exists and under any belief that equilibria assets can have positive prices whenever the rate of growth exceeds interest rates (Hirshleifer, 1977); although market power does not of itself lead to speculation (Newbery, 1989). As noted above, data constraints for Australian water trade limit traditional study of market power and speculation, as identifiable trade details are not available (BoM, 2020b). This highlights a need for greater ownership and accounting transparency (Seidl *et al.*, 2020), and the need for better understanding of water market fundamentals and price increase drivers.

To better understand market fundamentals and price increase drivers for water assets we draw on two main schools of thought; the *Keynes-Hicks Theory* (i.e., speculators differ from non-speculators and are willing to assume more risk in exchange for higher payoffs) and *Working Theory* (i.e., speculators believe they have better information and capitalise on that knowledge gap). These two schools of thought are bridged by Hirshleifer (1977) who argues four prerequisites must be observed for speculative price increases. First, *information situations* lead traders to expect price changes on the basis of additional information emerging before any market close. Second, in information situations, *individuals must adjust to both price and quantity risk* ahead of trade decisions. These two fundamentals broadly correspond with *Working Theory*. Third, there are *two inter-related market equilibria*—time t_1 where traders face uncertainty and time t_2 where some or all uncertainty has been revealed. Fourth, speculative trade behaviour is *conditional upon market scope* for individuals to hold probability beliefs that deviate from typical individuals based on attitudes to risk and transaction costs. These two fundamentals are broadly consistent with *Keynes-Hicks Theory*.

In the case of sMDB water markets, Hirshleifer's prerequisites can be used to better understand water market fundamentals and drivers of speculative price increases. We accept the presence of information situations because, while there is scope for improvement (Grafton *et al.*, 2016) especially with respect to the quality/quantity of price information (Wheeler *et al.*, 2014a), access to public water information such as storage levels and inflows, expected evaporation rates, carry-over rates and restrictions in a given season are regularly used by irrigators in support of trade decisions (Loch *et al.*, 2012). This information is important because water traders are essentially playing a game against nature, and any increase in announced allocations—that is, the volume of water allocated against the water right each year—may drive price reductions in the market on the basis of later (increased) allocation supply. No increase (i.e. allocations are never lowered after an announcement) may motivate price rises under an expectation of constrained supply.

Allocation announcements begin in off-peak water demand periods (e.g. June-July). Under ‘normal’ conditions, announcements may increase as Winter rains provide additional supply. Demand for water begins in Spring and increases during Summer (i.e., Nov-Mar) before falling to negligible levels in Autumn. Thus, water traders with optimistic beliefs about future allocation announcements may delay purchasing while pessimistic traders will buy early (Hirshleifer, 1977) depending on access to carry over or ‘banked’ water. By contrast those expecting poor future allocations may delay selling and wait for higher market prices to emerge on the back of increased demand. Potential for differentials in market close positions therefore clearly signal Hirshleifer’s first precondition and a key market fundamental that is unique to water trade.

Importantly, this bet against nature approach is consistent with Arrow (1953), where producer decision-making is dependent upon the net return from all choices/payouts by state of nature and the probability of state events. This suggests a potential to analyse water trade drivers using state-contingent analysis that takes event probabilities (e.g. announced allocations) into account with respect to decision-making (e.g. trade), and any payoffs from that decision (Chambers and Quiggin, 2000). We will return to the state contingent analysis in the Model and Discussion sections.

With respect to the other prerequisites for speculation in water markets the picture is less clear. Stochastic supply/demand characteristics may generate rapid price shifts in sMDB water markets, as evidenced by previous research (see for example Bjornlund *et al.*, 2011, Loch *et al.*, 2013, Wheeler *et al.*, 2008, Wheeler *et al.*, 2010, Wheeler *et al.*, 2013, Wheeler *et al.*, 2014b, Zuo *et al.*, 2014). However, it is difficult to know what information traders rely upon to help them make choices, as there are numerous sources of data with varying degrees of accuracy (i.e., there is no central market price source, nor single trusted source of driver information). Further, while there is evidence to support higher returns on water market products relative to other investments (Bjornlund *et al.*, 2013), inherent price risk will be increased by associated fixed fees and charges that accrue to water rights in Australia whether the rights are used or not. Fixed costs increase the requirement for water entitlement speculators to sell/lease water allocation seasonally for income; making water markets more akin to property market speculation. While these characteristics meet the second speculation prerequisite of adjustment to price and quantity risk there is some ambiguity which we will explore in our analysis of the drivers of, or constraints to, speculative price increases (e.g., hoarding behaviour).

With respect to the third prerequisite, multiple equilibria can emerge in water markets based on supply/demand elasticities, especially for perennial producers with limited scope for input substitution where water is required in all states of nature (Adamson *et al.*, 2017). Underlying demand from perennial production will always be present in the market to, at a minimum, preserve costly capital investments (Loch *et al.*, 2019, Adamson and Loch, 2020). Under that set of arrangements, perennial producers will hedge risk until their uncertainty of supply is partially/fully resolved. Perennial producers may also be forced to trade at price levels well above ‘normal’ market rates when supply/demand are both inelastic (Adamson *et al.*, 2017). This suggests potential for price-increasing speculative behaviour from within the market (i.e. traditional irrigation users) over external parties (i.e. non-landholders), although external speculative behaviour may still be possible.

Finally, theoretical treatments of speculation assume costless trades, price-taking behaviour, and instantaneous market-clearing—factors that do not align with water markets (see Table 1). In fact, there are very different costs and benefits associated with different traders and investment behaviours that will impact upon, or factor into, decision-making. Identifying these differences may help to identify motives for water speculation and payoff opportunities consistent with the fourth prerequisite of market scope. We will explore all of these issues more closely in the sections that follow, based on a set of hypotheses.

2.1. Hypotheses to test

We first hypothesize that hoarding behaviour in sMDB water markets, as flagged by some observers (e.g., Sullivan, 2019b), will be unsubstantiated in the market trend data because it does not make financial sense—and that hoarding is unprofitable due to the inherent fees and charges associated with water asset ownership. Second, we hypothesize that cost-structure differentials make speculation more probable for certain market participants in line with the fourth prerequisite discussed above. Third, we hypothesize that supply/demand elasticity motivates perennial growers to pay higher prices under rational decisions to secure water inputs for capital protection purposes and these decisions may be falsely identified as speculation. The data and methods used to test these hypotheses are detailed below.

3. Data and Methods

To test our hypotheses we identified three suitable analytical methods. First, requirements for individuals to adjust to price and quantity risk—and hoard resources to increase prices—can be evaluated using analyses of aggregate water market data trends via demand and supply characteristics sourced from publicly available data. Second, costs of and gains from speculative trade can be evaluated via a cost-benefit analysis (CBA) of market entry and trade investment options, which are different for internal (e.g., landholding) and external (e.g., superannuation fund) participants. Adopting state contingent analysis of changes to water supply (i.e. uncertainty) over time also enables some consideration of how these costs shift, intensifying future market price increases. Finally, calculations of annual water supply and demand elasticities in the sMDB can be used to identify changes to market equilibria over time, which may identify stakeholder groups more likely to hoard water and/or speculate in sMDB water markets.

3.1. Allocation water market data trend analysis

Sources of data for the market trend, CBA and elasticity analyses included the Australian Bureau of Statistics' Water Use on Australian Farms data series (ABS, 2019), aggregate trade data from the Bureau of Meteorology's Water Market Information Dashboard (BoM, 2020b), price and trade volume data from state water trade registries (for example DELWP, 2020), irrigation infrastructure operator databases (e.g. Murray Irrigation Ltd.), and climate observations from the Bureau of Meteorology's Evapotranspiration (ETOT), Soil Moisture and Rainfall Anomalies datasets (BoM, 2020a). All data were initially checked to identify fitness-for-purpose with respect to the hypotheses and assessed for anomalies by conducting a series of reverse output tests to establish data integrity. Data were then assembled by themes (e.g. water supply and trade data; agricultural production, irrigation and water use data; and climate data) so that grouped databases could be assembled to provide inputs for the analysis.

