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How could water markets like Australia's work in China?

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ABSTRACT

What hurdles lie in the path of the Chinese government's plan to introduce water trading? This question is addressed by reviewing lessons from establishing water markets in Australia, and then assessing an early scheme to create them in China. In Australia, markets in water opened up over several decades, with gradual recognition of what was needed to avoid negative third-party effects. Trading there is now crucial: in drought years nearly half the water used by farmers is traded. Australia's experience throws light on the key requirements for a water market – though markets in China will, naturally, be fashioned to suit its own conditions. The pilot work by Tsinghua University in Gansu Province has led the way in having trading at the local level in China. Compared with Australia, however, rights are not as tradeable, metering is poor, and plots are tiny. Trading has mostly been by water user associations, made up of several hundred farmers, but this dampens the incentives that make markets effective – and can upset individual farmers. Possible ways past these hurdles are discussed.

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Introduction

In recent years Chinese authorities have shown increasing signs of being committed to developing water markets (e.g. State Council's Decree No. 1 of 2011, with trade as one tool to meet its 'three red lines' for water; the Chinese Communist Party's reform resolution of 2013, point 53, 'Develop ... water rights trading schemes'; and the launch in mid-2016 of the China Water Exchange – see cwex.org.cn/html/en/). This to some extent follows from observations (including by agencies like the World Bank) of the great value that trading has been in other places where water is scarce, notably Australia. This article assesses the feasibility of replicating this success in China.

Several commentators have pointed to the challenges and pitfalls of introducing water markets in China, given the lack of clearly defined and well-enforced water rights (e.g. Calow, Howarth, & Wang, 2009; Speed, 2009a; Sun, 2009). In recent years rights to water have been

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made clearer for provinces and levels below them, but rarely down as far as the farmers who are the end-users of most of the water. This article deepens appreciation of the obstacles and what might be done about them, by drawing lessons from on-the-ground experience of developing water markets in Australia, and of starting to develop them in China.

It begins by detailing why water trading in Australia is so beneficial – and is becoming more so as the climate becomes drier. Trading has been introduced incrementally, and the article describes from a practitioner’s point of view the significant lessons learned along the way about the essential requirements, both for water users to be willing to participate in the market, and for negative third-party effects, or externalities, to be avoided.

Recent efforts to introduce trading between farmers in the Shiyang River Basin in north-west China were to some extent consciously trying to emulate Australian water markets, to produce equivalent outcomes. In evaluating these efforts the article looks at whether the essential requirements identified in Australia are present in Shiyang, and where a requirement is absent, what steps could be taken to overcome this difficulty.

The biggest stumbling blocks in Shiyang are found to be matters embedded in China’s geography and culture, widespread across the country. Accordingly, the article assesses how difficult it is going to be in China generally, what measures are needed, to create a local-level water market that flourishes and has integrity – and thus to reap the sorts of benefits that Australia has been able to reap.

Methodology

In presenting what was learnt during the slow, cautious opening-up of trade in Australia, the article draws heavily on the understandings of the lead author, who was the key official responsible for water trade in the state of Victoria for nearly 20 years – and who as such was in daily discussions with farmers, water brokers, local and interstate officials, and scholars, and periodically arranged legislation or drafted regulations to widen the scope for trade, or occasionally to shut down a loophole. An array of published government reports and academic studies provides documentation, back-up and context.

When Tsinghua University set about developing a pilot water trading scheme in the Shiyang Basin, this author was invited to use his Australian experience to make an assessment of the obstacles to trading there and how they could be overcome. Accordingly, he sat in on the intensive meetings that were being conducted with Basin officials and farmers, for a week in 2013 and again in 2014. Designed to find out about local situations and encourage take-up of water trading, these meetings were led by the article’s co-author, who was Tsinghua’s project manager for the pilot scheme.

Once again, the first-hand knowledge gained in the course of establishing the pilot scheme has been supplemented by a review of some of the most thoughtful and revealing studies concerning water rights and trading in China. This has tended to confirm that conditions and challenges in the Shiyang Basin are not significantly different from those in the great mass of irrigated agricultural areas across China.

Water markets in China do not need to be exactly like Australia’s (Wang, Wan, & Biswas, 2017). Already there are moves in China, for example, towards having provinces trade water – trading on a much grander scale than anything in Australia. Nevertheless, what has been learnt over a long period in Australia, often by trial and error, can help to develop a realistic

understanding of the challenges China faces, particularly in building local-level trading (Speed, 2009b).

A very diverse range of water markets in various countries is looked at by Grafton, Libecap, McGlennon, Landry, and O'Brien (2011), and again in the collection of Easter and Huang (2014). Both these works highlight the importance of institutional arrangements that are able to minimize barriers to trade, while at the same time preventing any negative impacts.

Sun, Wang, Huang, and Li (2016) have recently assessed market-based policies for irrigators in the Heihe River Basin, just to the west of the Shiyang Basin. Their study found that issuing water certificates which enabled trading had little lasting benefit; hitches included patchy implementation, small farm sizes, and lack of metering.

By uncovering and gauging hurdles like these which could stand in the way of China having successful markets, the present article aims to increase understanding of what the best way forward might be.

The benefits of water markets in Australia

Water markets have proved to be immensely important in Australia, in enabling best use of limited water supplies. The middle of the continent is largely desert. In the south-east, where the bulk of irrigated agriculture takes place, it is still quite dry: inland of the principal mountain range, average rainfall is mostly less than 500 mm. Droughts there can last for many years, and they are evidently getting worse (Bureau of Meteorology, 2017).

The most significant river is the Murray, which (including its northern, largely unregulated tributary, the Darling River) drains a basin bigger than the Yellow River's but has only a quarter of the Yellow River's natural flow. The River Murray and its southern, more regulated tributaries have been heavily exploited for irrigation, so that mean flows at the Murray's mouth have dropped to about 40% of natural (CSIRO, 2008). Median flows have suffered more, falling to about 20% of natural, and during the last long drought flows out to the sea stopped altogether for several years.

