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BUILDING CLIMATE-RESILIENCY IN WATER MANAGEMENT:

A Case Study on California Water Markets

Dissertation submitted by
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DECLARATION OF AUTHORSHIP

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ABSTRACT

California's climate variability, rising populations, and corresponding developmental growth are putting a strain on the state's fresh water supplies. As water security risks increase, water markets can be a useful tool in facilitating climate resiliency. This paper will examine California's Water Market activity in relation to transaction costs as well as compare it with the water market in Australia's Murray-Darling Basin's, which will provide valuable insight on how transaction costs affect water market participation levels. Supported by the New Institutional Economics theory and water trading records dating back 30 years, findings [are expected to] show how lower transaction costs leads to more frequent use in water markets. When there is more utilization of a water market, it encourages more efficient and flexible water reallocation during climate variability, which can lesson the costs of water scarcity.

LIST OF ABBREVIATIONS

DWR= Department of Water Resources

MDB = Murray-Darling Basin

NIE = New Institutional Economics

SWRCB = State Water Resources Control Board

US = United States of America

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INTRODUCTION & BACKGROUND

The American author Mark Twain once said, “whiskey is for drinking, water is for fighting,” which has been repeated in jest by Californian politicians in order to ease the tension during water negotiations. With a history of bold pioneers, opportunistic gold miners, and lone cowboys taking land rather than sharing, tensions can run high when discussing claims to such a necessary resource. Yet as California faces more climate variability, reaching record-breaking wettest and driest years within the last five years, it’s hard not to take notice (National Centers for Environmental Information 2017a; 2017b).

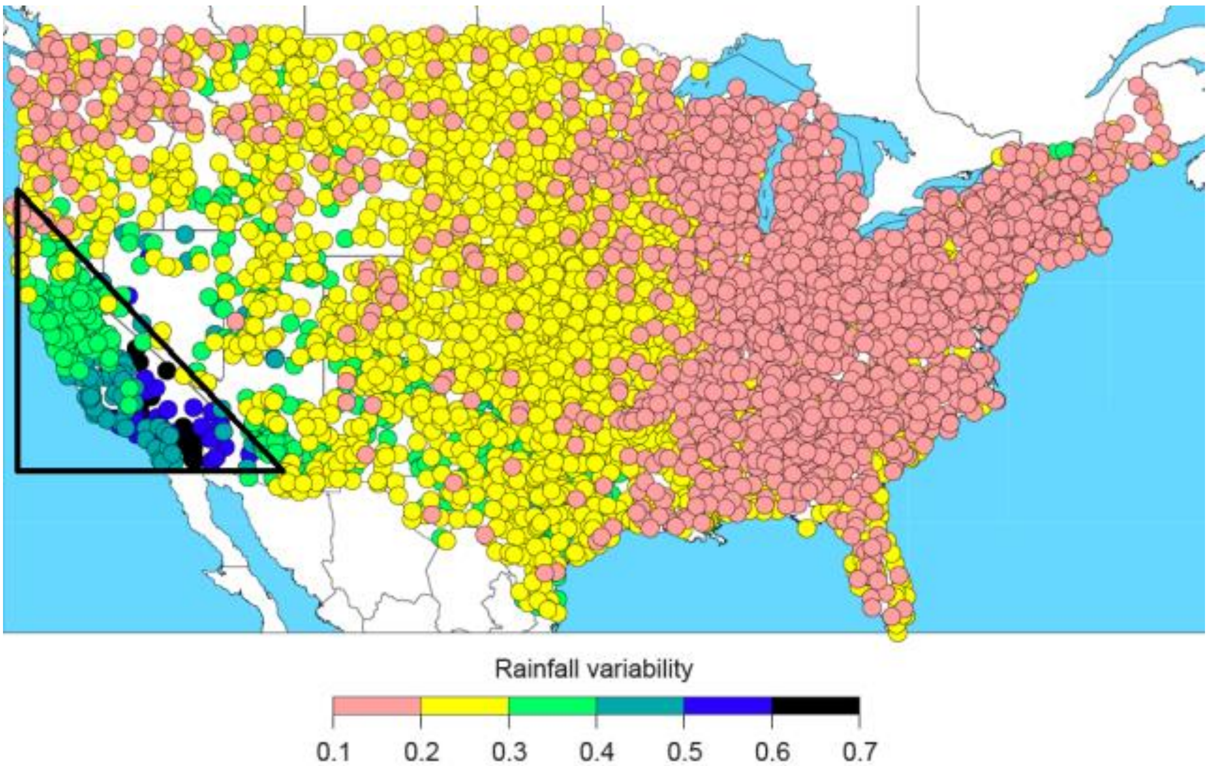


Figure 1: Coefficients of variation of total precipitation between 1951-2008.
Reprinted from “Atmospheric Rivers, Floods and the Water Resources of California,” by Dettinger, Michael, Fred M. Ralph, Tapash Das, Paul J. Neiman, and Daniel R. Cayan, 24 March 2011, retrieved from http://www.mdpi.com/2073-4441/3/2/445/htm Copyright 2011 by MDPI AG.

California has one of the most extreme climate variability when compared to the rest of the US as illustrated in Figure 1. The most variation lies in Southern California, where roughly

21.6 million people live[1] (US Census Bureau, 2011). With both flooding and multi-year dry periods, also known as droughts, the state faces unique water management challenges in order to stabilize its water security.

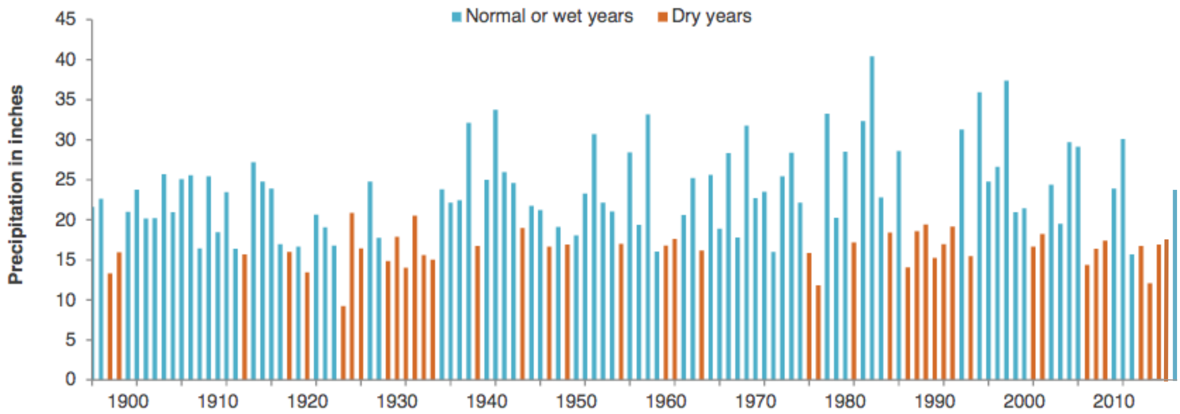


Figure 2. Average precipitation in inches from 1896 to 2016.
Adapted from *What If California's Drought Continues? Technical Appendix*, by Hanak et al., August 2015, retrieved from http://www.ppic.org/content/pubs/other/815EHR_appendix.pdf. Data from Abatzoglou, John T., Kelly T. Redmond, and Laura M. Edwards (2009) and the Western Regional Climate Center (2017).

Figure 2 shows the varying levels of precipitation over the years in California, especially how droughts are a recurring feature of the state's climate. Orange bars represent dry years[2] and appear quite frequently, averaging every 4.8 years. The data for years 2015 (17.755 in.) and 2016 (21.959 in.) were added to complete the data compiled by the Public Policy Institute of California, continuing the high variability trend (Hanak et al., 2015).

DEPLETING CALIFORNIA'S WATER 'SAVINGS'

Population increases and agriculture development has strained fresh water sources in some areas and poor water management of these competing sectors has left some cities without water, like in East Porterville (Perez, 2015). Water resource allocation is considered a "wicked" problem since urban populations, agriculture and other businesses, as well as

[1] Based on 2010 population estimates in Imperial, Los Angeles, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, and Ventura counties.
[2] Based on Sacramento Valley measurements by the California Cooperative Snow Survey.

environmentalists don't agree on water allocation objectives, each fighting for priority over the other. Additionally, environmental issues don't show a clear cause and effect since changes in water policies often address different facets of the problem or even spillover into other sectors unintentionally.