For water supply and trade data, a series of extract-transform-load routines captured the necessary observations, with subsequent stratification and additional metrics applied to enable filtering and extraction of commercial trades. Trades were only selected where prices ranged between >=$5 and <=$2,000/ML (megalitre, or one million litres) to exclude zero-dollar and outlier prices at surface water system level (e.g. Goulburn, VIC Murray, Murrumbidgee). At a later stage in the analysis, the removal of 'noise' associated with the recently announced Water for Fodder program (DAWE, 2020) was carried out to minimize potential impact from that announcement. Following these processes, a series of routines were composed to calculate monthly, 30-day, and rolling-centred statistics at different spatial/temporal scales. These resulted in daily/monthly/seasonal/annual analyses for whole of MDB, North/South MDB, and surface-water systems. For agricultural production and water use data observations on agricultural output, water use and irrigated area were cleaned and normalized using attribute standardization techniques. This allowed custom spatial modelling routines to be created, and for the data to be transformed into consistent spatial regionalization and timeseries units. This process was necessary to ensure consistency with the supply data and requirements to analyse variables at different spatial scales. For the Bureau of Meteorology climate data, we converted all observations into a consistent format to enable timeseries extraction. We further developed a custom attribute classification approach to assemble the final database, allowing us to conduct consistent spatial modelling. As such, we were able to create both frequency distributions and zonal statistics at various spatial scales for all variables of interest.

3.2. The speculation CBA model

As discussed, from our assessment of the available data it would be challenging to identify speculative behaviour in sMDB water markets using traditional econometric approaches. The inability to identify individual trades/traders negates capacity to identify behavioural motives for trade, and how water is utilized. However, CBA allows us to assess possible drivers of speculation based on potential costs/payoffs from trade. CBA explores different trade-offs from allocating factors of production (land, labour, capital and water) between alternative investment options, such as speculative trade. For example, if net present value (NPV) = 0, then the trader has broken even. When $NPV > 0$ the trader is profitable. Finally, when $NPV < 0$, the trader is expected to make a loss. We assembled a range of scenarios and sensitivity tests (Table 2) to examine CBA model changes in response to alternative parameters for a set of market participants including landholder (e.g., irrigators) and non-landholder investors (e.g., superannuation funds). These classifications are consistent with ACCC (2020), where equity positions capture differences between non-landholders that must purchase an entitlement to begin speculating over time (e.g. investing in an entitlement for the first time) and existing-landholders that have current or grandfathered rights to trade; and therefore lower total costs of market entry.

If we assume an external trading agent with no position in the market, they will first need to purchase a water right. We further assume that such an agent may need to hold that right for a minimum term to achieve capital gains given the structure of water markets, as per Hirshleifer's trade scope prerequisite. We therefore adopted a 10-year analytical frame as the basis for our CBA where volumes that accrue to the entitlement are traded annually. To account for this we modify Crean *et al.*'s (2015) two-period state-contingent cost equation as a basis for speculative decision-making outcomes across a water year (i.e. May to April)—recalling that we noted this analytical approach as a suitable method in the Theory section. In state-contingent analysis there will be an initial cost to set the trade up (e.g. in the May period as per our analysis) followed by a second cost/income maximization move once the state is partially/fully revealed (e.g. before or after January each year as a strategic point of 'usual' trade highs ahead of peak water demand), as specified below:

$$Max\ E(Y) = -C_{t=1}(w,r,p) + \sum_{s=1}^{S} \pi_s\big(r_s - C_{t=2}(w,r,p)\big)$$

Similar to Crean *et al.*'s (2015) approach, the risk neutral maximizing profit objective function $E(Y)$ depends upon the π probability of state s occurring, where r_s is the revenue received from selling/leasing allocation water in state s, and w and p are variable ($/ML) and fixed trade costs respectively. Thus, $C_{t=1}(w,r,p)$ are any water trade costs committed prior to the revealed state, while $\sum_{s=1}^{S} \pi_s\big(r_s - C_{t=2}(w,r,p)\big)$ is the probability weighted sum of state-contingent revenues derived from stage two trade less any additional state contingent costs to fulfil the trade. This approach aligns well with Hirshleifer's (1977) speculation prerequisite related to two inter-related, but distinct, equilibria in the market. The purchased or held water entitlements are either high security (e.g. volumetric allocations available in 95% of years) or low/general security (e.g. volumetric allocations available in 30% of years). Linked to these entitlements will be fixed water fees or charges that may/may not accrue against the agent depending on their landholder status (e.g. local benefit area fees may only apply to irrigator entitlement holders).

Table 2: Model scenario and sensitivity test parameters

Scenario/Sensitivity Test:	***Scenario Values:***			
Equity Position:	Non-landholder	Existing-landholder		
Water Share Type:	General Security	High Security		
Fixed Water Charges:	Yes	No		
Loan Type:	Interest Only	Principal/Interest Repayment		
Capital Gains Tax:	Excluded	Included		
Capital Growth Rate:	7%	8%	10%	12%
States of Nature:	Normal	Drying	Drought	Wet

Each scenario had two to four values or levels associated with it. External agents assumed to have required financing to purchase an entitlement may choose between interest-only or principle-interest options, each with different repayment schedules. Capital gains tax can be included, or not, dependent on the circumstances of the agent and their trade exit decisions at the conclusion of the 10-year period. For the non-landholder models, where exit is assumed to occur, termination fees are capped at 10 times the infrastructure access fee. To determine the end value of the entitlement, we assume a base capital growth of 7% that, given a discount rate of 5% over the investment period, brings total growth down to 2-3% which is in line with global average data (Quiggin, 2019). A further model run using an 8% growth rate extends our initial analysis to cover the spread above, while two additional model runs reflect expected asset growth rates in the literature (e.g. Bjornlund *et al.*, 2013) of around 10-12% on average. Finally, state of nature outcomes considered normal, drying, drought and wet cycles with variable probabilities that could be altered to reflect uncertainty with respect to future sMDB supply and demand conditions (Table 3).[1]

Table 3: State of nature probability scenarios

	State of Nature Distribution %			
Scenario:	Normal	Drying	Drought	Wet
Base	40%	10%	20%	30%
R2	30%	20%	30%	20%
R3	20%	30%	40%	10%
R4	30%	20%	10%	40%

The state of nature frequency scenarios are based on eight future sMDB climatology models developed by CSIRO (2017). The models were all run using the mitigation 45 representative concentration pathways (RCP) scenario, and computed out to 2045. These scenarios subsequently represent the possible range of outcomes provided by the model predictions. A final set of investment models considered cost/benefit differences over 10 years between an investment approach (i.e. purchasing an entitlement to then trade annually) and an existing-landholder approach (i.e. already trading annually). The model uses actual 2018-19 fixed water charges associated with entitlement (water share) ownership from the Goulburn-Murray Water management system in northern Victoria.

Additional data for capital borrowing and market interest rates was sourced from the Canstar comparison website (https://www.canstar.com.au/interest-rate-comparison/), while water share and allocation prices were sourced from Waterfind Weekly Reports and Waterpool Allocation Trade data (https://www.waterpool.org.au/permanentTrade.aspx). Median and average allocation water price fluctuations were based on data included in

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[1] We could examine a scenario consistent with the latest IPCC predictions for future drought conditions in Australia by 2050; that is, an expected probability of droughts in 75% of years. However, the timeframe is outside the scope of our current CBA and, while it would be possible to extend that timeframe, is also considered beyond the scope of the current debate. By 2050 we would expect to see fundamental changes within the water market that would be challenging to predict and represent in our models.

ABARES (2017). Finally, the model does not consider carryover as part of the analysis, as speculative trade must begin and conclude within a market ‘period’ to conform with theoretical constraints. Further, any inclusion of carryover would be more aligned with futures or hedge trade activity, which was not the focus of this paper but has been considered elsewhere (Bayer and Loch, 2017).