In recent times the national government has invested several billion dollars in buying back water rights and in projects to reduce losses, the aim being to protect the river's environmental health.

Constitutional responsibility for managing water lies with the states – which are like China's provinces. This article refers mainly to water markets in the state of Victoria, but similar developments occurred in its two neighbours, New South Wales and South Australia, and water can also trade between these states, because they share the River Murray.

Up until the mid-1980s, water rights were tied firmly to pieces of land, and could not be moved. A prime factor leading to loosening this rigid system was the fact that the last major storage had been completed, so no new water rights could be issued. All the most economical sites for storages had been used; and anyway growing awareness of the needs of the environment meant the limits to what could be harvested had been reached (NRE [Department of Natural Resources & Environment], 2001).

Trading was introduced gradually, its scope being opened up bit by bit, with learning along the way. First of all, trade in the current year's 'water allocations' ('temporary trade') was allowed; trade in ongoing 'water access rights' ('permanent trade') came later. At first trade was only allowed within a communally supplied irrigation district, but later trade could

take place between farmers in different districts, and out of districts altogether, to private diverters.

Initially there was a limit on trade out of an irrigation district, of 2% of the district's entitlements each year. The concern was that the irrigators left behind in the district would be left with a heavy financial burden in keeping the district operating. Later this limit was raised to 4% a year, and finally, 20 years after the first trade out of districts, it was removed altogether (NRE, 2001; Tim Cummins & Associates, 2015).

Similarly, at first all trade had to be from one farmer to another. Then people who had no land at all were allowed to buy water access rights, but only up to a limit of 10% of all the rights in a system. This limit was put in place to reassure farmers that big-time investors – 'water barons' – would not buy up lots of rights, pushing up the price and making it hard for genuine farmers to get water. But this limit too proved unnecessary and was scrapped (Tim Cummins & Associates, 2015).

Again, urban water authorities are now allowed to buy water access rights from farmers, to meet the needs of their residents and industries (NRE, 2001). But this has been a sensitive matter, and the main city in Victoria – Melbourne – still can only obtain water from irrigation areas by paying for savings. Trade by farmers across state borders is now reasonably free, but only after extensive negotiation to ensure a level playing field (NRE, 2001, chapter 9).

So in Victoria water trading has been introduced gradually, in the course of three decades (the broad, basin-wide story is told in National Water Commission [NWC], 2011b; and Wheeler, Bjornlund, & Loch, 2014). The process can correctly be described as one of 'crossing the river by feeling the stones'. On more than one occasion an avenue for trade has come to light that is to traders' advantage but has adverse effects on third parties, and a restriction has had to be urgently applied (see e.g. NRE, 2001, p. 71).

Many farmers were initially wary about water trading, if not downright hostile to it: they feared that water would trade away from their district and fall under the control of wealthy speculators. But the concerns have largely subsided, as farmers one by one tried out trading and discovered its usefulness. Now almost every serious farmer has bought or sold water: water trading has become an accepted, indeed valued, part of carrying on their farm businesses (for more detail see NWC, 2011c).

The water market as set up has not been problem-free. The rise in the value of water access rights was of direct benefit only to the pre-existing private holders, and made it costly to retrieve water to meet environmental needs. And rights became more heavily utilized: caps were put in place to stop overall extractions growing, pulling back water from those previously utilizing heavily, but less water ran off farms and found its way back into the rivers (Young, 2014).

A dispersed scattering of small farms in the old, communally supplied districts has sold water to greenfield developments with higher-value enterprises – or to the national government for the environment – eroding the old districts' viability and hurting their long-standing communities (Fenton, 2006; HRSCRA, 2011). On this front, though, arguably the market has just facilitated structural changes that were happening anyway, and were needed (Wheeler et al., 2014). Overall, enormous benefits have come from having trading of water, as explained below.

Trading leads to water being reallocated to its most productive use

Reallocation happens through the decisions by individual farmers to buy or sell water, not by government command. Water moves away from poor land, for instance land that has become salinized. Water moves to the most profitable crops and to the most competent farmers. Through the water market, farmers who are not doing well have the option of selling their water and using the proceeds either to start up in some other occupation or to retire (NWC, 2012, 2014).

In Victoria large amounts of water have moved permanently away from annual cropping and dairying in the salinized mid-river areas, to better land downstream and to more valuable plantings, like horticulture. Trading also allows the current year's allocations to move around according to availability in a particular year, and the prevailing commodity prices. Thus, when water is plentiful and relatively cheap, it is bought to irrigate annual crops like rice or cotton – or to provide extra for wetlands.

Trading provides an incentive to use water well and make savings

In Victoria the fees that farmers are charged each year cover the cost of getting the water to them – at least the operating cost, and in theory the capital cost of infrastructure, though in practice this has often ended up with the government. These fees are in the order of A\$30 per 1000 m³ (or 1 megalitre) for storing water in major storages and delivering it in channels; this is a fixed fee, and there is a smaller variable fee for use of the water. The price of water on the market, on the other hand, is often far higher: in dry spells the price on the temporary market has been up around A\$400 per 1000 m³ (Tim Cummins & Associates, 2015).

Meanwhile, the market price for ongoing water access rights has gone up and up, from about A\$150 per 1000 m³ as the market started in the mid-1980s, to over A\$2500 per 1000 m³ in 2016/17 (NRE, 2001; Victorian Water Register website, waterregister.vic.gov.au).

All this makes evident just how valuable water is. The opportunity cost of a farmer failing to use his water is very high. The market thus is a very forceful driver of careful use of water by farmers. It has led to a lot of investment by farmers in drip irrigation and other more efficient systems. It has also made it more economical for there to be public investment in efficient delivery systems, for example plastic-lined channels that eliminate seepage.

Trading minimizes the damage inflicted by drought

When water is in really short supply, its value on the temporary market surges. Individual farmers, based on their individual enterprise, can decide whether to buy extra water – e.g., to keep their fruit trees alive – or whether they would be better off taking advantage of the high prices and simply selling the small amount of water they have. Having water shuffled around like this in the middle of a serious drought is much better than what happened in the old days, when the government would be under pressure to decide which farms should get the water.