The five-year period between January 2012 and December 2016 ranked first in warmest temperatures ever recorded in California, likely exacerbated by climate change, with the state's Governor Jerry Brown officially announcing the drought's end the following year as a precaution that temperatures wouldn't return (National Centers for Environmental Information, 2017a; "Executive Order No B-40-17", 2017). In times of drought, California residents typically supplement their water consumption with stored water from previous wet years. However, the dry years are becoming too frequent and thus, reservoirs are drying up with water experts foreseeing most of them not lasting through drought periods (Famiglietti, 2015). Yet, building new ones won't recover more water since a 2009 study on the state's proposed reservoirs and dams found that due to water storage facilities already existing on the majority of main streams, they would only provide a one percent increase in water supplies (Hanak et al., 2009).

Furthermore, wells are also drying up and many are waiting years on a waitlist to dig deeper. This is due to recent groundwater overpumping, which is causing irreversible reduction in aquifers' water storage capacity as well as causing significant subsidence, or sinking of land (Buis et al., 2017; Smith et al., 2017). Water from aquifers, or naturally occurring underground reservoirs due to the ground's permeable and porous properties, is an integral part of California's supply, contributing to 40 percent of the total consumed in an average year and more than 50 percent in a drought year. While environmental uses make up half of the water consumed and some of that water percolates back into the ground, 80 percent of California residents depend on using groundwater, sometimes entirely (Knudson, 2015).

However, groundwater pumping is still unregulated in California so landowners directly under an aquifer are only limited by what is called ‘reasonable’ and ‘beneficial’ use (SWRCB, 2017). New data from NASA’s Gravity Recovery and Climate Experiment (GRACE) satellite reveals California’s Central Valley aquifer, which is largely used for agriculture, is rapidly being depleted and labeled as “highly stressed” (Richey et al., 2015). GRACE’s image below (Figure 3) shoes the dramatic amount of groundwater being depleted from 2002 to 2014 in California’s.

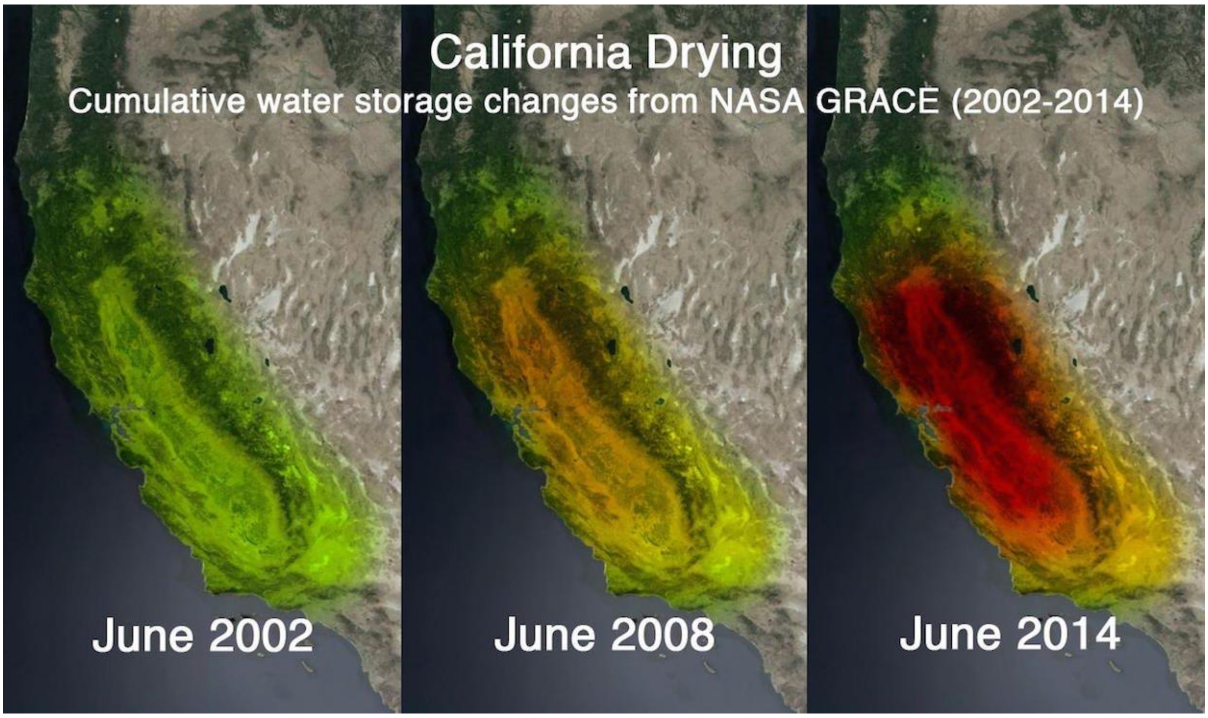


Figure 3. Satellite Images of California’s Central Valley Aquifer Groundwater Levels in 2002, 2008, and 2014.
Reprinted from “NASA's GRACE Sees a Drying California”, by NASA/JPL, 1 October 2014, retrieved at https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA18816.

Between 2002 and 2014, colors changing from green to orange to finally red signify greater accumulated loss of groundwater. The areas in red comprise of California’s Sacramento and San Joaquin River basins, which includes the Central Valley. NASA stated that between 2011 and 2014, the affected area lost 12 million acre-ft. annually, which far exceeds the state’s residents’ annual consumption. This leads to speculation regarding where the depleted water went, with NASA believing farmers used the water to support the region's high agriculture production (NASA/JPL, 2014). According to a US Geologic Survey, California aquifers are so depleted that it would take 50 years for them to refill from rain and snowpacks, but this estimate is contingent on pumping stopping completely, which isn't realistic given the lack of groundwater regulation (Krieger, 2014a).

Climate change also affects the snowpack in the Sierra Nevada Mountains, which recharges California's rivers and reservoirs in the spring and summer, typically providing 60 percent of the state's fresh water supplies (Berg and Hall 2017).

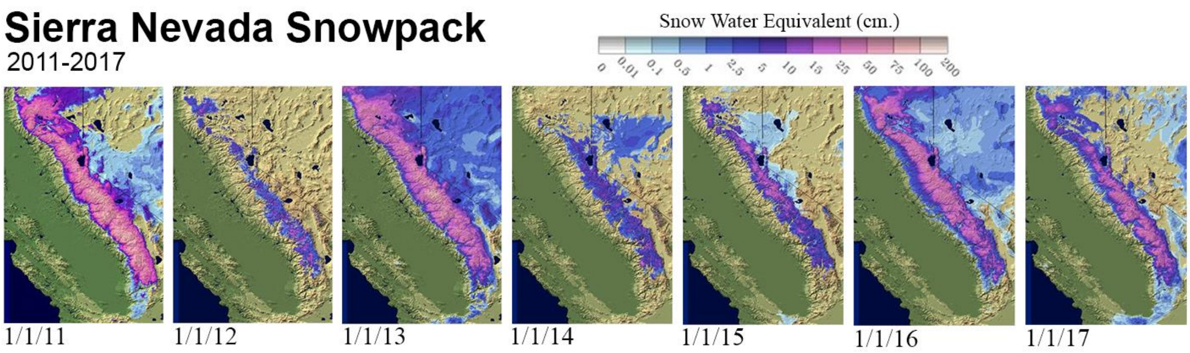


Figure 4. Sierra Nevada Snowpack's water content in centimeters between Jan. 2011-2017. Adapted from the Regional Snow Analysis: Sierra Nevada, by the National Operational Hydrologic Remote Sensing Center, January 23, 2017, retrieved from https://www.nohrsc.noaa.gov/nsa/index.html?region=Sierra_Nevada&year=2017&month=1&day=1&units=e.

As shown in figure 4, reduced snowpacks in 2012, 2014, and 2015 meant even less water stability during periods of high climate variability. During the most recent drought, a UCLA study revealed the snowpack was anywhere from 25 to 43 percent below what it would have been without climate change, depending on the elevation, and predicts the snowpack could disappear completely during future droughts (Berg and Hall, 2017). Behaving like 'business as usual' while depleting water savings that take decades to recharge while future water availability is predicted to be even more scarce doesn't bode well for California's water prospects. Solutions need to address California's root water issue of improving water efficiency since its fresh water sources cannot sustain excessive surface water withdrawals and groundwater pumping during frequent drought periods.