3.3. Elasticities

In our calculations of annual water supply/demand elasticity we broadly follow guidance of Scheierling *et al.* (2006). Further, Adamson *et al.* (2017) state that, as both supply and demand shift toward perfectly inelastic outcomes we should expect rapid price increases as perennial users pay very high short-run, and somewhat lower long-run, price premiums to protect capital investments. This, in turn, may result in a market run as users within confined water systems react to those around them. Finally, whilst uncertainty might be expected to resolve over time, equilibria shifts and perceptions of ongoing inelastic supply/demand conditions may see high prices persist among relatively small user groups, which may be evidenced by demand-hardening over time. We therefore calculate supply/demand elasticity values and look for evidence of demand hardening to evaluate any impact that might have had on water allocation prices.

4. Results

4.1. H_1: Water market hoarding is unsubstantiated/unprofitable

To test this hypothesis we use long-term analysis of sMDB agricultural production and water use, water market trade trends and climate outcomes data. Non-commercial trade volumes (i.e. zero-dollar trades) in the sMDB outweigh commercial trade volumes (i.e. trade values between $5 and $2000) by a factor of two-to-one in most years (BoM, 2019). Surface water trade volumes since 2012/13 have averaged 1500GL (gigalitres, or one billion litres of water) per annum; although in some years they averaged as high as 5000GL. The linear trend in trade volumes is positive over the period 2009/10 to 2018/19, providing initial evidence against hoarding behaviour. As shown later, our model results highlight the benefits from, and requirements to, trade water allocations seasonally to ensure positive financial gains. Thus, it is not surprising to us that at some point during the year—whether speculating or not—traders are required to close out their position to benefit financially, and this motivates the release of resources over hoarding choices.

Yet, some market commentators (for example Sullivan, 2019b) have sought to link higher allocation water prices in recent years (e.g. 2019/20 in Figure 1) with hoarding behaviour and reductions to trade volumes. An analysis of market data and trends does not bear that out. For example, the megalitre volume of commercial trades by surface system aligns closely with the water season, and shows reasonable volumes on offer through the critical Autumn and Summer months up until 2019/20, where our data ends (Figure 2). Seasonal counts (Figure 3) of surface water trades by system also support the conclusion that no reduction in trade volumes on the market is evident. Similarly, there is little evidence of reduced trade volumes over the last two years. In fact total supply/demand, trade volumes into the markets, and carryover levels (excepting 2016/17 when final seasonal supply exceeded demand) are all quite stable between 2010/11 and 2019/20—although the rapid median trade price increase can clearly be seen from 2017/18 onwards (Figure 4).

Whilst this might support a view that intra-seasonal hoarding is taking place in the early stages of a water year, when reductions in volumes on offer are occasionally apparent in some surface systems, overall there is no evidence to support hoarding of water resources within the market. This begs the question: what is driving price increases if not diminished trade volumes onto the market? Here again, we return to our long-term analysis of market data and trends.

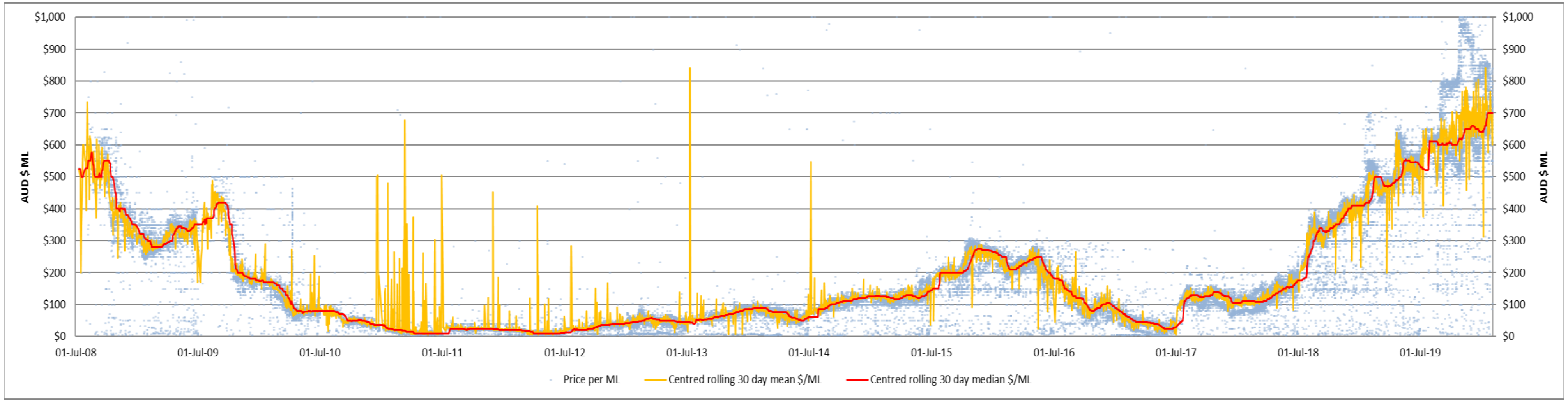

Figure 1: Daily trade price, 30-day centred rolling median/average price for sMDB based on >=$5 and <=$2K allocation water price values 2008 – 2020 (excluding water for fodder trades). Source: Authors' own analysis based on BoM (2020) data

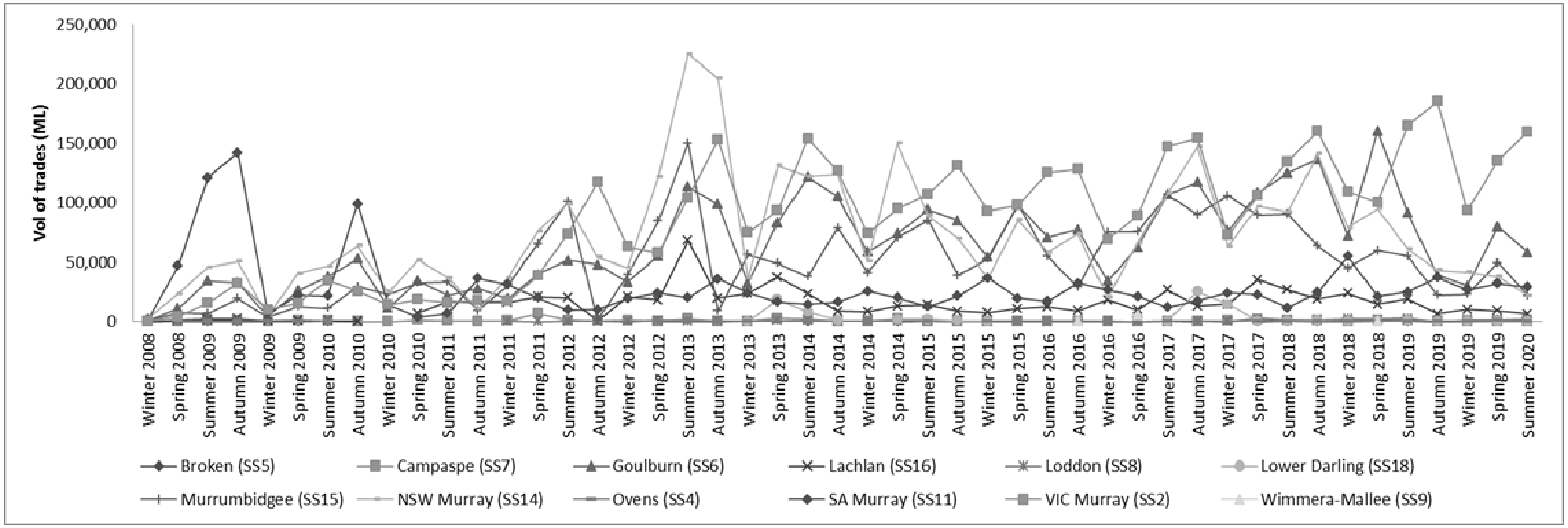

Figure 2: Seasonal trade volume (i.e. > =$5/ML and <= $2K allocation water price values) by sMDB surface system 2008-2020. Source: Authors' own analysis based on BoM (2020) data