South-eastern Australia recently suffered its worst recorded drought. Inflows to the River Murray from 1997/98 to 2009/10 were 47% less than the average over the previous 100 years. In 2008/09, allocations to Victoria's high-reliability access rights were alarmingly low: they only got to 35% of the nominal value of the rights. In that year trade of allocations boomed. Water bought by farmers totalled 44% of the amount of water they put on their crops

(57%, counting \$0 transfers between related parties). Twenty per cent of all the water consumed – including by towns – was traded in from the two neighbouring states (Tim Cummins & Associates, 2015). Trading had enabled a massive moving around of what little water was available, to all the players' advantage (NWC, 2012).

Conditions that are essential for water markets

Consistent with the theory and practice of water markets described in many studies (two excellent examples relating to China being WET, 2006; and Xie et al., 2009), Australia's experience in introducing water trading indicates there are five prerequisites. These are matters that must be addressed in order to have an active, well-regulated market.

Clear local rights to water, backed by firm bulk sharing rules

First and foremost, it is important that the rights that are to be traded are well defined. Victoria had a history of defined water access rights going back decades before trading started, and as trading has developed rights have been further clarified and refined.

Water access rights are held by individual farmers. A typical dairy farm is around 100 hectares and has a water right of about 400,000 m³, while a horticultural block is some 10 hectares with about 100,000 m³ of water right – though there is a lot of variation, with a few very large corporate farms appearing. A small number of rights are held by urban authorities, and by environmental agencies for providing water to wetlands.

Farmers' rights had always been recorded in registers kept by the relevant water authority, but all the rights are now in a new, state-wide water register, and anyone can inspect them online. The register also records the allocation made in the current year to each right, and the use and trade of that allocation, though this is considered private information and can only be accessed by the holder of the right.

While rights are expressed in volumetric terms, they won't always be fully met: they are a share of the available water. In Victoria, allocations for the current year are first made evenly to all the high-reliability rights (whether held by farmers, by urban authorities or for wetlands). If there is sufficient water for these rights to be met 100%, then water will be kept in reserve to ensure that, with minimum expected inflows, they can be fully met in the following year. Only if there is still more water available, will allocations be made to low-reliability rights.

The rules for making water allocations, starting with what water is available to be allocated and what water should be left in the rivers for environmental needs, are set out in statutory instruments – e.g. Bulk Entitlement (River Murray – Goulburn-Murray Water) Conversion Order 1999, available at <http://waterregister.vic.gov.au/water-entitlements/bulk-entitlements>. Buyers tend to use rights more fully than sellers, so it is vital to have a cap on total extractions. The rules are accessible on the Victorian Water Register website, providing transparency: a farmer will not know exactly how much water he or she will receive in the coming season – that depends on the weather – but will know, and be able to check, exactly how this is determined.

Because the River Murray is shared by three states, it was crucial to decide their shares. The basic carve-up was agreed to over 100 years ago, in 1915: the two upstream states, Victoria and New South Wales, are each entitled to half of the inflows above Albury (just

beneath the mountains) and all the inflows from their tributaries below Albury, but each must contribute half of a fixed entitlement for the downstream state, South Australia.

This agreement (the latest version, called the Murray-Darling Basin Agreement, 2007, can be found on the Murray-Darling Basin Authority's website at <https://www.mdba.gov.au/river-information/water-sharing>) paved the way for the construction of four large storages, with a total volume of 10 km³ (Victoria and New South Wales have storages on their tributaries which in total add up to almost the same volume again; this compares with the mean natural flow at the Murray mouth of 14 km³). These storages enable strong winter-spring flows to be kept for summer-autumn irrigation needs, and flows in wet years to be kept to some extent for dry years.

Victoria is entitled to half of the storage volumes as well as half the inflows. Thus, it is able to manage its water independently of the other states – for example, it can set aside reserves for Victorian water rights, making them relatively reliable, while New South Wales follows a different policy, allocating all the water it has available. There is dependable measurement of inflows, and publicly accessible accounts are kept of losses, extractions and so on debited to each state all the way along the river.

The states cannot trade their water: it is all committed to entitlements lower down. Likewise, rural water authorities cannot trade their water, except the allowances given to them to cover delivery losses, and only then if they can show that they have made savings. It is the farmers – and the urban authorities and the holders of wetlands water – that can trade water, and their rights have been clearly defined.

Metering and recording of water use, with enforcement

About 100 years ago a senior engineer in Victoria's rural water agency invented a wheel with fins, which turned a counter as water flowed from a channel onto a farm. The Dethridge wheel came to be used to measure all farm deliveries – though in the last few years it has started to be replaced by a remotely controlled and monitored gate, which tracks the water level in channel and on farm, thus providing even more accurate measurement.

Where irrigators pump from streams themselves, at first the volumes were simply estimated from the area of land irrigated, but nowadays there is normally an in-line meter, which again is very accurate. All usage measurements are quickly uploaded into the state-wide water register.

It wasn't so long ago that farmers were treated as heroes for thinking of ways to steal water without the bailiff noticing. But now, at least in the southern Murray-Darling Basin, where water is regulated by large public storages and where the bulk of irrigation and trade takes place, such behaviour is frowned upon, because people are aware that it means taking water off neighbours. People who are caught are taken to court and prosecuted, and then fined, and their names published in the local newspaper. The number of such cases is kept to a handful, even in the worst drought.

It is a different story in the more remote, northern Basin. Despite taxpayers' money going to improve river flows, recent investigations show that a few large cotton-growers are taking out vastly more water than they should – as a result of tampering of meters, unauthorized embankments to catch overland flows, lenient rules on pumping and trade set by the New South Wales government, and ineffectual enforcement (ABC's Four Corners, 'Pumped', 24

July 2017). This is the opposite of what's required for a good water market, indeed for proper water management.

While straight-out stealing like this is now uncommon in Victoria, metered overuse can be a problem that has to be carefully managed. Either way, when the current year's water allocation is trading in the market at perhaps A\$400 per 1000 m³, reasonably tight management of rights becomes especially important. If someone has sold water, they must have correspondingly less water to use, or the trade has a negative impact on other water users. Having a market puts the spotlight on ensuring that no one uses more than they are allowed.