WHAT IS BEING DONE?

Historically, solutions for drought periods have focused on state-mandated water restrictions. California Governor Jerry Brown has pushed for record-breaking conservation targets of 25 percent reductions in urban water consumption during the state's most recent drought ("Executive Order B-29-15", 2015). The Governor also imposed fluctuating cutbacks on water allocations for appropriative water rights holders, or landowners with water on or below property they purchased after 1914, as part of his drought emergency conditions (2012-2016 ± one year) (DWR, 2017).

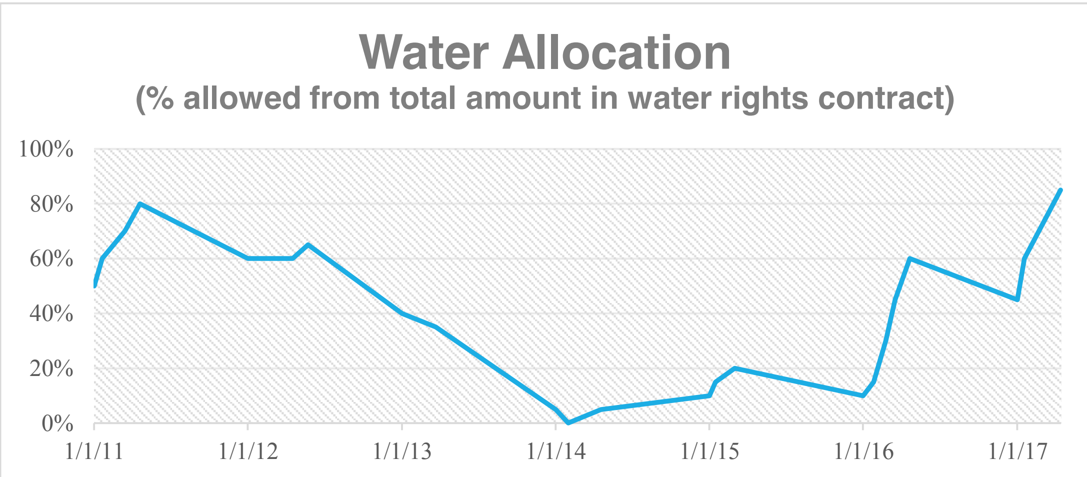


Figure 5. State-mandated water allocation cutbacks for appropriative water rights holders between January 2011-2017 in California.
Data from the DWR (2017).

During a drought, water cutbacks for water rights holders isn't new and is often predicted, but never as low as the most recent drought, as illustrated in Figure 5 (2012-2016 ± one year). During non-drought years, water allocations typically remain above 50%, meaning appropriative water rights holders are allowed to use the majority of water on their property, as defined by their water rights contract. Alternatively, drought year allocations are considerably less and even forbidding any water use in the beginning of 2014 (DWR, 2014). However, these cutbacks can no longer be supplemented by surface water from reservoirs and groundwater from wells. More long-lasting policies are needed to address the core issues of California's water management and reform outdated water institutions that weren't designed for a time when water demand exceeds supply.

Desperate to find an ambitious solution, policymakers have proposed building desalination plants, shipping icebergs from the Arctic, and even Governor Brown's own $17 billion tunnel project. Yet, Californians remain skeptical due to environmental impacts from these projects and their grandiose budgets that would ultimately raise taxes. Residents are also concerned these projects would encourage farms and other industries to receive more government-subsidized water instead of embracing conservation behavior and technology. The municipal water agency serving Southern California, Metropolitan Water District, is greatly invested in Governor Brown's project as they are looking for a more reliable way to transport water from the north to the desert south, but many in the north see it as an unsustainable plan and an assault on their resources (Rogers, 2016).

Water markets are marketplaces that enable transactions between buyers and sellers for the temporary or permanent use of water in exchange for money.

***Allocation trades*, which can have short-term or multi-year contracts, *permanent access entitlement trades*, and *exchanges* are the types of transactions that can occur in a water market.**

California policymakers are turning to their 40-year old water market in hopes its market-based mechanisms will motivate residents and businesses to value water in times of scarcity, leading to more responsible and efficient water use. The water market was established after the governor heard they support California's economic growth from commissioned reports and research from the Rand Corporation praised (Governor's Commission to Review CA's Water Law, 1978; Phelps, Moore, and Graubard, 1978). Although 1980's legislation helped to facilitate trading, California's Water Market had a slow beginning and only increased in trade activity after the state's Water Bank Program completed the first large-scale voluntary water transfer in 1991 (Hanak, 2015). *Water banking* can facilitate trading when water is able to be stored, either from strategically adding surplus water or buying surplus water from others, with the intention to sell it (Varghese, 2013). In the past, California has created water banks during drought years to buy surplus water in order to ensure water availability for environmental replenishment and as a backup source for drought-prone areas, like Central Valley. Water banks are also governed by water municipal districts, which can be trusted with using water banks for the benefit of their constituents. Although water banks can be a great tool in water markets to increase water flexibility and reliability, they do require public oversight (Ronstadt, 2012). In 1988, the DWR purchases 19,000 acres to build the Kern Water Bank that would provide a five million acre-ft. of water storage (SOURCE). Kern County Water Agency, the governing district for the surrounding area, retained control of the water bank through extortion in the Monterey Agreement and subsequent Amendments in 1992. Under California law, residents have the right to veto trades happening in their district and this is exactly what Kern County Water Agency threatened (Gesing and Zenovich, 2017). Now, the majority of the water bank is owned by two agricultural empires, who bought government-subsidized water and sold it back to the government at a big profit, with sources saying roughly $200 million (Taugher, 2009). Potential profits can lure Californians into saving more for times of drought, but a lack of oversight can end up costing the government more money than its worth.

KEEPING CALIFORNIA'S WATER MARKET AFLOAT

As of now, the California water market is considered *thin*, meaning there are relatively little transactions. Estimated trading volumes of three to five percent of total urban and agriculture water consumption restrict the market from determining a *going price*, or competitive rate, a market-imbedded feature that attracts potential players (Hanak, 2015; Howitt, Medellin-Azuara, MacEwan, Lund, and Sumner 2014). Potential buyers will see the benefits in participating as long as the economic returns from using the water outweigh the costs in obtaining the water and the water market is perceived as the most cost-effective option to achieve their water objectives. Whereas sellers will be attracted to water markets as long as the negotiated price produces higher net returns than their previous use for the water (Colby, 1990a, p. 1116). Bear in mind, more nuanced economic value from water fostering healthy ecosystems and opportunities for more development does play a role in these decisions, but this paper does not have enough time to evaluate them in depth. Rather, this paper aims to measure the direct costs of participating in water markers since they can be more easily quantified and are therefore usually responsible for a market's success or failure. With experts praising the benefits of water markets, yet such a small percentage of utilization in California, policymakers are posed with a new problem; how to improve it.

WATER RIGHTS

The current water rights framework in California is outdated and was never intended to handle the challenges caused by scarcity. The State of California owns all of the water in the state[3], whereas water rights only allow the use of water, not its ownership. Founded in the Gold-Mine era, this flexibility allowed gold miners to access water streams, dredge them up,

[3] Except for National Parks and Forest, which would then belong to the US Federal Government.

and move on to the next stream. Miners also wanted to be first to streams, or have priority over those who came later in case there was gold (Thornton, 2011). Thus, the state's water rights are organized by a seniority-based system with older riparian rights holders given priority over newer appropriative rights holders[4].