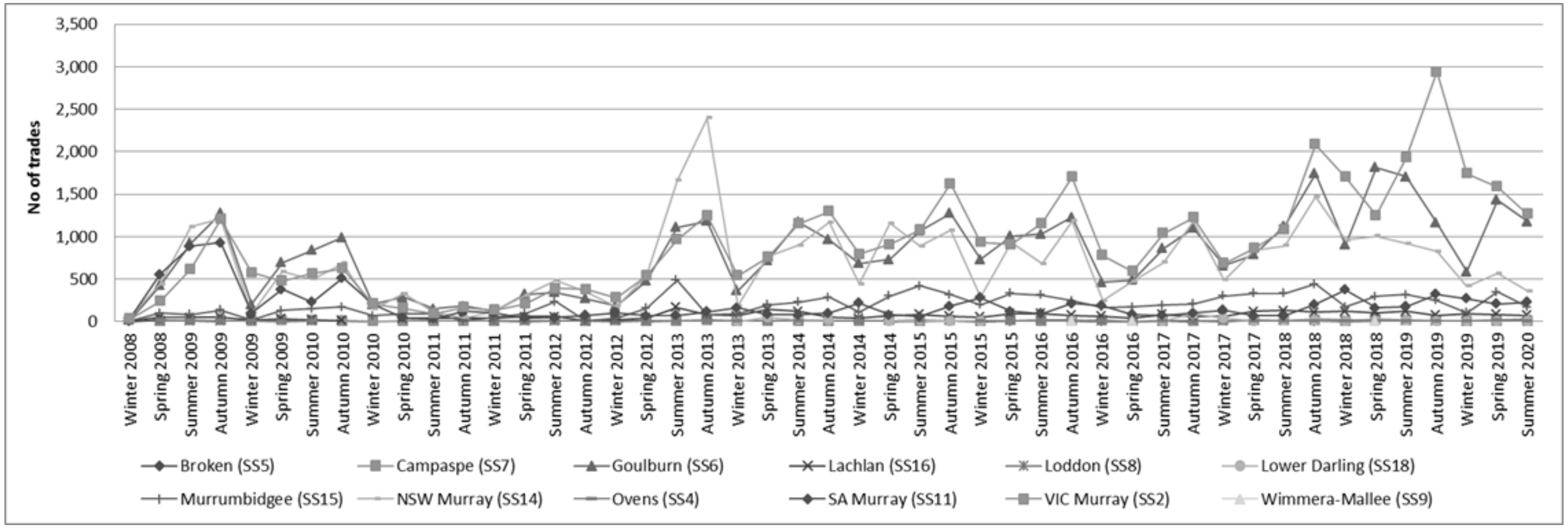

Figure 3: Seasonal count of commercial trades (based on >=$5 and <=$2k allocation water price values) by sMDB surface system 2008-2020. Source: Authors' own analysis based on BoM (2020) data

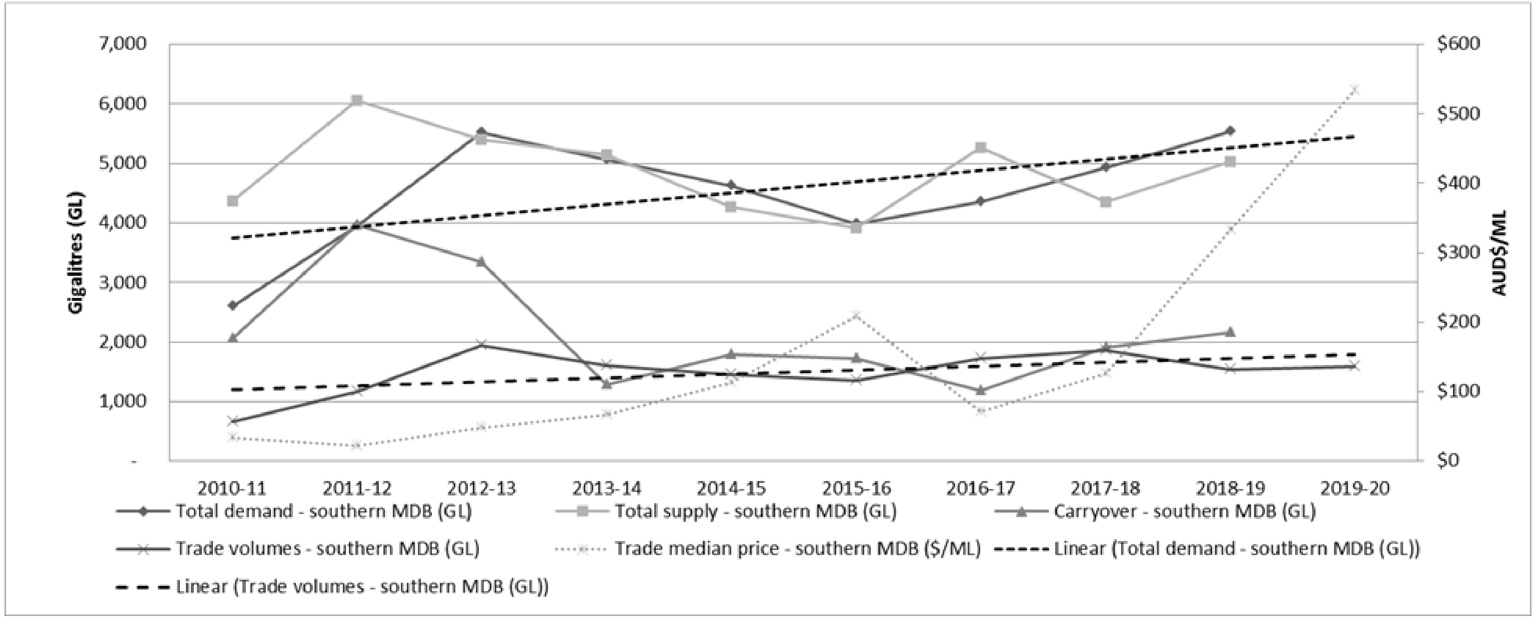

Figure 4: Major market trade trends in the sMDB, 2010/11 – 2019/20. Source: Authors' own analysis based on ABS (2019) and BoM (2020) data

To start, we tested the idea that transformations of agricultural sectors (as major water users) might have impacted trade outcomes where business activity, land utilization and/or water application patterns had altered. The ABS stratify farms at alternative estimated value of agricultural operations (EVAO). We examined the data for the number of farms operating at the $5K and $40K levels which aligns to contemporary definitions of agricultural businesses (ABS, 2017). The data changes from a focus on $5K businesses to $40K businesses around 2015/16, hence the overlap in the figures shown. The analysis suggests that from 2004/05 to 2015/16 9.7% of farms operating in the $5K level left the industry, while at the $40K level 8.8% of farmers left the industry between 2010/11 and 2017/18. Conversely, the total agricultural area in operation has increased by 10% from 2010/11 to 2017/18 based on EVAO $40K (Figure 5).

