Do Water Markets Drive Ownership Consolidation?

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Abstract

Concerns about ownership consolidation and sectoral reallocation resulting from the privatization and trade of water are predominant barriers that inhibit the adoption of water markets. However, systematic empirical evaluation of these processes is lacking. We study trends in ownership shares and trading behavior in one of the world's largest and most liquid groundwater markets, located in California's Mojave Desert. Adoption of volumetric property rights allowed for trading of groundwater to begin in the middle of the 1990s. Previous open-access water use and the initial allocation were both highly unequal, with the top 10% of water rights holders extracting more than half of pumpable water. We document that trading in the Mojave market over the course of 25 years mildly increased ownership inequality. Public water supply systems dominate the top ownership shares, and those systems increased their shares over time via trade. In addition, top ownership shares are driven by differential application of pumping ramp-down policies designed to achieve long-term sustainability. Over this period, roughly half of original owners sold out of the market completely. We document that small- and medium-sized participants who sold out of the market received payouts of over $10 million in aggregate.

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1 Introduction

Water markets have received attention as an effective way to efficiently allocate water and for their promise as a tool for climate change adaptation. However, water markets have not been adopted in many areas facing extreme scarcity, and, when implemented, are often underutilized by irrigation districts and other potential market participants (Hagerty, 2023; Ayres and Bigelow, 2022). Concerns about ownership consolidation and sectoral reallocation resulting from the privatization and trade of the resource are predominant barriers that inhibit their adoption. Fears exist about the potential exercise of market power and the cultural change from the loss of small-scale farming operations. Theoretically, trading could lead to consolidation as low productivity firms exit and high productivity firms acquire rights, reflecting increased resource use efficiency. However, these dynamics can be difficult to characterize and, in part due to the paucity of data on existing water markets, systematic empirical evaluation of these processes is lacking.

In this paper, we characterize the dynamics of water rights consolidation and evaluate the role that trading plays in the consolidation of ownership. Our setting is California's Mojave Desert, an arid region that is home to one of the world's largest and most liquid groundwater markets. Adoption of volumetric property rights allowed for trading of groundwater to begin in the middle of the 1990s after the previous open-access regime saw steep declines in the groundwater levels. Our setting allows us to evaluate the initial allocation of property rights, trading dynamics, and trends in consolidation in a region characterized by multiple uses (agricultural, municipal, and environmental).

The initial allocation of rights—which were grandfathered based on historical water use—was highly unequal, with the top 10% of water rights holders extracting more than half of pumpable water. We document that trading in the Mojave market over the course of 25 years mildly increased ownership inequality; in particular, the total volume of rights to pumpable water held by the top owners shows a slight increase over time. Public water supply systems dominate the top ownership shares, and those systems increased their shares over time via trade. In addition, top ownership shares are driven by differential application of pumping ramp-down policies designed to achieve long-term sustainability. Finally, we also decompose top ownership shares to show that both compositional changes among the top owners as well as their continued asset accumulation drive these dynamics.

Over this period, approximately 40-50% of original owners sold out of the market completely. But a low Herfindahl-Hirschman Index suggests a competitive marketplace that fairly compensates those that voluntarily sell their rights. We document that small- and medium-sized participants who sold out of the market received payouts of over $10 million

in aggregate.

This paper contributes to our understanding of how cap-and-trade markets achieve cost-effectiveness and what that implies for the political economy of reform. Concerns about consolidation often drive opposition to the use of tradable permits to manage open-access resources. In particular, these barriers have proved salient in fisheries reform: fears exist over the loss of small-scale fishers and fishing communities, and potential market power abuse of those who hold large shares of fishing quota (Grainger and Parker, 2013). Consolidation of fishing permits has been discussed and evaluated in several contexts (Grafton, Squires and Fox, 2000; Copes and Charles, 2004; Agnarsson, Matthiasson and Giry, 2016; Kroetz et al., 2017, 2019). Sutherland and Edwards (2022) estimate the extent to which the introduction of tradable fishing quota in Alaska led to a decrease in population and declines in taxable sales revenue in affected remote communities. Concerns over water trading are arguably more contentious, particularly when traders involve entities that serve drinking water customers. Yet, the extent to which market regimes have led to the consolidation and structural changes to communities in the water sector is much less understood.