Table 1.
Overview of California's Water Rights System

<table>
<tr><td colspan="2">Riparian Rights

Bought/sold with the property, typically touching a natural source of water</td><td>▪ Do not require permits, licenses, or government approval for trades
▪ 'Reasonable use' must not harm upstream or downstream neighbors
▪ Water cannot be stored, any surplus must drain back into source of water
▪ Encouraged to report annual water usage to the SWRCB
▪ Equal claim with other riparian rights holders regardless of purchase date</td></tr>
<tr><td rowspan="2">Appropriative Rights

Bought/sold separately from the land</td><td>Senior Rights
Bought pre-1914</td><td>▪ Permitted to divert water from natural water source, which is then available to use, or else it's lost ("use it, or lose it" mentality)
▪ Encouraged to report annual water usage to the SWRCB</td></tr>
<tr><td>Junior Rights
Bought post-1914</td><td>▪ Permitted to divert water from natural water source, which is then available to use, but only if there is sufficient water for senior rights holders[5]
▪ Mandated to provide annual water usage to the SWRCB</td></tr>
</table>

Note. Data for all rights' descriptions are from the United States v. SWRCB (1986), Curtailments Due to Lack of Water Availability (2014), and Herzong (2006).

As shown in Table 1, the riparian and appropriative senior water rights holders have very little government oversight, while the appropriative junior water rights holders are more restricted (Littleworth and Garner 2007). In addition to these rights, districts with state water contracts distribute water to their residents. Conflict ensues when there isn't enough water for everyone, including rights holders, water districts, fish, and wildlife. A University of California, Davis study found "since its establishment a century ago, the [SWRCB] has issued water rights that amount to over five times the state's average annual supply" (Grantham and Viers, 2014, p. 2). This over-allocation of water is "likely to lead to conflicts among water users, particularly during periods of water scarcity when insufficient water is

[4] Except for appropriative senior rights that were bought earlier than riparian rights.
[5] May be enforced by fines from the SWRCB.

available to satisfy all face-value water right demands" (Grantham and Viers, 2014, p. 7).

NEW CHALLENGES

Water markets face the challenge of assuming fungibility, even when it's well known that buyers value the water differently depending on where it's going and its purpose versus its intrinsic value. This is due to concerns over future water availability from current California residents since sending more water to urban and commercial sectors allows for growth, which involves supporting more people. More people means a higher water demand for the same water supply as before they appeared, forcing current residents to claim a smaller piece of the pie. An example of a contentious water rights sale happened in California in the early 20th century, which later inspired the 1972 movie *Chinatown*. Los Angeles began to grow rapidly and the city couldn't sustain its rising population without more water. The Los Angeles Board of Water and Power found water over 250 miles away in Owens Valley that was feasible to transport, so the city started buying their water rights in large quantities. By 1935, Los Angeles had bought 95 percent of water rights from their agriculture sector and 88 percent of water rights from their urban sector. Yet, the process wasn't easy. Due to valuation disputes from inaccurate land value data, group negotiating stalemates, and the trade outcomes negatively affecting others, the negotiations were hostile, bitter, and occasionally violent. In an attempt to put pressure on Los Angeles to raise asking prices, Owens Valley farmers embarrassed Los Angeles with bad publicity, which later morphed into the city becoming a negative symbol for urban sprawl. After the majority of Owens Valley water was gone, the town subsequently turned into a dustbowl, taking farmland out of production, while Los Angeles property values grew by 600 percent, which was made possible by the increased migration and development opportunities (Libecap, 2015). The mass water rights buy-out had lasting effects on all trades to growing urban sectors as it "poisoned subsequent attempts to persuade farmers to trade their water to thirsty cities. Several Californian cities now pay a price for their water that is several times higher than what the federal government charges its heavily subsidized farmers." ("Liquid Assets", 2003, p. 15). The rapidly-growing city of San Diego ended up paying $225 per acre-ft. for water from Imperial Irrigation District, where local farmers were paying $15.50 per acre-ft. (Libecap, 2015). Even today, there are still instances of "historical disjunction that has developed between and among rural and urban water users regarding the amount we consume and the price we pay for water." (Culp, Glennon, and Libecap 2014, p. 2). Data from California's Water Market confirmed the belief that prices are generally higher for urban end-users with water trades between cities showing the highest price and transferring water from farms to cities places second (figure 6). These higher prices reflect the higher social costs associated with enabling urban growth. The median price was a much better predictor of average prices than the mean price due to the data containing a few expensive outliers, which were all from a high-end resort to residents in its own town (urban-to-urban).

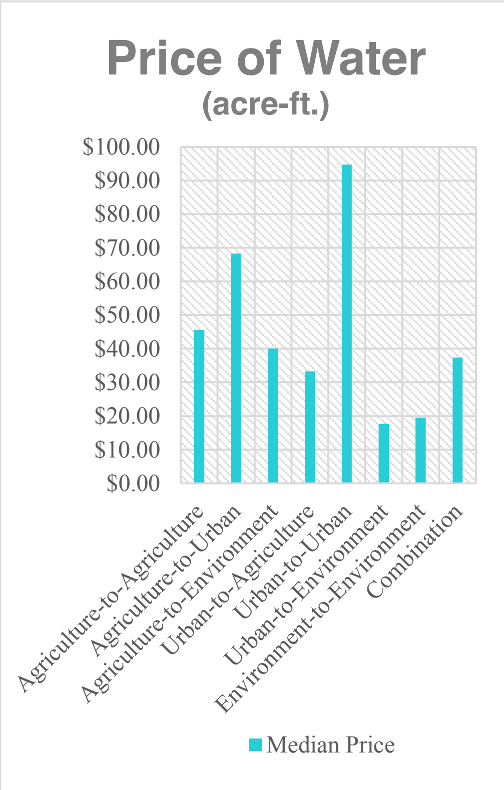
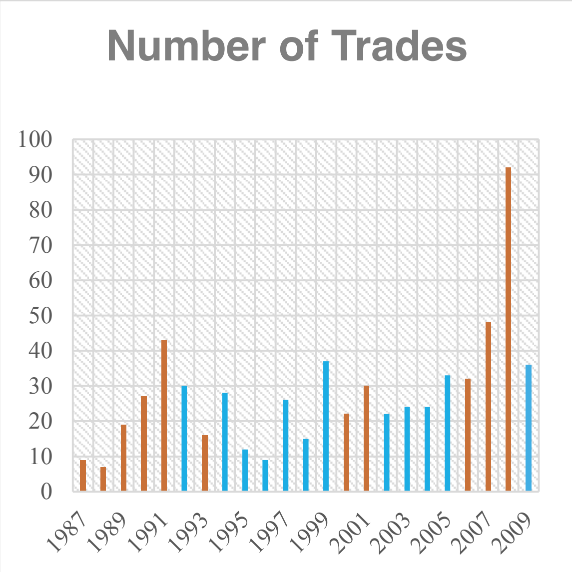


Figure 6. Median Prices for Water Traded in California's Water Market between 1987 and 2009.

Data from the *Water Strategist* (various dates). Median amounts were used in order to limit outliers' impacts. Prices were adjusted for inflation and trades without price data were omitted. No water was traded from an environmental purpose to agriculture or urban uses.

Appealing to concerns of supporting California population growth and development, selling water for agricultural purposes is much less risky long-term and therefore lower in price since even if the farm expands its business from the additional water, farms are much more accommodating to water shortages due to land fallowing and seasonal hiring options.

2008 had the most trades ever recorded for California's Water Market (figure 7). However, the total amount of water being traded (figure 8) didn't match the high user activity.



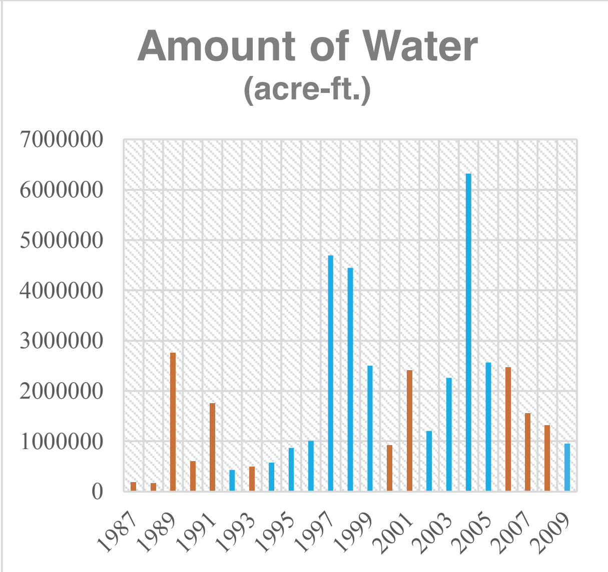


Figure 7. Number of Trades in the California Water Market between 1987 and 2009.
Data from the *Water Strategist* (various dates).