Trading rules, to avoid third-party effects

A lot of the initial trading restrictions – on water leaving districts, or going to non-farmers – have been discarded, but there are still some important rules, mainly about *where* water can trade to. A key one is that water in a system regulated by a major public storage can generally trade downstream to a connected regulated system. For example, a farmer supplied out of the Goulburn River, a tributary of the Murray, can sell to a farmer supplied out of the Murray itself. And 'back trade' is possible: a farmer on the Murray can sell to a farmer up on the Goulburn, if there has been a downstream trade out of the Goulburn first. (All the rules are on the Victorian Water Register website, waterregister.vic.gov.au, and the reasons for most of them are given in NRE, 2001; for broader, Murray-Darling Basin water trading rules see <https://www.mdba.gov.au/managing-water/water-markets-and-trade>.)

Initially, permanent trade between systems was implemented by converting the right in the seller's system to a buyer's-system right – for example, converting a Goulburn right into a Murray right. But this requires a judgement about the relative worth of the rights, which is tricky to decide now and might change in the future (NRE, 2001). If a Goulburn right of 100,000 m³ is replaced by a more reliable Murray right of say 90,000 m³, will the water sent from the Goulburn each year to the Murray be, over time, neither too much nor too little to cover the allocations made to this new Murray system right?

Nowadays, such trade is carried out by retaining the sold right as a seller's-system right – in the example, as a Goulburn right – but making the allocation made to it each year available for use in another system – the Murray. This way there is no impact on anyone else.

In general, trade of water is not like trade of cars or cows; it can easily have all sorts of negative impacts on other water users or the environment unless it is very carefully regulated.

By way of another illustration, when a farmer in New South Wales sells to a farmer in Victoria, a volume of water must be transferred from New South Wales to Victoria. But Victoria doesn't get any extra storage space, and if Victoria's half of the relevant storage happens to be full at the time, Victoria will miss out on having this extra water. All the farmers in Victoria will be a little bit worse off (Carryover Review Committee, 2012; NWC, 2011a).

Proper approval and recording of trades, and good water accounting

A trade of a water access right or of some water allocation will almost always require assessment and approval by one or more authority. It will most obviously need to be assessed

against the trading rules just discussed. And if it is approved this will need to be recorded, the buyer's and seller's rights or allocations being appropriately adjusted.

Moreover, as just touched on, if the trade is from one system to another, then the seller's system will need to provide some water to the buyer's system, to make up for the buyer's system now having an extra commitment. Good accounting is required, or else a system may have extra rights that it has to meet but not have the extra water to meet them.

In an active water market, processing of trades needs to be as streamlined as possible. In Victoria, this has been achieved in a number of ways. One very important step was to unbundle the old composite water rights, separating out the actual right to access water (which is what is traded) from the right to have it delivered along a channel, and from the permission to use water on a piece of land.

The new, purer water access rights are homogeneous over very large areas, and can be traded without reference to any local matters like the channel used for delivery, or how the water will be used on land – those matters are all dealt with separately. The result has been a radical simplification of the trading process. (Hamstead, Baldwin, & O'Keefe, 2008; describe how unbundling was carried out across the Murray-Darling Basin and the lessons learned. As explained in Australian Bureau of Agricultural & Resource Economics, 2007, how far to unbundle is a matter of judgement: the costs of having separate types of rights can outweigh the benefits in terms of faster trade approvals.)

One issue that can complicate trade is the different losses incurred in delivering water to different locations. In most parts of Victoria losses are considered to be largely fixed rather than variable, and are ignored. Say there are eight farmers taking water from a channel. If one stops taking water, or if an extra farmer takes water, the losses of water from the channel will be much the same (NRE, 2001). Rights to water are taken to be rights at the farm-gate, and don't change on account of being exercised by delivery along a channel or by pumping directly from a stream. The separate delivery right held by farmers being supplied out of channels covers the losses.

Processing of trades in Victoria is now very easy and smooth, being conducted in the state-wide water register. Trade of water access rights can be approved within a few days, even when it is interstate. Approval of allocation trades has been automated: a farmer wanting to sell to someone who has agreed to buy can apply online, paying the fee that covers the processing costs; the system will check that he has water to sell and that the trading rules are met, and the trade will take effect within seconds.

Matching buyers and sellers, and providing market information

Unlike approving and recording trades, helping buyers link up with sellers is not something that a public authority needs to be involved in. It is really the sort of role that real estate agents play in the housing market – with lawyers and banks getting involved at settlement.

In Victoria, one water authority did establish a water exchange, but all the matchmaking is now handled by various private broking companies – which are subject to a code of conduct, and are monitored by consumer protection agencies. Likewise, payment of money from buyers to sellers is not through water authorities but is managed by intermediaries and through contractual obligations.

There is certainly a case, when water markets are just starting, to help them along by having water authorities assist with matchmaking – for example by having a noticeboard

where sellers and buyers can post bids. But there are traps with this as well – risks of favouritism and corruption, which can give the market a bad name, and risks that payments from buyers to sellers get mixed up with the normal fees paid to water authorities.

Especially in a market that is just starting or that is thin for some other reason, it helps to promulgate market information. The prices that are being paid are of particular interest to would-be traders. In Victoria the price agreed to by the buyer and seller has to be included in the application form submitted to the water authority for approval of the trade. This enables up-to-date prices to be reported on the Water Register website.

Difficulties encountered in China, and ways of tackling them

A lot of the key requirements for a water market, which have been described above as they have been worked through and put in place in Victoria, can likewise be sorted out for water systems in China, without meeting any insurmountable barriers. For example, trading could start off highly restricted, and could be made gradually freer as the crucial trading rules for particular locations are identified and a lot of unnecessary checks are eliminated, just as happened in Victoria. However, there are a few fundamental differences between China's circumstances and the situation in Australia which make introducing markets like Australia's very challenging.