Characterization of the likely impacts of market adoption on water use patterns and local economic structure will be important to inform the ongoing implementation of California's Sustainable Groundwater Management Act (SGMA). In particular, early studies suggest that the large economic costs of adjusting to increased groundwater scarcity under SGMA can be partially mitigated by effective trading and banking programs (Hanak et al., 2023; Ayres et al., 2021). SGMA requires groundwater users to form local agencies and create and implement groundwater sustainability plans, many of which plan to develop allocation plans and allow for trade (Bruno, Hagerty and Wardle, 2024). Understanding the changes in ownership in the Mojave basin will help inform the adoption and design of water markets in California and other arid regions likely to experience increased water scarcity under a changing climate.

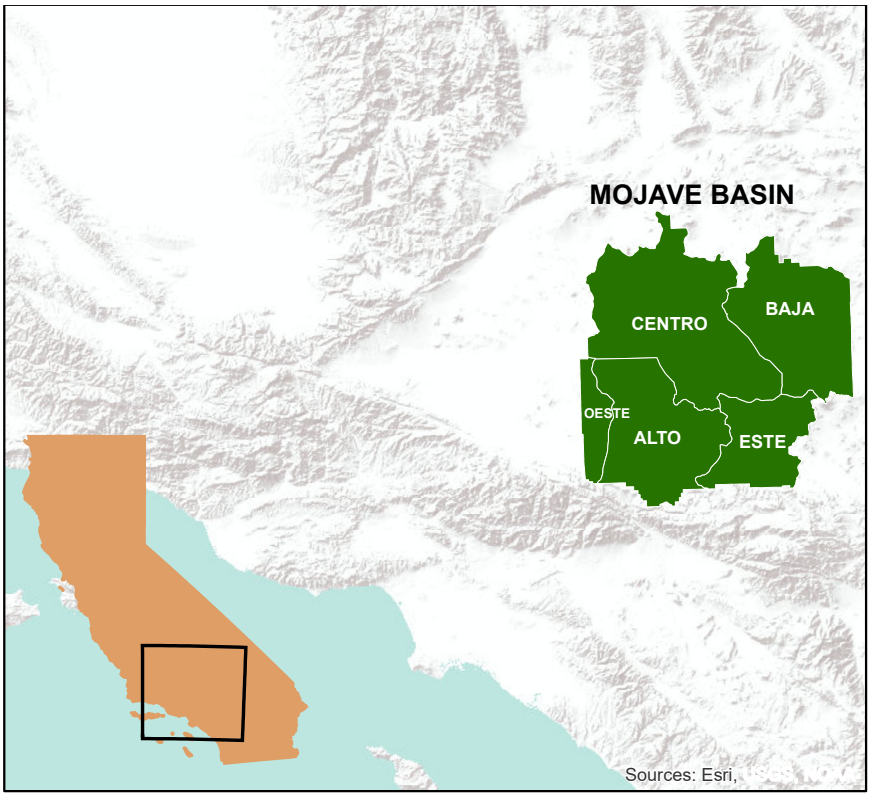
The paper proceeds as follows. Section 2 provides background information on the Mojave groundwater market and descriptive statistics on user types and trends over time. Section 3 describes how we measure inquality through changes in consolidation, including a decomposition analysis of the top ownership share. Then, Section 4 discusses the conditions under which owners sell the remainder of their rights and exit the dataset completely. Here we attempt to address questions of equity by characterizing their compensation. The final section concludes.

2 Mojave's Groundwater Market

Our empirical setting is the Mojave River Groundwater Basin, located in San Bernardino County, California. Following persistent groundwater overdraft from the 1940s onward, a property rights based management system was established for groundwater in 1990s via a court adjudication process. From 1990 and 1996, groundwater users in the basin negotiated a settlement that clarified secure and tradable property rights to groundwater pumping. The court process set total limits on extraction, allocated pumping rights to individual users and municipalities, and designated a third-party administrator to approve and oversee transactions. This has lead to one of the most liquid markets for groundwater in North America with estimated benefits of almost $500 million (Ayres, Meng and Plantinga, 2021).

The Mojave market is divided into five subregions shown in Figure 1 that operate as separate markets, a distinction that was made due to the underlying hydrology. Buyers and sellers span agricultural users, recreational lake operators, municipalities, industrial operations, brokers, and environmental interests. The majority of trading activity is concentrated in the Alto subregion, where the town of Victorville has seen substantial population growth.