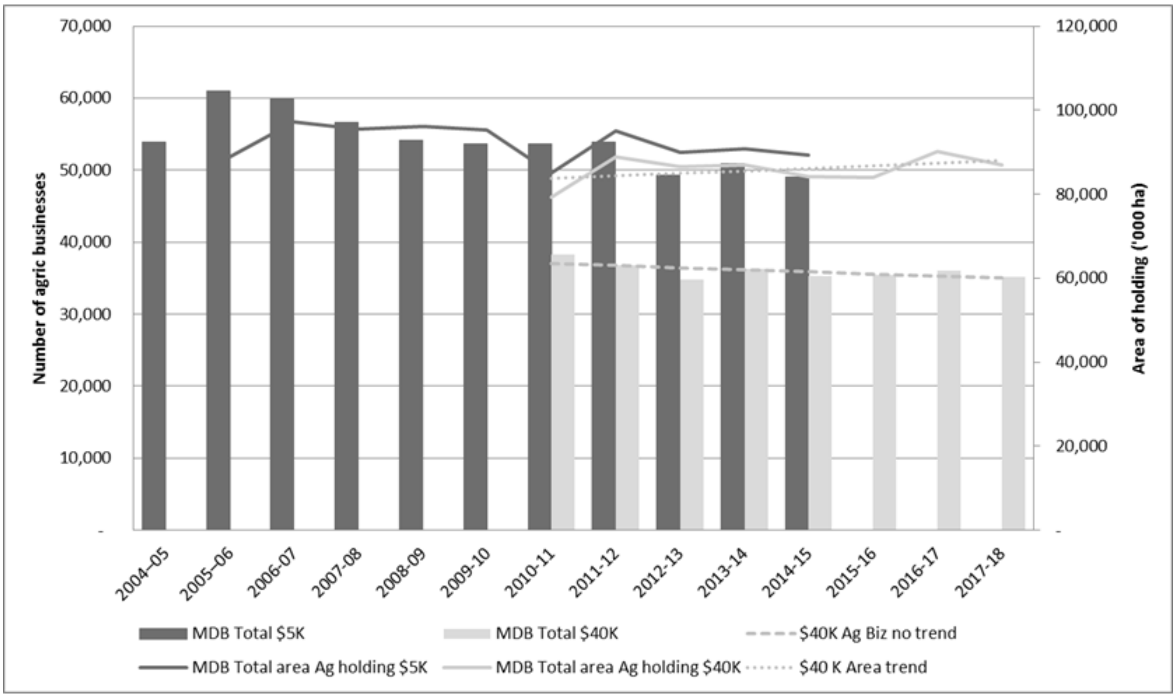

Figure 5: Number of agricultural businesses in the sMDB ($5k and $40k Estimated Value of Agricultural Operations [EVAO] categories), 2004/05 – 2017/18. Source: Authors' own analysis based on ABS (2019) data

Water demand also appears to have hardened across the sMDB. In particular, perennial area and water application rates have increased since 2010/11 by around 53% on average (Figure 6). Changes to plant densities, maturing tree-crops driving high water requirements, and a relocation of perennial commodities to downstream areas of the sMDB may have driven these increased water demand and application rates (e.g. ML/hectare requirements).

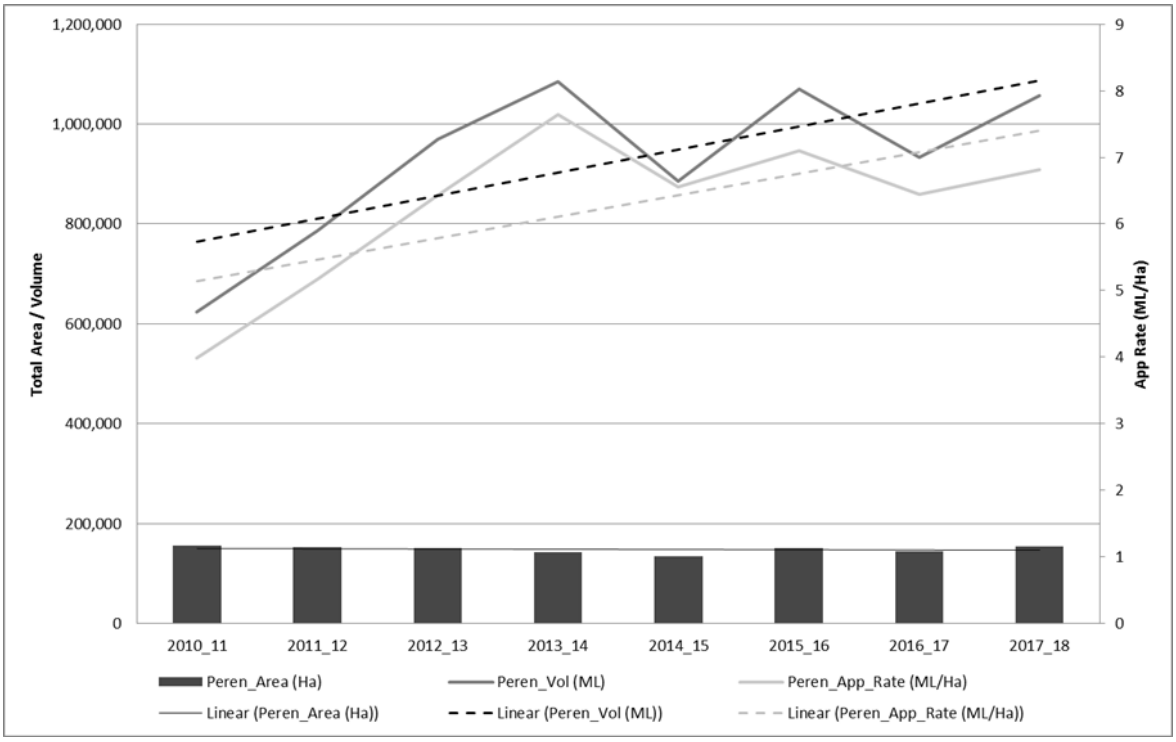

Figure 6: Perennial area and water application rates (volume and area), 2010/11 – 2017/18. Source: Authors' own analysis based on ABS (2019) data

The increasing trend for water application volumes and perennial watered area in the sMDB suggests that pressure on agricultural users to trade should be steady or increasing. However, there have also been changes to individual commodity returns that may feature in decision-making. For example, average AU$/ML returns over the last 20 years (normalized to 2018 prices) have decreased for perennial fruit tree (e.g. almond) and grape-growers in the sMDB, but increased for cotton and cereals. This might suggest a greater willingness by cotton/cereal growers to hold onto water where possible, rather than trading it on the market, to generate farm production and 'traditional' income—unless they can secure a relatively high price premium. However, this should not be thought of as hoarding where the definition as stated above only relates to non-landholding users (see Sullivan, 2019a). By contrast, perennial irrigators with a lower capacity to pay high prices for water inputs on the back of poorer returns, may be forced to consider alternative coping strategies beyond the market. We return to this in the Discussion section.

Our study identified one source of information that may inform the high allocation water prices experienced in 2017/18 and 2018/19. The source of that data was market trade and volume observations from Murray Irrigation Ltd.; a major irrigation infrastructure operator along the Murray River in New South Wales. If we examine that data over the period 2000/01 to 2018/19 (Figure 7) low trade volumes and inflated price outcomes can be viewed during the height of the Millennium Drought (2005/06 – 2009/10). Roughly the same trade volume and price outcomes can be observed in the 2017/18 to 2018/19 period, where trade volume fell to around 100GL, and prices began to climb upward (~AU$400 to $600). In the initial period (2005/06 to 2007/08), irrigators had not previously experienced allocation declines and were caught short in many cases (Loch *et al.*, 2012). Panic buying ensued, water shortages were widespread, many farmers were faced with switching off water to crops, and eventually replanted.

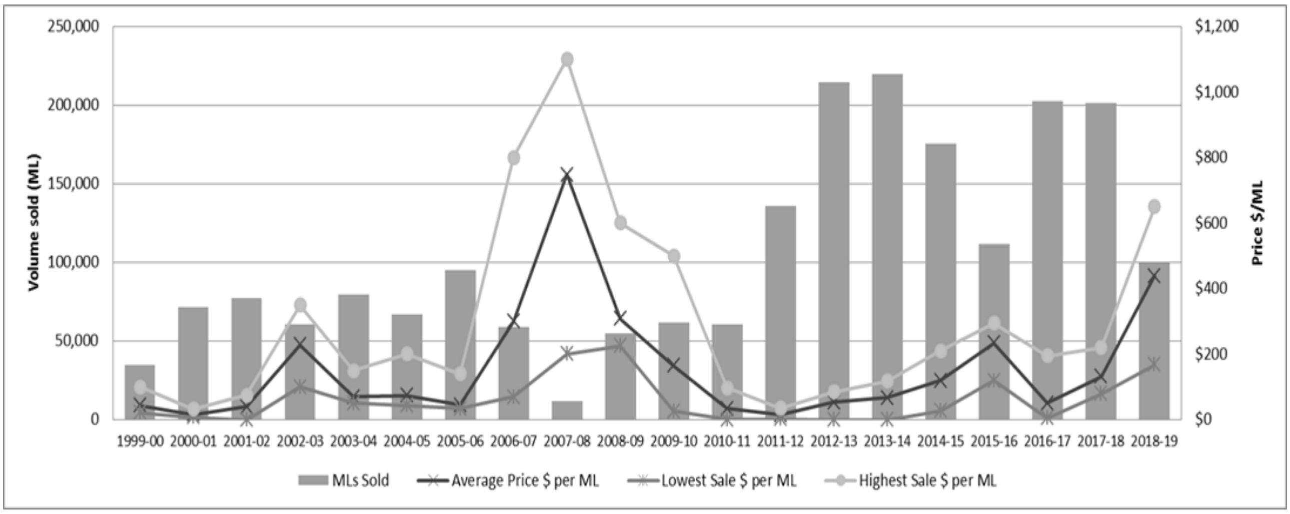

Figure 7: Water trade volume and price, Murray Irrigation Ltd. 1999/2000 – 2018/19. Source. Murray Irrigation (2019)