Figure 8. Amount of Water Traded in the California Water Market between 1987 and 2009.
Data from the *Water Strategist* (various dates).

Note. dry years are represented in orange and wet years are represented in blue

Even though the amounts of water were small, the higher utilization of the market in 2008 alludes to market mechanisms pushing players toward efficiency, however over a third of data had incomplete price information so it's hard to confirm. Water consumption remained stable when considering population rise, only decreasing as shown in figure 9.

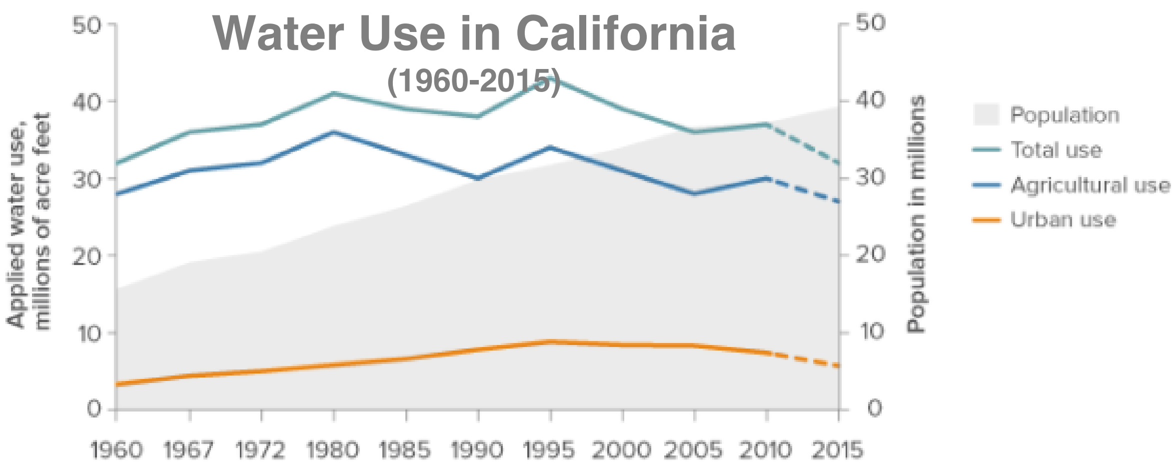


Figure 9: Water Use in California between 1960 and 2015.
Adapted from *Water Use in California*, by Jeffrey Mount and Ellen Hanak, July 2016, retrieved from http://www.ppic.org/publication/water-use-in-california/. Data for 1960-2014 water use from DWR (various years), data for 2015 urban water use estimates from the SWRCB, and data for 2015 agricultural water use estimates from Ellen Hanak et al. (2015).

A regression analysis of the amount of water traded and the state's overall water consumption proved there was no significant correlation between the two, contrary to the notion that the increase in market activity was affected by market mechanisms. On the other hand, the lower social costs of exporting smaller amounts of water, especially in a dry year, could have led to the higher incidences of smaller water amounts being traded, but it's unclear whether the opportunity costs outweighed the fixed costs affected since the utilization rate was so low.

BENEFITS OF WATER MARKETS

Water is essential to quench the thirst of cities as well as industries' desire for growth. During extreme climate variability, like periods of drought, water markets can be particularly beneficial in lessoning the costs of water scarcity. For example, the US's food security is largely dependent on California farms given their role in providing two thirds of the country's fruits and nuts and over a third of the county's vegetables (California Dept. of Food and Agriculture, 2015). In terms of allocative efficiency, trading water among California farmers or even just reallocation to higher value crops can mitigate losses in agricultural sector revenues. While reallocating water cannot eradicate water scarcity, mechanisms embedded in water markets can help shape behavior for more efficient water conservation, leading to productive efficiency (McCann and Garrick, 2014). Another example can be seen where market flexibility can allow the government to maintain minimal instream flows for sustainable ecosystems through earmarking budget money to buy water that specifically benefits the environment. Moreover, market regulation can enable transaction approval procedures to include environmental protections that minimize the risk of overdraft. These market-specific elements can not only help support wildlife, but help prevent some species from extinction and other grave consequences from changes in ecosystems.

Similarly, transporting water can be strategic as a means to augment flow levels when creating hydropower. Since the water isn't necessarily used during the energy production process, the entire amount of water is still delivered to the buyer while also helping produce renewable energy along the way; a win-win for traders and the state (Houston and Whittlesey, 1986). Water markets have the potential to ease water scarcity's detrimental impacts on agriculture and the environment, while building resilience amidst increasing water and energy demands from California's rising population. Furthermore, water is essential for business development and growth, especially given California's role in harboring much of the high-tech giants in Silicon Valley. Businesses that provide much of the internet's popular content, like Google and Facebook, use water as a cooling agent in their data centers (Glennon 2009). Reliable access to water enables air conditioning units and other cooling methods to dispel the heat generated from thousands of internet servers and other hardware, keeping them from overheating and failing (Glennon 2009). Thus, water trading can mitigate losses and even be beneficial for farmers, the environment, the energy sector, and the high-tech industry in California.

LITERATURE REVIEW

Measuring the deterrents of using water markets can be difficult since water transfers occur in highly complex institutions. Markets and water often have conflicting intrinsic characteristics since water's mobility and fluidity present challenges of externalities. Renowned economists and environmentalists alike have attempted to quantify these costs in different ways using various methods. Further analysis on the subject helps clarify and guide this paper's more open-ended variable.

TRANSACTION COSTS

In a perfectly competitive market, there would be no government interference, long-term social costs, nor infrastructure limitations. All potential market participants would be completely informed, so water would naturally be transferred to the highest cost-efficient purposes. In reality, protective regulation, limited delivery networks, and consequences on social welfare do play a role and these market barriers often encumber market information from being easily accessible to potential buyers and sellers. The differences are typically labeled as *transaction costs*, or impediments to transactions that keep the market from being 'perfect' in economic terms. One part of the transaction costs entails searching for, negotiating, and implementing the exchange, which includes paying for more human capital as well, like staff and public servants (Garrick, 2015). Streamlining bureaucratic processes and increasing accessibility to information can reduce this cost as much as possible. This information can be about transparency in available water quantities and prices as well as overall clarity in the water trading process. These costs are shouldered by both the buyer and the seller and are directly indicative of making market entry more or less approachable, especially to newcomers (Regnacq, Dinar, and Haanak 2016).

Another transaction cost stems from legitimacy efforts to specify and enforce the exchange, which can include institutional changes, like water rights reform (Garrick, 2015). Policymakers attempt to minimize this transaction costs by making the process more easily-understood and legitimate, but see these costs as a necessary evil since market flexibility demands constant adjustments (Garrick, 2015). Yet, changing Californian water rights to more market-compatible water-access and withdrawal rights that can be separate from land rights has been a contentious issue due to path dependency and embedded norms (Williamson, 1998, p. 27). Institutional economic theory reassures policymakers that when the costs of maintaining the status quo are more than the transaction costs, which will naturally encourage water efficient actions, people will be more receptive to reform (Garrick Whitten, and Coggan, 2013).

Transaction costs can also include assessing the resources involved during collective resource actions. One of the main transaction costs of water markets is uncertainty that comes with defining water rights given California's institutional hierarchy of riparian, appropriative, municipal water district, and state and federal water rights (Challen, 2000). However, other experts label California's institutional hierarchy as more polycentric due to the interplay of cooperation and competition with each other (Ostrom, Tiebout, and Warren, 1961). Either way, this interconnectedness of water allocation necessitates tradeoffs between the policy goal of economic efficiency and environmental protection, equity, and social cohesion (Colby, 1990b). Transaction costs address these tradeoffs as reflected in the challenges from collective action when sharing a common resource, like freeriding and externalities felt by downstream users and the environment (Ostrum, 1990). Sellers must demonstrate the trade doesn't negatively impact neighbors' water flows through costly measurements, impact assessments, and an endorsement from the competent authority to approve the trade. This "no-injury" regulation translates into additional fees for legal representation, brokerage services, and hydrology study contractors, all born by the seller.