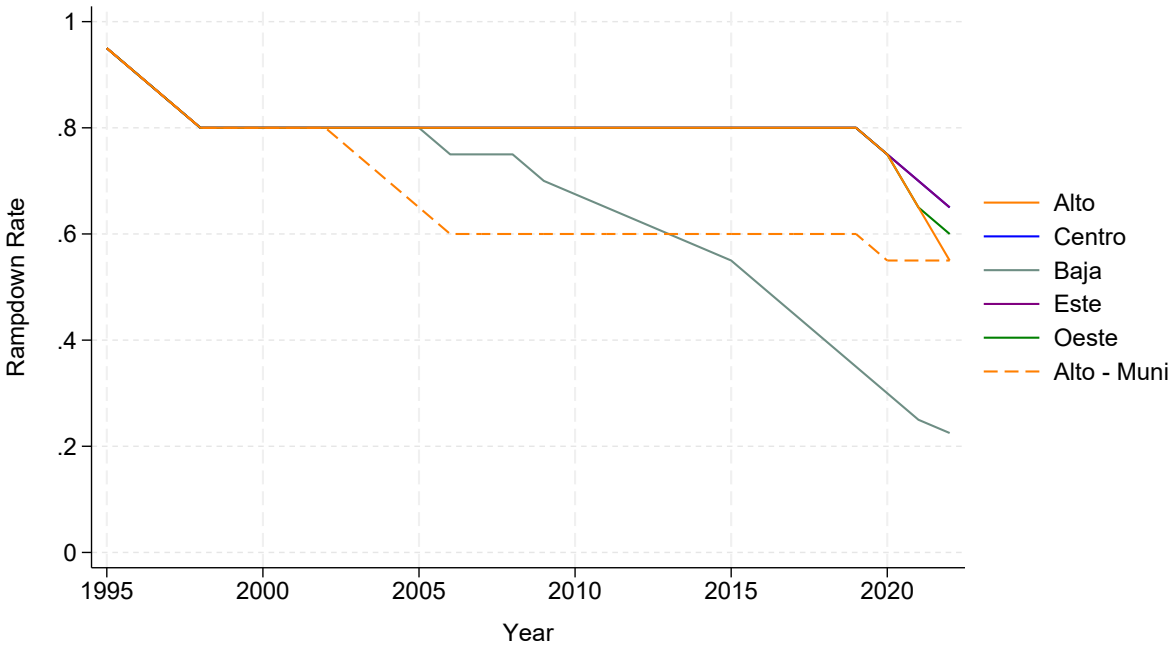
Figure 1: Map of the Mojave Groundwater Basin



NOTES: The Mojave adjudicated area is shown in green with subareas outlined and labeled.

Property rights for groundwater are defined in acre-feet and called Base Annual Production (BAP) rights. These BAP rights can be traded. The initial BAP allocation exceeded the sustainable yield of the basin, but the aggregate allowable pumping has been ramped down over time to stabilize aquifer levels. Each acre-foot of BAP translates, via the current year's rampdown rate, to an annual Free Production Allowance (FPA) that also can be used to pump water in that year, traded, or carried over for one year. As shown in Figure 2, rampdown rates have varied across the five subregions.

Figure 2: Differential Rampdown Across Subareas



NOTES: Rampdown rates, as proportion of initial BAP allocation, are plotted for each subarea. In the Alto subarea, rampdown rates differ for municipal and non-municipal pumpers; the dotted line reflects the rate for municipal pumpers and the solid line for all others.

Our primary data describe the price, quantity, and transacting parties for temporary leases and permanent sales of groundwater pumping rights from 1994 to 2020. The names of transacting parties have allowed us to identify sellers and buyers by user type (municipal, agricultural, industrial, environmental, or broker). By first collecting data on the initial allocation of BAP ownership and then combining this with transaction data over time, we can see how ownership has evolved through trade. We distinguish between original owners that held BAP at the time of adjudication and newcomers who purchased water rights midway through our sample period.

The share of BAP ownership held by municipalities increased by over 10 percentage points from 32% in 1995 to almost 44% in 2020, with the biggest increases in municipal ownership

share occurring in the Alto and Oeste subregions. Major municipal water providers are located in Victorville and Barstow. As shown later in Figure 4, the total number of owners has declined over time, with almost half of the owners being newcomers by 2020.