This section will draw on the efforts led by Professor Zhongjing Wang and Dr Hang Zheng of Tsinghua University – both of whom had looked at water markets in Australia – to develop a pilot trading scheme in the Shiyang Basin of Gansu Province. The Shiyang Basin can be considered typical of irrigated areas in the drier northern half of China, where water markets would be most valuable. Three major obstacles encountered in Shiyang, it is argued, are indicative of what will arise elsewhere in rural China.

The Shiyang River Basin consists of six or seven rivers that emerge from the Tibetan Plateau, join up and flow north towards a terminal lake and the Gobi Desert. It is very dry – annual rainfall is about 200 mm – and it gets cold – average temperature in winter is -6°C . The Basin's two million people depend on irrigation, but more water was being taken than the 1.66 km^3 renewable resource, so the lake had dried out, desert was encroaching, and groundwater was being used up and getting salty. In 2007 a new, high-level, water resources allocation plan – prepared under the Water Law of 2002, and approved by State Council as part of the Key Restoration Plan for Shiyang River Basin (Gansu WRD & DRC, 2007; see also WET, 2006) – carefully divided up the water between counties, irrigation districts and towns, and between household use, industry, agriculture and the environment.

A focus of the pilot trading scheme was one irrigation district that gets all its water from the Xiyang River. Accounting for about a seventh of the Basin's water, this district has 25,000 farms, clumped into 70 water user associations (WUAs) that correspond to villages, each with about eight teams of 50 or so households (information from local officials). An annual irrigation plan is developed: the WUAs say what area of what crops they would like irrigated, different crops requiring irrigation at different rates and times; their bids are compiled into a plan for the district, fitting with the high-level allocation plan and the seasonal conditions; each WUA then gets told its volume of water for the year, and then tells each household its volume (information from local officials).

There had already been a little local trade, and, while local officials were hesitant, they were prepared to cooperate. At Tsinghua a web application was built that was smart enough

to perform many functions: upload farmers' accounts, take applications to trade, give approvals by various authorities, undertake an exchange, handle buyers' payments, and provide market information.

Nevertheless, the amount of trade occurring is still slight. Just 3% of the total water allocation was traded in 2014 (see the assessment by Xu, Zheng, Liu, & Wang, 2016, Table 3). And there is as yet zero trade of ongoing rights (permanent trade).

Achieving an active water market in the Xiying irrigation district faces a number of hurdles. Of the key requirements for good markets identified from Australian experience, two of the most significant will be difficult to meet: clear rights to water, and metering of water use. And there is a third, underlying problem: small, fragmented farms. These three major difficulties, which reflect conditions common across China, are discussed below, together with ideas for tackling them.

Constrained rights to water

The Shiyang Basin has been a leader in China in instituting rights to water for each farming household. At the start of each year (in about February) households are given a blue certificate, showing how much water the household has been granted for that year (the household's *shui quan*, or water right). That is like the annual 'water allocations' in Australia, and is an important step, able to support trade. As discussed below, though, the allocations can be reduced if inflows are lower than expected. And while ongoing water access rights have been identified, at present they are tied up tightly with land.

Ongoing water rights locked to land

In developing the 2007 plan that drastically cuts water use, farmers' rights were determined on the basis of households having the 2.5 mu (1 mu = $\frac{1}{15}$ hectare) for each of their members that was assigned in the 1990s when new 30-year leases began, and 350 m³ average annual allocation for each of these mu of 'water-right land': four irrigation rounds each of 60 m³ per mu – usually enough to grow wheat – plus an extra 110 m³ (Gansu WRD & DRC, 2007). These rights were subject to some variation, e.g. they provided a larger volume of water per mu on the edge of the desert.

In an irrigation district, water for agriculture is allocated evenly to the water-right land, say 410 m³ per mu, depending on the season. Allocations are being gradually reduced to the target of 300 m³ on average per mu by 2020, as part of the plan to wind back water use to sustainable levels (Gansu WRD & DRC, 2007). Individual households thus do have ongoing rights to access water. At present, though, they are wrapped up with rights to land and cannot be traded independently.

Water officials don't keep records of the water-right land: the numbers are provided by farmland bureaus, then written by WUAs in a book signed each year by the farmers, and copied onto farmers' annual water certificates.

Land rights are no longer adjusted as much as they once were. Village administrations used to periodically redistribute land between their households – for example, to make sure each had a fair share of relatively fertile land (a lot of land is getting degraded – see Deng & Li, 2016), or simply to reflect changes in household size. In the 1990s farmers were given 30-year leases, strengthening their hold over land. Nowadays, if a household gets bigger it won't qualify for more water-right land; however, if there is less than one mu per person,

nominal or 'fake' land may be allocated, so the household qualifies for extra water (which could be used, say, in a greenhouse). And very minor reallocations still occasionally occur, for events like a girl marrying elsewhere (information from village leaders). Across China, women's rights to land are receiving better recognition, but local practice on this and similar matters doesn't always keep up with central policies (Ping Li, 2003).

While rural land tenure is far stronger than it was, farmers still have *use rights* over land rather than ownership. Land is subject to being requisitioned for a road, a factory or a city. 'Despite a relatively clear legal and policy framework on rural land tenure, rural households continue to have weak rights over land and often face expropriation risks' (World Bank & Development Research Center of the State Council, 2013, p. 30). Farmers are supposed to be monetarily compensated when their land is resumed, but people in Shiyang Basin say there is no compensation for the concomitant loss of water.

For the present, then, farmers' ongoing water rights are bound up with land, and there is no scope to trade them separately. In Australia, at least half (in one recent year, as much as 90%) of the turnover – and, consequently, at least half of the benefits from trading – is in the permanent market, i.e. in trade of ongoing rights (Aither, 2017). The Shiyang Basin, with its 'water-right land', is not far off this – though before ongoing water access rights are split off from land rights, the land rights themselves may need to be strengthened even further. In the meantime, it is only the current year's water allocations that can be traded.

Constraints concerning the current year's water allocations

In Xiying district – but not necessarily in those places in China where storages are relatively large – there are two issues concerning the current year's allocations which detract from having a deep and active market, and have to be handled.