County ordinances can also add rules to the approval process, like having sellers obtain an extra assessment for groundwater exports. If opposition to the proposed water trade arises, sellers can spend years in court to resolve the conflict (Colby, McGinnis, Rait, and Wahl, 1989). These pre-approval costs can again deter market entry due to a high up-front investment and encumber social cohesion (McCann and Easter, 2004). Especially in rivers where flows are largely climate-dependent, uncertainty in knowing accurate water availability and impact assessment outcomes can further discourage market entry since the seller is unable to foresee if the up-front costs are worth it, which also limits options for buyers in the marketplace.

One way to minimize externalities is establishing a cap-and-trade system where there is clear imposition of diversion limits. This not only balances production and conservation, but allows the market to lower the cap when too much water is being diverted out of the environment (Garrick Whitten, and Coggan, 2013). Transaction costs do not equate to inefficiency as NIE founder's Oliver Williamson attests, but rather as a corrective tax to factor in different externalities induced by the water trade (Williamson, 1985; Colby, 1990b). Especially when considering long-term water sustainability, transaction costs are necessary to see beyond achieving market efficiency and to consider adaptive efficiency as the policy goal of water markets.

Even with efforts to minimize California water market's transactional costs, water economist Richard Howitt still describes the system as very "haphazard", "fragmented", and "nontransparent" (Krieger, 2014b). Efforts to expedite and streamline the contract and approval process revealed how long the process actually took, even for short-term transfers

(Figure 10). To ensure the trade won't affect other water users' flow, additional measurements have to be taken, making it "almost a two-year process for a transfer that's three months. So it's quite involved and scheduling is a limiting factor because of these considerations. That does play a part in how to plan and prepare for long-term and short-term transfers especially under these drought conditions" (Cordova, 2014).

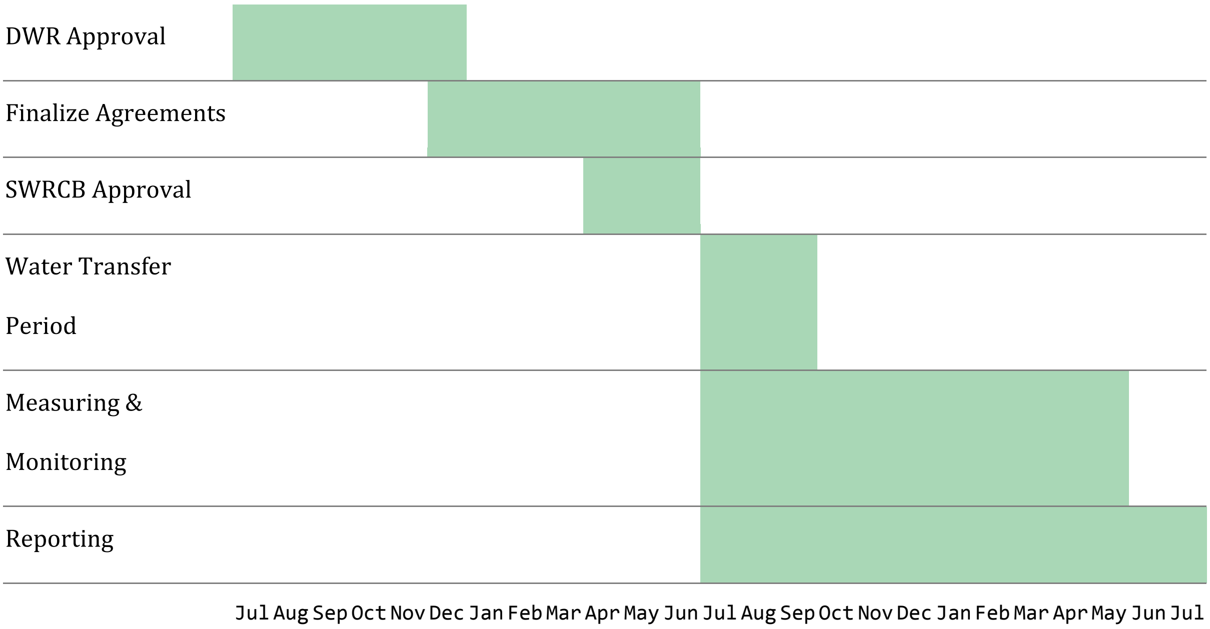


Figure 10. Timeline of California's Water Trade Process.

Adapted from the Future of Water Transfers After the 2014 Drought (p. 23), by Andrea P. Clark, Andrew Hitchings, Darren Cordova, and David R. E. Aladjem, 2014, Retrieved from http://www.acwa.com/sites/default/files/page/2014/11/water-transfers-ppt-2014-final.pdf..

Not all trades take years to complete. The DWR's water bank projects was able to bypass much of the steps due to the water being bought, stored, and sold from a reservoir with set quantities that didn't affect other water rights holders' entitlements. Even without these transaction costs, it is estimated the DWR absorbed transactional costs of 8% of the total water purchase price from their water bank transactions in 1991 (Howitt, 1994). Other studies estimate transaction costs are higher for non-water bank transfers, which can be explained using additional costs rooted in rational choice institutionalism (McCann and Easter, 2000; Garrick and Aylward, 2012). First, local restrictions on trade reflected communal efforts to protect water during droughts. Second, risk aversion concerns kept buyers weary of transfers travelling through state and federal infrastructure. Third, unclear groundwater trading rights allowed for its exploitation and resulting non-cooperative game theory strategy. While groundwater pumping remains unregulated, its transaction cost will be lower than water trading, which will deter people from using California's Water Market.

THE THEORY OF NEW INSTITUTIONAL ECONOMICS

New Institutional Economics (NIE) best supports this paper's hypothesis: less transactional costs will yield higher water market trading activity. As mentioned previously, transactional costs are sometimes needed to improve water market conditions or compensate for externalities. On the other hand, lower transaction costs tend to encourage investment and trade.

NIE expert Douglass North defines institutions as the "rules of the game", created to constrain and shape people's actions. Organizations are then considered the players, which are creators from the opportunity set formed by the institutional framework (North 1992). Organization perceptions are also important to consider since they can vary widely and affect their behavior. Perceptions come from one's culture, personal experience, and learned knowledge. Culture specifically is quite complex and consists of values, the intergenerational transfer of information, and other behavior-changing factors (North, 1992). Embedded norms and learned negative associations with selling water to growing cities in Southern California could explain part of why there are greater transaction costs for trades where the end-user is in the urban sector. Then the question arises about if these increased transaction costs are enough to deter potential traders from the marketplace. In California, urban end-user trades account for 38 percent of the total trades (figure 11).

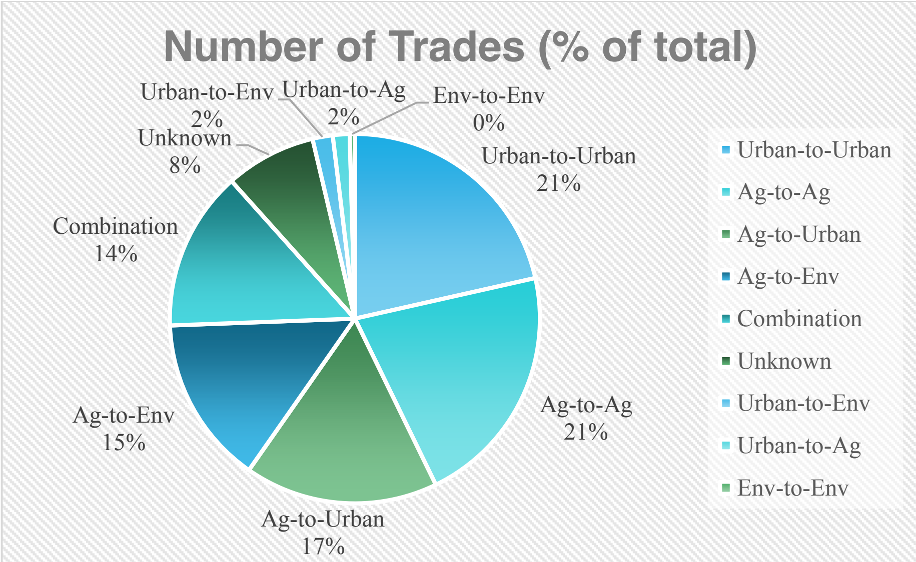


Figure 11. The Number of Trades by Sector in California's Water Market.
Data from the Water Strategist (1987-2010). Percentages are rounded to the nearest one percent.