3 Inequality Measures

To track consolidation of ownership rights in the Mojave, we borrow a core measure from the wealth inequality literature: the top ownership share. In particular, we focus on the share of BAP ownership rights held by the top 10% of BAP owners in the basin. We focus on top ownership shares for two main reasons. First, BAP rights reflect a claim to water resources within the basin and thus constitute a form of wealth. Understanding the distribution of this particular form of wealth is informative about forms of consolidation that are of interest to both policy discussions and economists. Second, previous work in the wealth inequality literature has developed methods to decompose temporal changes in top wealth metrics that can shed light onto underlying wealth accumulation (consolidation) dynamics (Gomez, 2023).

We note that the initial allocation of BAP ownership rights in the basin, as described in the previous section, both reflected and resulted in a highly concentrated distribution of pumping and ownership. The top 10% held 65% of BAP, and the top 1% held 25%. These measures are relatively high in comparison to broader measures of wealth inequality in the American economy (Kopczuk, 2015), although we note that water ownership share distributions are not especially well understood. Another point of comparison can be taken from the recently completed Las Posas groundwater adjudication in coastal California, which saw the top 10% initially receive rights to approximately 58% of pumpable water.

Over time, this top ownership share in the Mojave has grown from roughly 65% to approximately 75%, a roughly 15% increase. (See Figure 3 below.) We discuss drivers of these increases in the following sections.

3.1 Decomposition

We follow Gomez (2023) to decompose inter-annual changes in the average wealth of top owners[1] into *within* and *between* terms. The *within* term captures the extent to which average wealth among top owners changes as a result of relative rates of asset growth among top owners compared to other owners. The *between* term captures how compositional changes among top owners—i.e., non-top owners acquiring more assets and displacing existing top

[1]Under certain conditions this approach can be used to decompose top *shares* as well; we take average wealth levels as our current dependent variable of interest and leave decomposition of shares to future work.

owners—drive average wealth changes.

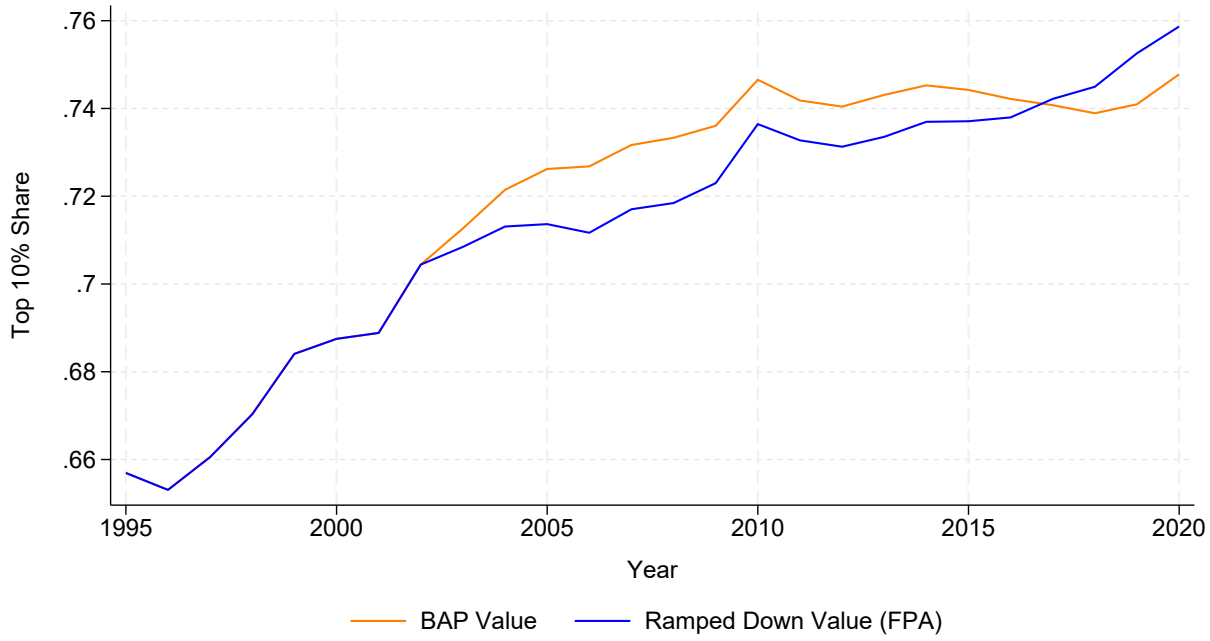
In the original application of Gomez (2023), the wealth under analysis is the market value of a wide variety of assets whose values can change for a number of reasons including appreciation, transfer, etc. We focus instead on units of BAP rights held by individual pumpers in the Mojave to highlight dynamics in the concentration of resource claims. Doing so also allows us to focus on specific drivers of consolidation independently of changes in market prices—primarily trade and the long-term ramp-down process instituted under the stipulated agreement. Accordingly, the *within* and *between* terms presented below reflect changes driven by market transfers and any relative differences in the application of ramp-down across subareas.