One is that the high-level allocation plan is based on *average* flows, i.e. what is predicted over the coming months (Zheng, Wang, Hu, & Malano, 2013). Consistent with this, after allocations have been issued for the current year, it may turn out there is less flow than was assumed. Then allocations which have been issued have to be cut back; farmers' blue certificates make it clear that this may happen.

In the regulated water systems along and around the River Murray, the total volume of the main storages is relatively large – over a third *greater* than average annual flows. The current year's allocations can be based on water already in storage. There is no risk of making allocations that later have to be reduced.

Issuing allocations and then subsequently cutting them back is to be avoided if at all possible, even where there is no market. What if someone has already used all their allocation by the time the cut-back is applied? It becomes even more awkward if there is a market, and allocations have been traded. Someone has bought an allocation, but is not allowed to use it all.

The Xiying reservoir has only about a tenth the volume of average annual flows, and flows mostly occur in summer, from May to August. So there is little scope to hold water at the beginning of the year for late in the year.

One solution would be to get smarter at predicting flows – from the extent of snow in the mountains and so on. Another option would be to do as in Victoria, and start with low, conservative allocations, increasing them proportionally as flows arrive in the course of the year. To do this thoroughly in Xiying would mean that allocations would have to start very low indeed. A soft version of this has been adopted: if it looks like being a wet year, the initial

assumption is that it will be normal; or if it looks to be normal, it is treated at first as dry (information from local officials).

This is actually how Xiying farmers behave: they tend to be very reluctant to trade at the beginning of the year, in case the water they are counting on for later does not come through. They mostly wait to see whether they have spare water at the end of the year before deciding to sell – by which time there will not be many buyers. This makes for a limited market.

The second issue concerning allocations is related to the first one. Delivery of water takes place usually in eight discrete rounds, separated by three or four weeks during which there is no water in the canals. The annual irrigation plan determined for the district actually sets out the quantities of allocation to be delivered in each round.

This no doubt helps in the management of the first issue, where allocations are made but then cut back. The allocations in future rounds can be cut back, without the problem of their having already been used. There can even be a rule saying that, at any particular time, only allocation in the next round can be traded. But if allocation is always specific to a particular round, this has the effect of seriously segmenting the market, making it shallower.

Some of the small numbers of trades occurring already are simply to swap allocation between rounds – for example, selling some from the forthcoming round, and buying it back later.

Ideally, there would be complete flexibility in the rounds in which water allocations could be used; then water could be traded without reference to rounds. (Indeed, ideally allocation could be carried over for use in the following year, as it can in Victoria – though this requires large storages.) Complete flexibility would not work if all the farmers wanted to use their water allocations in the same round – there would not be enough water available at a given time. But this is inconceivable. It might be that a lot more flexibility can be introduced while still being able to deliver water when it is wanted.

Inadequate metering and recording of water use

These days, as part of cutting consumption to sustainable levels, most of the lateral canals delivering water to Xiying farmers are made of concrete and have blue steel drop-gates that let water out onto the farms (information from local officials). Insofar as water going onto farms is measured, this must be done by the time a gate is open – preferably taking into account the height of water in the canal.

In parts of Xiying at least, this does seem to be the method employed. There are schedules showing how long, to the second, each gate will be open (with ‘volumes applied’ always in the same proportion to the time open), and how long, to the minute, they have been open. How real these are, rather than just for show, is uncertain; but local officials said that water could indeed be cut off once the allowed time had elapsed, even if the water hadn’t yet covered all of a plot.

The alternative would seem to be just to use the area of a farm to estimate how much water has gone onto it. That is what happens in most of the Shiyang Basin, and no doubt in China generally. Often the canals are less even than in the Xiying district, and there are no steel gates – opening and closing outlets is done by means of shovelling earth (observed first-hand). Timing is only ever for the water entering a bigger canal, which might supply a whole team (about 50 farmers) – say 0.2 m³/s for 24 hours. It is then up to team leaders to manage the water going onto individual farms.

Using the area of land to calculate the volume of water supplied is necessarily rough, because the way water spreads over farms inevitably varies. And not being able to time how long outlets are open must make it especially difficult in dry years, when allocations are cut back so there's not enough water to cover the whole of a farm. Clearly there has to be much operational experience brought to bear on parcelling out water, and some negotiation.

Even in Xiying district, many of the leaders are not able – or not prepared – to produce usage figures for individual farmers. One reason mentioned by leaders for their being cagey about usage records and how they are arrived at is that being open could lead to arguments with farmers. Which suggests some of the leaders do not feel they are on very strong ground.

Installing the modern, electronic gates starting to be used in Victoria would be far too expensive where there are so many gates taking off small amounts of water. Dethridge wheels would be much cheaper but still may not be economical.

Reasonably sound gauging of the amount of water going onto farms would seem to be desirable even if there is no water trading. But it becomes more pressing with a market: farmers would get cross if a neighbour made money by selling his entitlement to water and then got delivered his usual amount, cutting everyone else short.

The best that can be done for the time being might be to work with traditional estimation methods but sharpen them up, for example by taking more explicit account of the depth of water in canals, and by having better and more open records. Ultimately, transparency should lead to fewer arguments, and more acceptance of how water is distributed.

This is certainly a difficult issue, and leads to the question in the next section: whether farms as currently constituted in China are too small to be players in a water market.

Underlying problem: small, fragmented farms

Looming behind the challenges of having better water rights and accurate water metering is the fact that in the Xiying district, as in most of China, the available water is being shared between a very large number of farmers, each getting relatively tiny amounts of water for quite tiny plots of land. In Xiying an average volume of 230 million m³ is shared between 25,000 farming households. In Australia, that volume would cater for only about 250 farms. The typical farm in Xiying is less than two-thirds of a hectare (10 mu) – and this is usually divided into several small plots some distance apart, of better and poorer land – and it all gets less than 3000 m³ of water in a year.