Experienced (or prudent) irrigators would therefore be aware of the potential downside to any repeat of these conditions, and react accordingly in advance to secure their capital base and production choices. This is consistent with the Victorian government's discussion paper on water market speculation, suggesting irrigators have learned from past events (DELWP, 2019). This may also explain recent allocation water price increases where perennial crop irrigators have been taking action in response to perceptions of future supply shortages. If we consider recent climate outcomes and soil moisture variability in the sMDB we can also observe evidence in support of negative perceptions about future supply (Figure 8). Analysis of BoM rainfall anomalies since 2010 clearly show more negative than positive results for the period 2000/01 to 2017/18 (Figure 9). Where CSIRO predictions suggest a drier future in the sMDB of between 20% and 60% (CSIRO, 2012)—and the IPCC predicts drought conditions in three out of every four years by 2050 (IPCC, 2018)—it is not surprising that in recent years irrigators may have taken it upon themselves to address this by purchasing water at higher than normal prices.

If a majority of irrigators follow the same strategy, as evidenced by other studies of market behaviour and long-term thinking (Wheeler and Cheesman, 2013), some may find themselves locked out of the market. This is especially true for irrigators with lower production system flexibility (e.g. perennial growers) that might be addressed by trade in more normal periods. We conclude that sMDB water demand has hardened in response to changed capital investment, tighter perennial margins, lower trade volumes on the market as a consequence of higher returns for annual producers, lower returns for perennial producers coupled with lower marginal trade benefits for annual producers, and concerns about water delivery to end-of-system locations (Slattery and Campbell, 2019). This has driven reduced capacity to pay high allocation water prices where irrigator's own entitlements are insufficient to offer an underlying supply in support of their investments (i.e. reliance on the allocation market by many, where total trade is later reduced). In the next section we offer some additional analysis to support these claims.

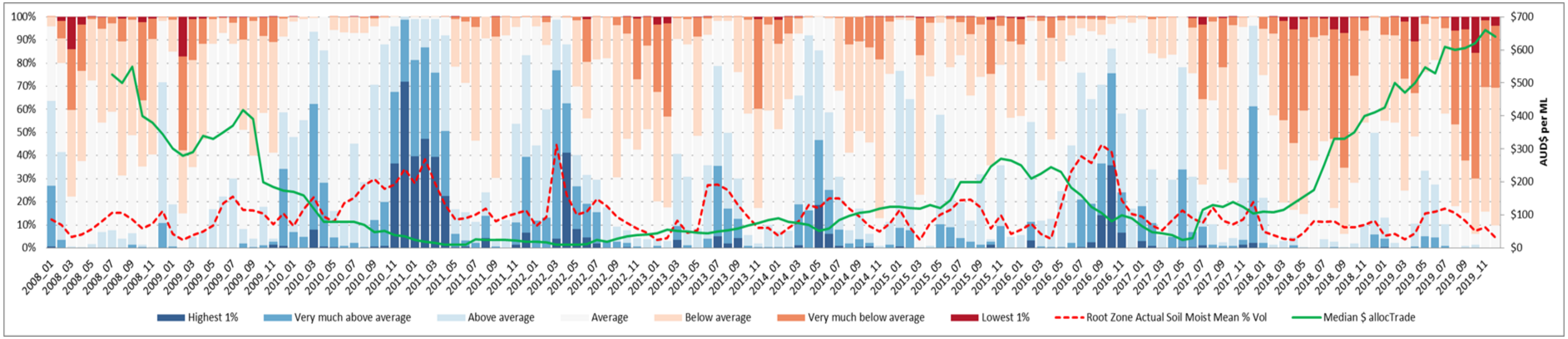

Figure 8: Southern Basin ETOT and relative soil moisture 2010 – 2019. Source: Authors' own analysis based on BoM (2020) data

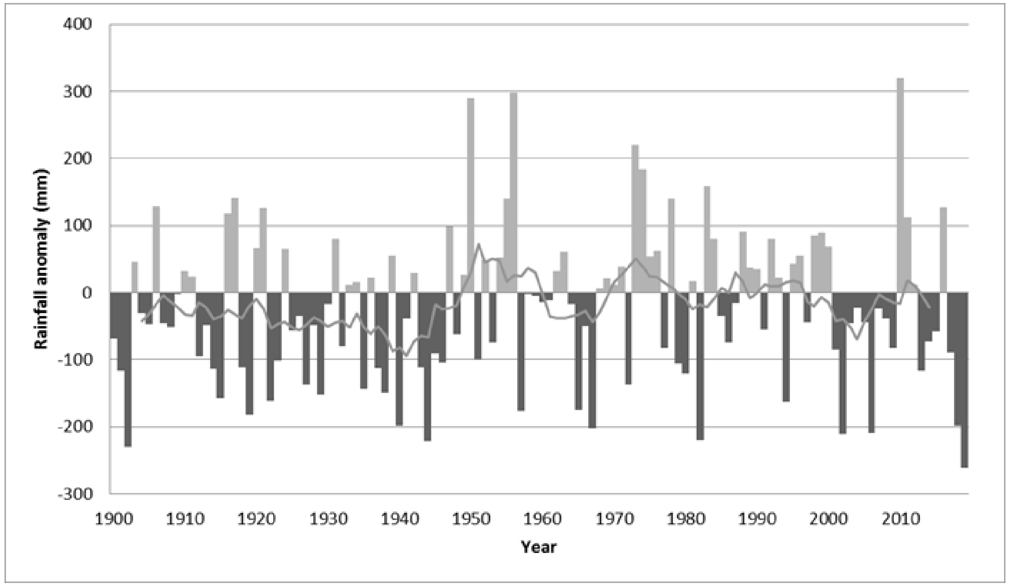

Figure 9: MDB rainfall anomaly based on 30-year climatology 1961-1990 data, with 10 year centred rolling average, 1900 to 2019. Source: (BoM, 2020a)

4.2. H_2: Cost differences motivate landholder speculation over non-landholders

The results of our model runs (Base, R2, R3 and R4 in Table 3) suggest speculative trade is highly likely in sMDB water markets; and with good reason as it can be very profitable. The CBA model results—inclusive of fixed and variable charges to trade—consistently return positive NPV outcomes for speculative trade regardless of landholding status; though non-landholding agents have higher market entry costs. Both significant internal rate of return (IRR) and return on investment (RoI) values are returned in 90% of years across each of the capital growth scenarios along with positive benefit/cost (B/C) ratios from speculative trade (Table 4).