Figure A.1 presents decomposition results for interannual changes in the average BAP holdings of pumpers in the top 10%, and Figure A.2 presents the same for ramped-down BAP values (i.e., FPA yield) (see Appendix). In both cases, the top panel presents year-on-year changes and the bottom presents cumulative changes over time. Over time, changes in the average value of top BAP holdings are driven by both the *within* and *between* terms. Both when considering nameplate BAP and ramped-down FPA yield, the *between* term is particularly meaningful in explaining increases in the early years of the groundwater market. Thereafter, compositional changes between those inside and outside of the top 10% become more rare, and subsequent changes in the overall trajectory of average wealth are driven primarily by the *within* term—reflecting relative accumulation of BAP by the top 10% relative to others.

In the case of nameplate BAP, this impact of the *within* is almost monotonically positive after the early 2000s, as the top BAP owners continued to accumulate BAP ownership via trade. When considering ramped-down BAP (i.e., FPA yield), however, the overall impact of relative accumulation has been negative over time. This follows from the differential application of the ramp-down policies adopted to bring the groundwater basin into balance (see Figure 2); in particular, the early additional ramp-down faced by municipal water providers in the Alto subarea had a large impact as municipal water providers are heavily represented in the top 10% of owners.[2] This slowed growth in the share held by the top 10% considerably—by as much as 12 to 15 percent by the mid-2000s. See Figure 3.

[2]Indeed, this skewed ramp-down burden experienced by Alto subarea public water suppliers may have induced additional BAP purchases on their part.

Figure 3: Top 10% Ownership Share



NOTES: Top 10% ownership shares are plotted for nameplate BAP holdings as well as adjusted (ramped-down) FPA yield from BAP holdings. The ramped-down values reflect ownership concentration in pumpable water.