Farms have got smaller as a result of the population soaring in the 1950s and 1960s. Now younger people move to cities for better prospects, but they do not qualify for benefits like education and health care there; they have to stay registered back in their original villages. Back there, old people look after the migrant workers' small plots of land and young children.

This *hukou* (household registration) system that ties migrant workers to the countryside is just starting to be loosened. There is resistance, though, from local governments, which lack the revenue to provide education and health care to a whole lot of newcomers in the cities. Local governments rely for funding on being able to dispossess farmers of land for their expanding cities – so they also resist farmers' being given stronger land rights.

Promises are being made to sort out this conundrum, which would open the way for people migrating to cities to sell their little pieces of farmland, and allow amalgamation of farmland into more economical units. Ways forward are well described in the *China 2030*

report of the World Bank and the Development Research Center of the State Council (2013). But reform will be challenging and will take a while to take hold, so for a long time yet, China's situation of having a multitude of small, fragmented farms is likely to prevail.

Xiying's leaders say that most farms get barely enough water to meet their needs. If they cut one round's watering by a minute they might save 10 m³, worth 20 cents at current prices – the benefit is miniscule. If there is not much in it for farmers, they will scarcely bother applying to do a trade (so it is crucial to have a simple, low-cost exchange mechanism). And it makes it harder to invest in metering and the other ingredients of a good trading framework.

Yet despite the tiny amounts of water per farm and the tight margins, there are still stories of water being applied unnecessarily. In China generally, water-use efficiency is said to be comparatively low (Xie et al., 2009). A market might well help in getting the small amounts of water that are available to be put to their best use. The experience of Australia suggests that the market can thrive most and be of the most benefit during the most extreme water shortages.

Should trade be at a higher level than individual farmers?

Really, the question that this situation leads to is whether it might be best to encourage trade at the level of the WUA, rather than at the level of individual farmers. This is the view of many of the local officials – echoing writers who have questioned whether 'thick and deep' regulation is practical (Xie et al., 2009, p. 65).

Their reasoning is that farmers tend not to be well educated; often they are not even literate. But while these old farmers might not be up for going online, it is possible they would soon get interested in market prices, and their own usage and remaining allocation, if this information were made available to them. Farmers in nearby Minqin County had to get used to prepaid tickets and smart cards as part of very tight control of groundwater extraction, and they managed all that okay (Ren & Wang, 2012).

There are serious drawbacks with WUA-to-WUA trade – this was evident from listening to WUA leaders argue about it. Which of the 400 or more farmers making up the WUA have saved or gone short of water – and so should share in the proceeds of a sale? They are not identified. And likewise who in the WUA gets, and pays for, water that the WUA buys? It is not clear. The usual drivers and feedback paths of having a market are blurred almost out of existence.

The proceeds of WUA sales have to be used for general WUA expenses, like maintenance, or perhaps just entertaining. Indeed, not long ago one WUA got 30,000 yuan (about A\$5000) from a trade, and it went into WUA leaders' private pockets (information from WUA leaders; see also Xu et al., 2016). As a result of this corruption, authorities stipulated that in 2014 the buyer was not to pay any premium to the seller, the buyer was just to pay the annual fee (0.2 yuan/m³) – which was a huge dampener on the market.

The risk of outright corruption is now being minimized through transparent accounting. Still, there is a quandary. Farms are very small for it to be straightforward to have trading at that level. But trading at a higher level weakens or even eliminates all the incentives that make markets worthwhile – indeed it can make farmers suspicious and annoyed.

Even if trade at the WUA level is what happens to start with, it looks to be important to make strong efforts to move as much as possible towards farmer participation. This would mean not only having transparency in all the trade occurring, including the prices paid, but

also linking sales and purchases to the greatest extent possible to those individual farmers who have given up water so some could be sold, or who are allowed to use the extra water that has been bought.

Lesser hurdles, and the challenges summed up

The above three interrelated obstacles to developing Australian-style water markets in China are those most difficult to find a way past, being deeply embedded in cultural and geographical conditions. Other problems are more amenable to solutions.

At present, for example, any application to trade in the Xiying district has to proceed up a chain – or actually two parallel administrative chains, one municipal, one water authority – to be audited and stamped-as-approved about four times. This seems unduly cumbersome, time-consuming and costly.

One thing examined by these administrators is whether the selling WUA really has extra water it can sell, and whether the buying WUA really needs extra water. Of course it is essential to look at whether sellers have unused allocation, but the assessments seem to go further, to look at what is being done that could validly free up water, and what the bought water will be used for. There seems to be a slightly paternal attitude towards farmers, no doubt well-meaning, but detracting from farmers being responsible for their own businesses.

Related to this, water allocations in some villages attract different authority fees depending on what crops are irrigated and the application rates (Che & Shang, 2015). To encourage water to be used efficiently, an appropriate application rate or ‘norm’ is set for each crop; a farmer can use more than the norm provided they pay fees at a higher rate for the extra water. Effectively the farmer is purchasing the extra allocation, complicating any market *between* farmers.

Remarking on Xiying’s high degree of regulation, Xu et al. (2016) say that authorities tend to regulate crop types in order to simplify water delivery and facilitate marketing. And, just as happened in Australia in the early days, they try to stop water trading away from their areas, with the consequent drop in activity. And authorities control water trade prices, not only because individual farmers are suspicious about what is happening to the proceeds of sales that are made by their WUAs, but also because farmers and WUAs near the bottom of canals, with less reliable water supplies, are angry at having to buy from upstream farmers and WUAs, who have had first go at the water and who are suspected of getting more water than they should.

What is prompting this control of trade prices relates to the three fundamental problems that the present article is drawing attention to: imperfect rights, inadequate metering and small farms. Many other matters can be sorted out over time. As in Victoria, authorities can become less fussy and controlling. Water rights or allocations can be refined so they do not include local matters like delivery. Trade can occur over wider areas, encompassing greater diversity in right types, water availability, soils, and crops, enabling greater gains from using the market (instead of as now, where trade is often only between farms with the same crops and the same surpluses or shortages of water). Trading rules can be pared back so they just deal with the locational and hydrological issues that must be dealt with to avoid third-party effects.