Although urban end-user trade prices are the same as agriculture and environment trades in Australia's Water Market, the transaction costs for out of district urban trades are equally if not higher than California's costs due to Australia requiring additional fees, termination and exit fees. These fees are intended to equal the transaction costs associated with contributing to the water conveyance infrastructure between districts as well as offsetting the possibility of stranded assets. Termination fees are applied to buyers who forgo water deliveries from their water district, with the assumption they are buying it from outside their district, while exit fees are applied when water is water sellers trading outside their district. In Australia's Murray-Daring Basin (MDB), these costs can range from around $170/acre-ft. to $227/acre-ft., typically representing roughly 15-20 percent of the total price district. Due to these costs, the number of trades with urban buyers make up even less of the MDB's trade makeup than California (Australian Competition and Consumer Commission, 2006). Thus comparing the number of end-user urban trades as a percentage of the total trade types in the California Water Market with the same percentage in the MDB's Water Market wouldn't give any clear answer.

NIE pioneer Elinor Ostrom explains that with public goods, like water, resource withdrawal for one user reduces the amount of the resource for another, or 'subtractability'. Rational choice institutionalism asserts that these systems usually fail as a result of individuals still having access to and using the shared resource regardless if they are sufficiently contributing to its upkeep, known as the 'free rider' problem. Yet, government regulation, privatization, and establishing a durable cooperative institution are ways to avoid failure. When looking at successful common pool resource governing, there are notable similarities that Ostrom coined 'designed principles'. There must be clearly-defined boundaries, consideration of local conditions when enforcing rules, existing collective choice contracts that involve all those affected, active monitoring of resource conditions frequently, access to conflict resolution tools, and sufficient recognition of organizing rights. For the success of larger common pool resources, greater oversight is needed due to layers being more complicated (Ostrom, 1990). Water Markets can keep people from taking advantage of a shared resource by providing a regulatory framework that would allow legitimate boundary setting, opportunities to negotiate and reform, veto powers from environmental agencies and affected water rights holders, and mediation services by the SWRCB.

METHODOLOGY

This paper's analysis uses pie charts to illustrate the sectors dominating the water market and bar and line graphs to visually display the variation in market activity over the dry and wet years. Most of the data used in this paper is collected from the journal *Water Strategist*, which later became *Water Intelligence Monthly,* totalling 692 trades in California from 1987 to 2009.

Finding a region of similar climate, population size and growth, agricultural consumption, and economy to California was key in creating an appropriate comparison. However, the region also needed to be distant enough from having a similar water market framework that would equate to similar transactional costs, like other Western US states. As illustrated in Table 2, Australia's MDB is similar to California in many ways, like climate, population growth, and agriculture production and consumption, but greatly different in population size and economic output. However, their differences were less important than the other factors compared.

Table 2.
Comparing climate, population trends, agriculture prominence, and economic health in California and Australia's Murray-Darling Basin.

Region	Climate Challenges	Population Size (2006)	Population Growth (2001-2006)	Agriculture Production	Agriculture Water Consumption	Economic Output (2011)
California	Prone to droughts and flooding	36.1 million	5%	Produces 1/4 of country's food supply	40%	$ 2.04 trillion (USD)

Murray-Darling Basin	Prone to droughts and flooding	3.4 million[6]	3%	Produces 1/3 of country's food supply	40%[7]	$16.79 billion (USD)

Note. California data for population statistics and economic output is from the Department of Finance (2012; 2017), agriculture production from the California Water Science Center (2017), and agriculture water consumption from the DWR (2016). Australia data for climate, population size, and agriculture statistics is from the MDB Authority (2017a-c); population growth from ABS, ABARE, and BRS (2009); and economic output from the Department of the Environment and Heritage (2014). The population statistics and economic output in the table are not from the most recent years because of limited MDB census data and is matched by California's data from the same years.

MDB's water market trades account for at least one-third of total urban and agriculture water use, which is significantly more active than California's three to five percent (Regnacq, Dinar, and Hanak, 2015). Data from the MDB Water Market was accessible through the Australian Government's Bureau of Meteorology. This data was more expansive, with a total of 238,542 entries, but only ranged from 2007 to 2015, didn't include information on sector nor names of entities, and in some cases didn't include prices.

For this paper, defining all the transaction costs for water market trades is too extensive. Thus, this paper attempts to divide transaction costs into three different areas: social risk, up-front costs, and fixed costs. Behaviors supported by Ostrom's common resource pool model can help determine social risk level. Administrative transaction costs can include . A lack of information, accessibility, and experience can equate to high up-front costs, as telling from first time participants and frequency in the market. Fixed costs can be determined by previous literature defining these costs for California as well as by comparing the characteristics of the market one with a lower formulated transaction cost.

[6] This figure includes people who depend on the region's water.
[7] This figure is adjusted to consider the environment as a water consumer.

SOCIAL RISK

Social risks are the hardest to measure given the extent of social perceptions affecting behavior. Temporary trades are much more flexible and can be seen as a safeguard against future uncertainties, which can ease social costs (Grafton and Peterson, 2007). Leasing water is more common than selling permanent water in both California and Australian water markets (Water Strategist, various dates; MDB Authority, 2015a; MDB Authority, 2015b). In the figure below, permanent sales and leases in California's Water Market are compared by year. There seems to be no trend between the two, only that leases are more common and more variable than sales.

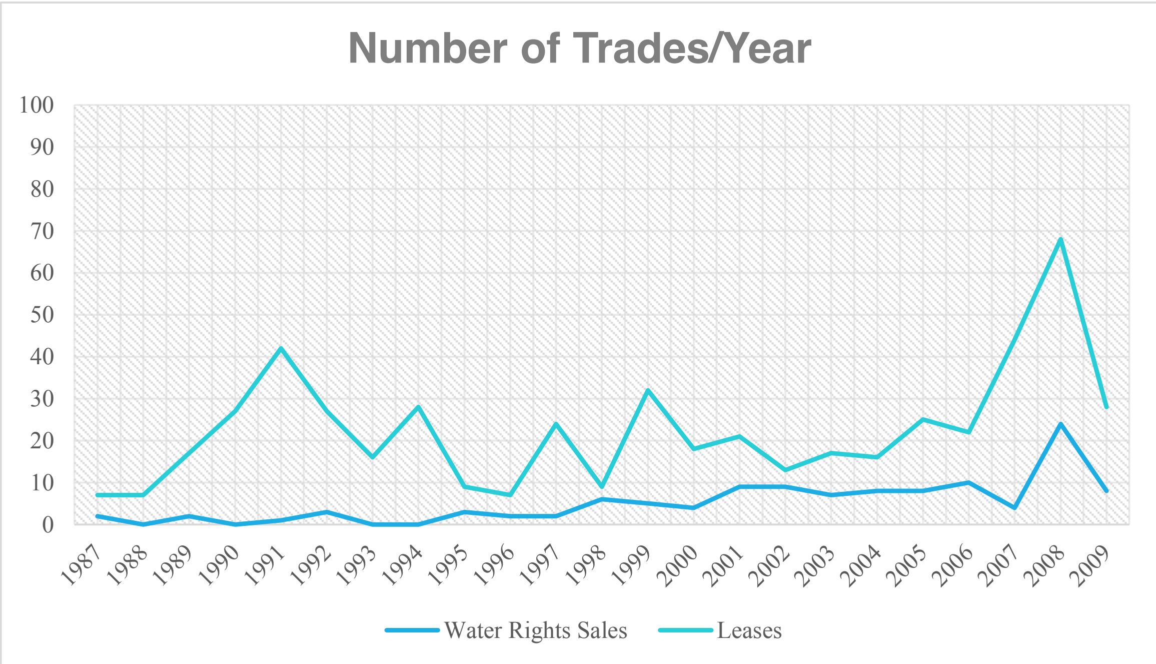


Figure 12. Number of Water Rights Sales and Leases in California between 1987 and 2009.
Data from *Water Strategist* (various dates)

UP-FRONT COSTS

High up-front costs can deter first time sellers and buyers. This can be reflected in a low frequency of first time trader participation. Up-front costs include barriers to information about available water, prices, market rules, and market procedures. This uncertainty can discourage buyers and sellers from entering the market, especially if they don't have prior experience. The percent of traders who account for first-time participants can reveal a lot about the market's approachability and overall health. MDB has made incredible strides in water market transparency and accessibility via online broker platform, like Waterfind, Water Pool, and H2OX (Locke, 2015). It also has easier water right rules that are defined as *entitlement rights*, or shares of a collective pool of water, and *allocation rights*, or access to amounts of water under entitlements based on seasonal availability. Permanent trades can only occur between entitlement rights and temporary trades transfer allocation rights (MDB Authority 2017d, 2017). California's Water Market is monopolized by members of the same water 'authority', or group of water districts and farms, that first time buyers and sellers are few and far between, only making up 18% of trading activity. While MDB's simpler water rights institution and technological advancements have facilitated first time buyers and sellers in the water trading process, and thus account for 58% of trading activity (Brozovic, Carey, and Sunding, 2002). As if water law wasn't already extremely complicated and confusing, California has made little effort to help first time buyers and sellers relative to Australia, and it's limiting their market's potential.