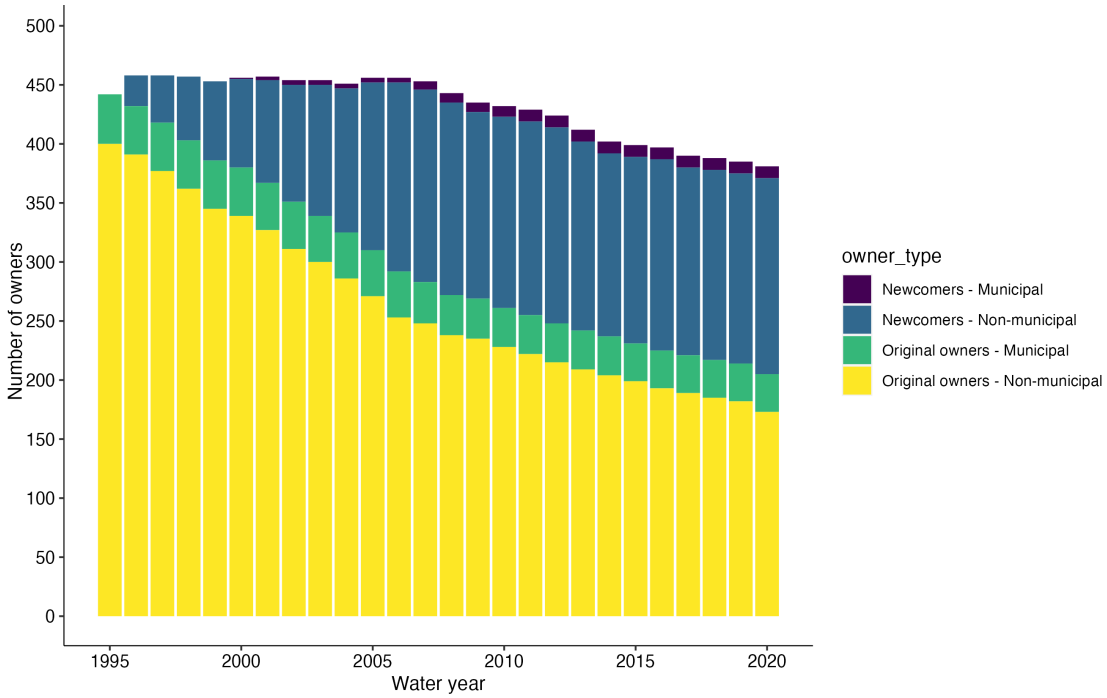
4 Sellouts

In addition to studying behavior of the top 10% of owners, we also consider the composition of those not in the top ownership group. Over our study period, compositional changes in the bottom 90% of BAP owners in the Mojave were driven in large part by original pumpers—those who initially received grandfathered pumping allocations under the stipulated agreement—selling out of the ownership pool completely. These sellouts are typically small farms and ranches that liquidated both land and water assets and ceased production all together as water prices increased. Roughly half of original owners had sold out by the end of our study period, see Figure 4. We investigate sellout dynamics because they can shed light on aspects of consolidation and market activity that often capture broad public attention related to water policy.

Through approximately 2007, new entrants into the market offset declining numbers of original owners, with the upshot that the total pool of owners remained roughly constant. The total number of municipal water purveyors remained roughly constant, and many newcomers were non-municipal, including solar power producers, environmental interests, third-party brokerage firms, and others. After 2007, the total number of owners declined by

approximately 13%, reflecting another margin of consolidation—the concentration of water resources in fewer hands, independent of the distribution across those hands.

Figure 4: Number of original and newcomer owners by type



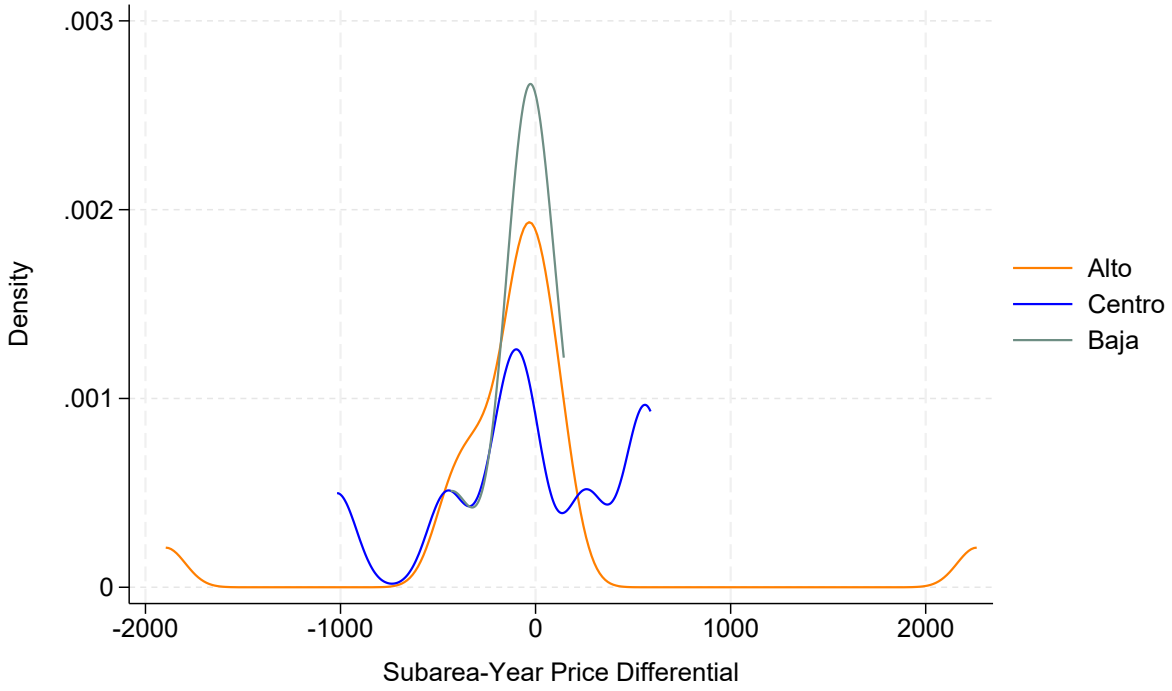
NOTES: Original owners refer to users who held water rights since initial allocation at the time of adjudication. Newcomers refer to any rights holders who purchased water and entered midway through the sample period.