Table 4: CBA model comparisons for non-landholders under differing water security types, loan conditions, and across varying capital growth rates (in 2019 dollars)

	Base - 7% Growth			**R2 - 8% Growth**		
CBA Model Runs:	NPV	B/C Ratio	IRRI	NPV	B/C Ratio	IRR/RoI
General Security/Interest only	$83,498	$1.32	22%	$93,403	$1.35	23%
General Security/Principle & Interest	$87,651	$1.34	17%	$97,556	$1.37	18%
High Security/Interest only	$25,454	$1.03	7%	$60,783	$1.08	9%
High Security/Principle & Interest	$63,763	$1.09	8%	$99,092	$1.13	10%
	R3 - 10% Growth			**R4 - 12% Growth**		
	NPV	B/C Ratio	IRR/RoI	NPV	B/C Ratio	IRR/RoI
General Security/Interest only	$115,550	$1.41	25%	$141,162	$1.48	27%
General Security/ Principle & Interest	$119,702	$1.44	20%	$145,315	$1.51	22%
High Security/Interest only	$139,771	$1.17	13%	$231,124	$1.27	17%
High Security/ Principle & Interest	$178,080	$1.23	13%	$269,432	$1.33	16%

Note: full scenario listed in Table 1. Capital gains tax is included in all of the model runs above due to positive NPV in each year of allocation trade, and final asset liquidation.

The model also predicts optimal periods to buy and sell within a season, to attract positive gains. Notably, under drought conditions speculative trade could result in an RoI of around 159% if the timing is ideal (i.e. fast and unexpected transition to drought conditions), offering high incentives to engage in speculative behaviour. However, modelled returns are based on a full-cost scenario including loan deposit and repayment expenses to secure an entitlement, as well as standard fixed water charges and brokerage costs which represent the actual costs of a non-landholder entering the market. At the end of the 10-year period, termination fees and capital gains tax expenses are also factored into the calculations to represent their market exit (in this case).

Importantly, the same market entry/exit costs are not relevant to an existing landholder (e.g. irrigator), who may also accrue tax credits for past years where farm income was negative—thus reducing capital gain tax impacts. So, while termination fee expenses may still apply if they similarly exit the market, the potential RoI to existing land-holders in sMDB markets would be expected to exceed that expressed in Table 4. This suggests far greater incentive for landholders, rather than non-landholders, to speculate in sMDB water markets for financial gain. Given that landholders can also i) benefit financially during periods of insufficient allocation to grow crops, ii) derive an income from speculative trade over agricultural production, and iii) offer inputs to other irrigators with higher risk profiles (e.g. perennial growers) it seems highly likely and logical that these factors are driving current high prices in sMDB water markets.

To test this further we expanded our CBA model to incorporate state contingent analysis (SCA) runs. For a more complete description of SCA see Chambers and Quiggin (2000), Mallawaarachchi *et al.* (2017), Adamson *et al.* (2017), and for the theoretical links between SCA and CBA see Adamson and Loch (2019). In summary, SCA enables an analysis of different probabilities for state of nature outcomes (e.g. dry, normal or wet conditions) to then input back into the CBA. These outcomes change not only the state inputs (i.e. water), but also the set of choices available. Our analysis provides B/C Ratio outcomes roughly equivalent to those reported earlier. However, the IRR and RoI values are almost doubled across the range of speculative trade choices, dependent upon the state of nature outcome (Table 5). Thus, using Arrow’s (1953) terms, speculative payoffs are always positive regardless of the state outcome. Since we expect drier futures in Australia, this would suggest the motives for speculative trade are only going to increase over time. Some users will naturally adjust and adapt to these changes, reducing pressure on the market. However, there will likely be good future opportunities for speculators to benefit, and for gains from trade to occur, supporting our second hypothesis.

Table 5: SCA scenario results from the CBA model (Base 7% growth)

State of nature outcome	NPV	B/C Ratio	IRR/RoI
Speculative Allocation Trade-Current SoN	\$36,227	\$1.40	40%
Speculative Allocation Trade-Drying SoN	\$56,259	\$1.46	46%
Speculative Allocation Trade-Drought SoN	\$76,290	\$1.50	50%
Speculative Allocation Trade-Wet SoN	\$33,762	\$1.49	49%

4.3. H_3: Elasticity changes signal demand/supply hardening, driving price increases

To test our third hypothesis a calculation of supply and demand elasticities present useful evidence to support price increases, and motives for market activity. Adamson *et al.* (2017) outline thinking presented by Olmstead and Stavins (2007) based on Griffin (2006), wherein the concept of choke prices are raised. These are points at which market prices far exceed normal equilibria as a result of high demand and supply inelasticity. Adamson *et al.* (2017) discuss both short-run (e.g., what might happen in the early stages of market panic-buying) and long-run choke prices which are set at lower levels commensurate with a diminishing capacity to pay price premiums based on financial limits. If we calculate supply/demand elasticities over the last 10 years in the sMDB we can see evidence in support of movements toward allocation water choke price outcomes. For those unfamiliar with this process, values of one indicate unitary elasticity (normal supply and demand), values greater than one indicate perfectly elastic conditions (high supply but no demand), and values approaching zero indicate perfectly inelastic conditions (low supply and high demand).

Following the Millennium Drought (i.e. 2011/12), supply (0.94) is relatively elastic; which makes sense given increased resources following flooding in the sMDB (2009/10). Demand and supply elasticities decrease over the period to 2015/16 when demand (0.06) and supply (0.04) approach perfectly inelastic status, corresponding with a median price rise to around AU$200/ML. While the elasticities do not relax very much in 2016/17, carryover reserves and trade in the market appear to intervene and reduce prices again (see Figure 4). However, by 2018/19 demand (0.03) and supply (0.07) once again approach perfectly inelastic status, and as storage inflows and carryover both reduce median allocation water prices soar above AU$600/ML by 2019/20 (Table 6 and Figure 1).

Table 6: Demand and supply elasticity in the sMDB, 2011/12 to 2018/19

	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Demand Elasticity	0.48	0.97	-0.15	-0.08	-0.06	0.04	0.10	0.03
Supply Elasticity	0.94	-0.53	-0.44	-0.05	-0.04	0.04	-0.02	0.07

Consistent with the choke price theory described above, highly inelastic demand and supply appear to be driving median allocation water price increases in recent years, rather than hoarding or other trade reduction activity by non-landholders. Again, as many academic market analysts would expect, underlying agricultural water demand—especially when we take recent hardening outcomes into account as described earlier—is a far more likely driver of high median allocation water prices. There is no evidence of external hoarding at play in the market, and none is needed to drive the outcomes experienced; worried irrigators with perceptions of drier futures and limited water are reacting rationally by purchasing the limited supply at high prices. Again, some in the market—as stated above, more likely other irrigators—are benefiting from this activity by gaining from trade.

5. Discussion

Table 7 summarizes the hypotheses and test outcomes. Our results align to the prerequisites of speculation theory detailed earlier. We find evidence in support of the second prerequisite of fixed and variable cost differentials that drive speculative trade outcomes in sMDB water markets. However, for existing landholders these costs are relatively small providing higher potential speculative gains from trade. Yet the costs of trade and holding entitlements also reduce incentives by non-landholders and landholders to withhold (hoard) water from the market in search of increasingly higher gains, where underlying risks to supply arrangements in Summer months may drive total losses. The third prerequisite is also visible in more regular inelastic demand and supply outcomes across the sMDB, which correspond to an increased probability of short-term and long-term choke prices in the allocation water market. Finally, with respect to the fourth prerequisite, differences between landholder and non-landholder right owners might motivate price increases in sMDB water markets; but differences between individual irrigators (i.e., perennial v annual water users) are also sufficient to warrant a similar conclusion. Therefore, it is presumptuous to blame price increases on non-landholding market participants.

Table 7: Summary of hypothesis test results

Hypothesis:		***Supported:***
H_1	Hoarding is unsubstantiated in water market trend data and unprofitable due to fees and charges for water asset ownership	Yes
H_2	Cost differentials make speculation more probable for landholding market participants	Yes
H_3	Inelastic supply/demand drivers of price increases will be incorrectly identified as speculation	Yes

What then does this mean for water markets in Australia; and by association those in other jurisdictions? Let us begin by remembering that speculation is legal regardless of any moral objections (see for example Sullivan, 2019b), and delivers economic benefits. Further, calls for increased regulation of external users and other investors are based on ‘folk analytic’ (Wittwer and Young, 2020) claims, rather than factual analysis and evidence should be provided before (largely impractical at any rate) changes are made.