FIXED COSTS

Fixed costs are part of trades no matter the institution's efficiency. Yet, with some trades taking two years to approve, they can become barriers of trade as not everyone can afford to wait that long for the payoff. Also, if the trade is small enough, it might not be profitable. The amount of small quantities water of water, as defined by under 1000 acre-ft., could allude to the fixed costs and determine the line where its worthwhile. In the chart below, trades under 1000 acre-ft. of water account for 16% of temporary trades (85 trades) and 32% of permanent water sales (38 trades) between 1987 and 2009. This data doesn't include informal trades, which may skew the data. After converting megaliters to acre-ft., the MDB's figures were significantly greater; 98% of both temporary (69,267 trades) and permanent (196,168 trades)

trades were small quantity trades. Thus, it’s clear that water markets have major potential for small scale trades, but low utilization of small quantity trades alludes to high fixed costs or challenges with conveying small volumes of water.

ANALYSIS

California's Water Market's utilization is roughly three to five percent of the total water used in the state and is relatively low in comparison to Australia's one-third (Regnacq, Dinar, and Hanak, 2015). Further analysis revealed key differences either over the years or between the markets. Supported by the theory of NIE, transactional costs can hinder trade and investment, but can also reduce risks and build legitimacy. Since some transaction costs occur in a complex web of externalities and third-party influence, it's important to bear in mind that their impact extends past the scope of this research. In the figure showing the differences in sales and leases in California's Water Market (figure 12), permanent water sales seemed more cautious. This could be due to water sales receiving more attention and negative judgment from neighbors as well as more restrictions from county ordinances, stemming from historical preconceptions about water grabbing. Alternatively, California's vague rules for rights holders during extreme climate variability could also be causing uncertainty on water availability. Another cause could be an aversion to the more laborious and costly pre-approval process than temporary trades. Large-scale data on failed trades are impossible to find, which would have been helpful in determining how many of them failed due to social costs. Unfortunately, more data is needed in order to make conclusive statements.

Upfront costs can also be a giant barrier of market-entry. These costs can begin even before the potential participant even pays for the water, with a labor-intensive search for the right deal, third-party assessments, and endorsements from neighboring right holders, which may even demand side-deals. Information and experience can lower these costs since costly mistakes or oversights easily made the first time are less likely to be repeated. MDB's impressively high occurrence of first time traders shows how approachable its water market is. This is most likely facilitated by for-profit water brokers who, like realtors for housing markets, can offer their experience to minimize potential risk and lower search costs, administrative costs, and legal costs. However, their knowledge cannot reduce fixed costs. Thus, it's very interesting that MDB showed 98 percent of trades were smaller, or less than 1000 acre-ft. This could reflect MDB's lower up-front costs and overall market health, but it could also be indicative of higher up-front costs for larger quantities of water, like tougher restrictions. Lower rates of small trades in a water market can also be due to uncertainties surrounding water laws or the understanding that there is a more profitable alternative. Informal markets or trading small quantities of water within districts would be cheaper than going through the SWRCB. The SWRCB's approval for agricultural land transfers is contingent on collecting crop pattern information and photo evidence from the last five years and a statement ensuring that the water would not be used for additional purposes (DWR, 2002).

LIMITATIONS

It is difficult to measure the extent of water trading in California due to limitations in available data. The *Water Strategist* kept records of every water transaction that was approved by the SWRCB between 1987 and 2009, and as mentioned earlier included trades for appropriative and water district water rights as well as riparian water rights trades if transported through state-owned waterways and infrastructure. Short-term, informal water transfers within districts was also not included in the *Water Strategist* records since those water transfers didn't require the SWRCB's approval. However, the transactional costs of informal markets would not have been comparative to the transactional costs of the formal water market since the latter would likely face more opposition from moving water outside the district and would also absorb the administrative costs from obtaining state approval. This may skew the data to show less water trading activity than occurring in reality, but is overall reliable since the total water trades needing SWRCB approval amount to roughly 95% in

California (SWRCB, 2016). The records also don't include failed water trades, which would have been helpful information when determining when transaction costs are too high.

The *Water Strategist* gathered a total of 692 trades in California between 1987 and 2009, but the majority of the records contained incomplete entries (e.g.: price, transfer type, transfer length, and sellers and buyers identity). The data also contained some noticeable inaccuracies, like mislabeled sectors and misspellings. Google searches of official websites helped cross-check and fix many of the noticeable inaccuracies, however, trading quantities and prices were not as easily accessible over the internet and cross-checking by contacting each entity for almost 700 trades wasn't possible given financial and time constraints. Even though the *Water Strategist*'s data is questionable accurate, it is possible to compute some general measures of water trading activity in California. Petitioning the SWCRB to publish its data online and interviewing water market participants could strengthen the data's reliability and broaden the analysis.

CONCLUSION & DISCUSSION

Water is necessary to live, so scarcity in times of climate variability needs to be addressed with resiliency plans rather than temporary relief. California is facing record-breaking temperatures and dwindling back-up water sources. In recent years, policymakers have focused on reforming its water market to better suit modern challenges. However, its trading activity is extremely low relative to other water markets, like in Australia. This paper attempts to explain this aversion to using it through transaction costs under the umbrella of NIE. Transaction costs appear to be higher for permanent water sales, market-entry, and fixed costs, but this doesn't suggest causality. Transaction costs of course play a role in affecting behavior, but the complexities California's bigger water management framework are the root of the issues. Not addressing the lack of a cap-and-trade mechanism due to groundwater being unregulated, and other hindrances on market-based mechanism keep the market from its full potential. According to Olstrom's designed principles, California's Water Market requires clearly-defined boundaries for its water rights as well as its limits, the "no-injury" clause to help prioritize equity, close monitoring of all sources of water, the SWRCB to continue mediating disagreements, and constant improvements in order to succeed.

This paper's findings will hopefully further research on water market reform, but also remind people of the importance of transaction costs when managing a shared resource pool. Broader implications could expand beyond California to other areas facing climate variability, but also in the context of scarcity, need to take additional steps of social justice to ensure the protections of vulnerable populations, such as farmers and indigenous groups. Regarding water use, Califronia is showing signs of a race to the bottom with prioritizing industries over a city's water supply, businesses selling government-subsidized water for a higher return, continuing to grow water-intensive crops during drought seasons, the privatization of shared water infrastructure, and excessive groundwater pumping. Elinor and Vincent Ostrom express caution with sage words of advice:

> "Designing institutions to force (or nudge) entirely self-interested individuals to achieve better outcomes has been the major goal posited by policy analysts for governments to accomplish for much of the past half century. Extensive empirical research leads me to argue that instead, a core goal of public policy should be to facilitate the development of institutions that bring out the best in humans. We need to ask how diverse polycentric institutions help or hinder the innovativeness, learning, adapting, trustworthiness, levels of cooperation of participants, and the achievement of more effective, equitable and sustainable outcomes at multiple scales" (2014, p. 197)

In conclusion, public policy frameworks surrounding shared resources need to be imbedded in mutual responsibility and cooperation rather than competition in order to truly be resilient. Increasing market utilization is a goal of efficiency when California really needs to focus on adaptive efficiency.

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