To understand whether sellouts were equitably compensated relative to other market participants, we compute a series of annual subarea-level price differentials. Specifically, we compute annual average per-acre-foot prices for transactions involving an original owner selling out as well as all other transactions and take the difference in each subarea-year. The three largest subareas by trading volume—Alto, Centro, and Baja—all saw sufficient transfers in both categories to compute meaningful statistics. Tests reject that average prices differentials, pooled across subarea-years, differed statistically from zero;[3] distributions of these price differentials centered on zero with some major outliers, especially in the Alto subarea. (See Figure 5.)

[3]The estimated average price differential, standard deviation, and fraction of years in which sellouts earned on average less per acre-foot than others are (in 2019 USD): Alto (-$73.0, $164.8, 12/19), Centro (-$49.7, $187.4, 5/8), and Baja (-$67.9, $60.6, 6/8). While it is true that point estimates are more often negative than positive in these subareas, the differences are not statistically significant and the magnitudes are trivial compared to permanent BAP transfers prices that regularly exceed several hundred (Baja) or several thousand (Alto, Centro) dollars per acre-foot.

Overall, our results suggest that original owners selling out of the market were equitably compensated compared to their original or newcomer counterparts. These water users and market participants were largely able to convert their water wealth to monetary wealth at prevailing market rates, and these sales in aggregate total more than $10 million USD (2019). This assessment does not, however, constitute a formal test for market power, which we intend for future work. It is conceivable that consolidation dynamics in the Mojave either reflected or engendered market power in some subareas.

Figure 5: Sellout Price Differentials



NOTES: Average price differentials are plotted for three subareas with sufficient transactions to calculate differentials in multiple years. The number of differentials calculated are 19 (Alto) and 8 (Baja and Centro). Positive values reflect reflect above-market returns for sellout parties.

5 Discussion

In studying consolidation and market dynamics in the American West's most liquid groundwater market, we find evidence that market activity increased consolidation—as measured by concentration among the top 10% of BAP owners—by roughly 15%. This comes against a very high degree of initial water use inequality among original owners, reflecting, via the grandfathering of BAP, highly unequal water access under the open-access conditions that preceded the stipulated adjudication agreement.

In looking specifically at drivers of top ownership shares, we document a number of facts that help us to understand consolidation outcomes. First, compositional shifts in the top 10% of owners, as captured by the *between* component of our decomposition, were pivotal in shaping early increases in consolidation; however, the composition of top owners did not change significantly after the first ten years, at which point increased accumulation of BAP among the top 10% continued. We also find that differential application of ramp-down policies to achieve basin-wide sustainability stemmed increases in consolidation of FPA—that is, actual pumpable water as opposed to nameplate BAP rights. At its peak, this differential reflected a 12 to 13 percent reduction in post-adjudication consolidation.

Furthermore, we document that historical pumpers who decide to completely sell out of the market represent an important part of consolidation dynamics. Roughly half of original owners had sold out of the market by 2020 (after approximately 26 years of trading). While the sale of water rights by these original owners, typically small farms and ranches, often prompts equity considerations among public and policy commentators, we find that these transactions largely produced market-rate, and substantial, compensation for water rights holders.

Fully evaluating the desirability of this market-based consolidation requires understanding to what extent it was driven by welfare-enhancing economies of scale in water use as well as whether it reflected or engendered opportunities to exploit market power by buyers or sellers. The latter is of special interest given the prominent role of public water suppliers as buyers in some subareas. We intend to explore these questions as we continue this work as well as investigate to what extent aspects of the legal process influenced consolidation. In particular, some details of the Mojave adjudication agreement were devised to avoid costly litigation over a legal doctrine known as "prescription," according to which cities could have established legal claims to water that, by right, belonged to landowners in the Mojave. In lieu of this litigation, landowners agreed to grant cities grandfathered rights under the same terms as they received in exchange for those terms being to base BAP allocations on *maximum*, as opposed to mean, pumping in the five years prior to adjudication (Garner, 1998; Szeptycki et al., 2018). This especially advantaged agricultural interests, who have much higher variance in water use than cities. To the extent this resulted in larger shares of basin water ownership being initially allocated to landowners, some quantifiable portion of post-adjudicaton consolidation was, in a sense, "baked in."