That will still leave those three obstacles, widespread across China, which are hardest to surmount. Surmounting them is ultimately necessary, though, if water markets like Australia’s are ever to work in China. The article has discussed possible ways forward, many of which

Table 1. Differences between Murray-Darling and Shiyang Basins, and their significance.

Murray-Darling Basin, Australia	Shiyang Basin, China	Significance of Shiyang's situation, locally and for China generally
Ongoing <i>water rights</i> are firm, and separate from land	Ongoing water rights tied to land, which is not tightly owned	No trade possible in ongoing rights. Before water rights are separated, land rights may need to be firmer. A challenge across all of China
Annual <i>allocations</i> follow clear rules, can be carried over	Allocations only valid for short period, and can be cut back	Allocations can be traded by individual farmers, but market shallow. Partly due to small storages locally. Some scope to make allocations firmer
<i>Metering</i> of all main irrigation supplies (except up north)	No meters at farm level, just estimates – not told to farmers	Creates distrust, e.g. among downstream farmers. Estimates and information should be able to be improved. A problem across China
<i>Farms</i> are often 100 times bigger than in Shiyang	Farms are small, and fragmented, and have small water rights	Meters for farms not affordable. Amalgamations rare, since people must stay registered locally. A China-wide issue. Moves being made to reform
Trade is always by <i>individual farmers</i>	Most trade is by associations of about 400 farmers	Incentives dampened, e.g. cannot give proceeds of trade to the farmer(s) using less water. Must have drivers with farmers as much as possible.
Targeted <i>trading rules</i> , quick trade <i>approvals</i> and proper <i>accounting</i> , good <i>market information</i>	None of this in place yet in Shiyang. Trade over-regulated. Cheaper water given for prescribed crops	Not having all this in place is a brake on trade, e.g. people can resist water moving to other places. And it also risks negative effects on third parties. But all these things could be put in place in a basin given local determination

are being contemplated by the authorities. The main points are pulled together in summary form in Table 1 and the bullet points below.

How to achieve local-level water trading in China

As has been argued all through this article, some of the steps needed to enable China to have Australian-style water markets involve significant structural changes.

- Ongoing rights to water need to be allocated to individual farming households (as has already been done in Shiyang), and these rights must be firm, and separated from land – which probably means that the measures taken over recent decades to strengthen rights to land will need to be carried further.
- Annual water allocations should be made according to transparent rules, as far as possible once made should not be reduced, and should be valid for the whole season.
- The water provided to individual farmers needs to be metered, or at least estimated using defensible methods, with good records kept and made accessible to the farmers.
- To make metering feasible, amalgamation of the small, fragmented farms needs to be easier – which will necessitate loosening the system that ties migrant workers to the land in the villages they came from, and establishing new sources of revenue for municipal authorities so they can afford to provide schools, health services, etc., for migrant families.

Given enough local skill and resolve, the other essential requirements could in theory be put in place overnight, though proceeding step by step would make sense.

- Trading rules need to be developed to prevent negative effects on other water users or the environment, but these rules shouldn't otherwise restrict trade.
- Obtaining approval for a trade should be made easy, with attention given just to key matters like whether the seller has unused water to sell.

- Water must be physically moved around to follow where rights have been traded to, so there needs to be good accounting of water.
- Up-to-date information on trade prices should be readily accessible to farmers, and it will help a lot to have matchmaking facilities.

Concluding words

Water markets in Australia have had huge benefits, in fostering the best use of very limited water supplies. It is now hard to imagine what Australia would do without them, especially in the face of a climate that is becoming drier. Mistakes have been made along the way (perhaps the worst one, in hindsight, was to open up the market before adequate water had been set aside for the environment), but gradually markets have been created which are well regulated and work smoothly.

On the face of it, water markets could play a very useful role in China, especially in the north, where there is such a water shortage. A lot of the issues and hurdles can be sorted out gradually, taking into account local circumstances, just as they were in Australia.

But there are a few big obstacles, common across China, to having local-level water markets. (Linking to the local level, in some places factories and cities have acquired large, long-term rights from irrigation districts by investing in concrete channels and other measures to reduce losses. This is how Victoria's capital, Melbourne, has obtained extra water, and deals like this have been frequent in places like Inner Mongolia – see WET, 2007. But these are authority-supervised, one-on-one contracts, not trades in a market with predefined rights and many potential participants – and while they can certainly be win-win, they do have hazards. The district selling water needs to first demonstrate that it does all come from real, lasting savings, and explain whether the proceeds will be for the benefit of the farmers – for example, by reducing their water fees. And when the water moves into other uses, will it acquire priority in dry years over water that has stayed with agriculture?)

In Australia more than half the turnover is in trade of farmers' ongoing rights. This sort of trade simply is not possible in China, and will not be until farmers have ongoing rights that are separate from land – which may only be achievable as rights to land are made even more robust and tradeable.

Trade of the current year's allocation is certainly possible, and some is already happening. But at least in Xiying district, this market is so far quite constrained and shallow. It could be deepened if ways could be found of issuing allocation that was not subject to being subsequently cut back, and which was valid for the whole year, and could even be carried over to the next year.

Getting an accurate handle on how much water is going onto each farm is definitely a challenge, though there need to be methods of accomplishing this even when there is no market, and perhaps these could be beefed up. The problem really arises because farms are so small and use such small amounts of water – an overriding difficulty unlikely to change fast, though reforms are afoot.

With farms so tiny, there is a preference amongst many officials and farmer leaders to keep trade at the level of WUAs rather than individual farmers. But trade that is only at the WUA level has serious deficiencies, since the particular farmers who gain or lose water are not the ones paying for or profiting from the trade: market signals don't work properly. It

seems important to connect trade costs and profits as far as possible to the individuals who get more water or less water for their farms.

It is clear that it will take a lot of work before water markets flourish at the local level in China. But it certainly seems worth China continuing carefully down this road – focusing initially on specifying users' rights clearly, and ensuring they are complied with and reasonable fees for them are paid. These steps in themselves will act as strong drivers for the better use of water.

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