Ultimately, it should be unsurprising that water prices have increased over time in the sMDB. Randall (1981) predicted such outcomes given maturing water development stages, while more recent reallocation (contraction) of rights to environmental users has reduced total consumptive supply which basic economics tells us should result in price shifts (Adamson and Loch, 2018). As we head further into a fifth stage of water development (i.e., sustainable use, see Loch *et al.*, 2020) prices will increase further again during scarcity—especially where users fail to appreciate the true risk of supply. The prospect of higher returns (prices) may attract other investors/speculators from different sectors; especially those with different views about/attitudes toward the supply risk of water, which will enable varied price discovery across alternative states of nature and future climate outcomes. This may result in greater information asymmetry and price disparity as evidenced in recent market data. Ultimately, this behaviour may diminish when true returns (i.e., a combination different right reliabilities by state of nature, the frequency of each state, and the trade price by state of nature) no longer provides a positive return on investment. But this outcome has yet to be experienced.

Our study also adds value to current government inquiries into (and future concerns about) market speculation and hoarding. First, hoarding in water markets is risky as traders attempt to bet against movements in the price, which can quickly change due to exogenous factors (Loch *et al.*, 2012)—a fundamental that does not appear to be widely appreciated by market observers. The analysis provided herein substantiates this claim, and that investors can profit more from risk-neutral attitudes to hoarding rather than risk-taking. Second, while speculation in water markets is challenging to identify—especially via traditional analysis approaches due to the nature and poor quality of data—a market fundamental with respect to differences between key participants is informed via our analysis. For example, investors in water markets differ from speculators by definition. Investing in a water entitlement from scratch (e.g. as an external non-landholder) to then trade annually so that costs are covered, is not typically likely to generate high returns—positive yes, but not as high as some might expect. Alternatively, speculative trade by existing or retired[2] landholders is far more likely to be profitable under a lower cost to trade base. Following that logic, we agree that speculation is likely in sMDB water markets, and has the potential to generate high returns for those that engage. This is because, again following the logic of those theories discussed above, we should expect to witness allocation water price increases from perennial crop landholder speculation where they: i) look at previous seasons and predict forward, ii) anticipate that supply will be tight and thus purchase allocation water to hedge that expectation, which iii) drives a market price increase and signals speculative activity to others, that then iv) increases perennial sector pressure to act as the price cycle rises further. This is evident in our analysis, and far more logical than claims of external corporate influences on market outcomes (again, see Testa, 2019).

Third, sMDB agricultural water demand is hardening as a result of i) transformed commodity and landscape mixes, ii) public irrigation efficiency investments that have driven a reduction in production system flexibility (i.e., encouraged switching to perennial cropping

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[2] A recent report shows that many irrigators are retiring from farming, but holding onto the water as an asset for superannuation purposes (Schlesinger, 2020). These ex-landholders are using allocation water trade to produce, or supplement, their retirement income. But such activity again reflects no hoarding of water to increase prices, and further undermines claims that corporate non-landholders are the cause of high allocation water prices in the sMDB.

as per Adamson *et al.* 2017), iii) tighter commodity margins for related sectors, and iv) perceptions of poor future supply. Many irrigators have reached (or exceeded) thresholds related to their minimum water input requirements (Loch *et al.*, 2019) and, in the face of that reality, short-term panic-buying has most likely occurred (Adamson *et al.*, 2017). Further, in the last two decades agriculture has not experienced periods of extended recovery between extreme events, diminishing capacity to adapt and cope with change. This is an example of economies of scale and economies of scope—although economies of scale will be more important where irrigators enjoy lower costs of trade as compared to non-landholding market entrants or recent entitlement purchasers. When we also consider the comparative information asymmetry between landholders located within surface water systems, and compare that to non-landholders, it is also more likely that speculative behaviour is being undertaken by agricultural users, (especially relatively large irrigation operations. In the analysis, more worrying is the possible change in behaviour by annual producers in response to improved commodity returns (e.g., cotton) as a driver of future price increases. Where more flexible annual producers have provided a (somewhat) reliable source of past trade to perennial producers with fixed production systems (NWC, 2011), shifts in that relationship may have direct consequences for trade volume and price outcomes. In any case, differences between market participants in support of speculative trades is clearly apparent through our CBA analysis, supporting theoretical expectations.

Finally, in Australian water markets it is now apparent that brokers have amassed considerable market power over annual prices—recalling though that market power may not in itself drive speculation. Brokers offer a useful service where they compile, parcel and then on-sell products annually, and anecdotal claims suggest corporate, broker and/or non-landholder market activity is as high as 14% (Sullivan, 2019b). Such services also increase market efficiency in terms of transaction costs over individual irrigators searching, negotiating, compiling and contracting by themselves (Loch *et al.*, 2018). Hence, the increased role and value attributed to brokers in recent years, where they provide a source of capital and risk hedging services to irrigators. However, many recent submissions to the Treasury (2019) inquiry flagged water broker trade volume signalling and manipulation as a source of market speculative price increases where information asymmetry is high (e.g., Almond Board of Australia, 2019, SunRice, 2019). The lack of any centralized and impartial price signalling in the market provides ample opportunity for water brokers to fill the void and manipulate perceived prices toward significant differences from real market prices. As noted by many submissions, opportunities for price manipulation have far greater potential to drive price increases in water markets rather than any hoarding behaviour of non-landholding agents. Subsequently, there is a clear requirement in the water market for improved resourcing, oversight and regulation by organizations such as the Australian Consumer and Competition Commission (ACCC).

6. Conclusion

In this paper we have sought to analyse water market fundamentals to inform claims of speculation and hoarding behaviour. Proving speculative behaviour via traditional analysis requires data that does not currently exist in public trade registries and databases. This means that, while possible speculative trade at an aggregate level (e.g. within one trade zone) resulting in ‘abnormal’ price outcomes might be identified using regression analysis, linking that activity back to individual users is difficult, costly, and may infringe upon individual privacy. While the agricultural sector would be prudent to recognize the value of speculative water input/capital injections at a time of increasing future risk, and welcome those contributions, it would also be prudent to recognize the underlying data limitations and act to address them. In conducting this research, we have uncovered numerous examples of poor data recording, checking, assessment and procedures—and compiled a list of points at which these issues could be readily addressed. While better governance and regulation is urgently needed, so too is a root and branch improvement to water market data.

The study also lends support to the view that any increased regulation of external users, largely impractical in any case, would likely result in negative outcomes. Before the agricultural sector as a whole imposes greater constraints to benefit one commodity group (e.g. perennial tree producers) it may be wiser to consider the costs of additional regulatory and monitoring burdens—and further impacts on an already vulnerable water market under current conditions. Instead, we would support the Victorian government's view that greater transparency and data rigor is needed to identify 'suspicious' or market-power-based trades in future; at the very least to alleviate any future claims of hoarding/speculation as they emerge in future drying periods. Improving the quality and reliability of water market data through independent central repositories that can be accessed by all would likely reduce information asymmetry issues for water market participants, and any scope for future price manipulation.

Finally, as climate change is expected to decrease future water supply, water prices are expected to increase further in value. From our analysis the sector expected to gain the most from this situation will be existing landholders who face lower market entry and exit costs. Thus, in our view the most important market fundamental is the point of contention that exists between those irrigators who need to buy water in all states of nature (e.g., perennial users) and those with an increased capacity to sell water in all future states (e.g., annual producers). Future climate change induced water scarcity will drive further rounds of adjustment and corresponding water price increases. Improved data, analysis and reporting of market fundamentals will help water markets to work efficiently so that these required adjustments can occur.

Data availability:

Data were derived from the following resources available in the public domain: The Australian Bureau of Meteorology at http://www.bom.gov.au/water/dashboards/#/water-storages/summary/state and http://www.bom.gov.au/climate/, the Department of Environment, Land, Water and Planning in Victoria at https://waterregister.vic.gov.au/, Murray Irrigation Limited https://www.murrayirrigation.com.au/water/system/water-data/ and climate models from CSIRO https://www.climatechangeinaustralia.gov.au/en/support-and-guidance/faqs/eight-climate-models-data/

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