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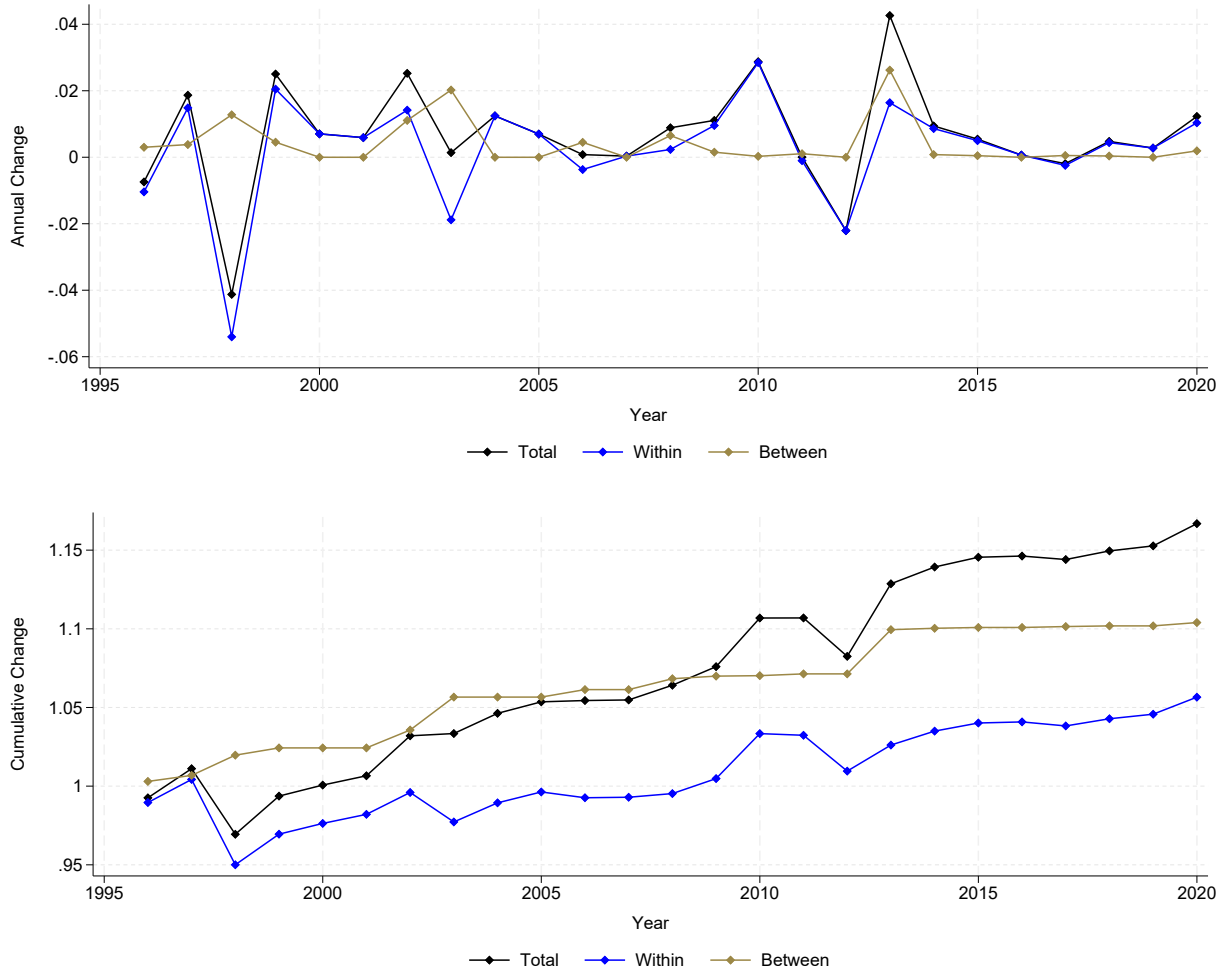
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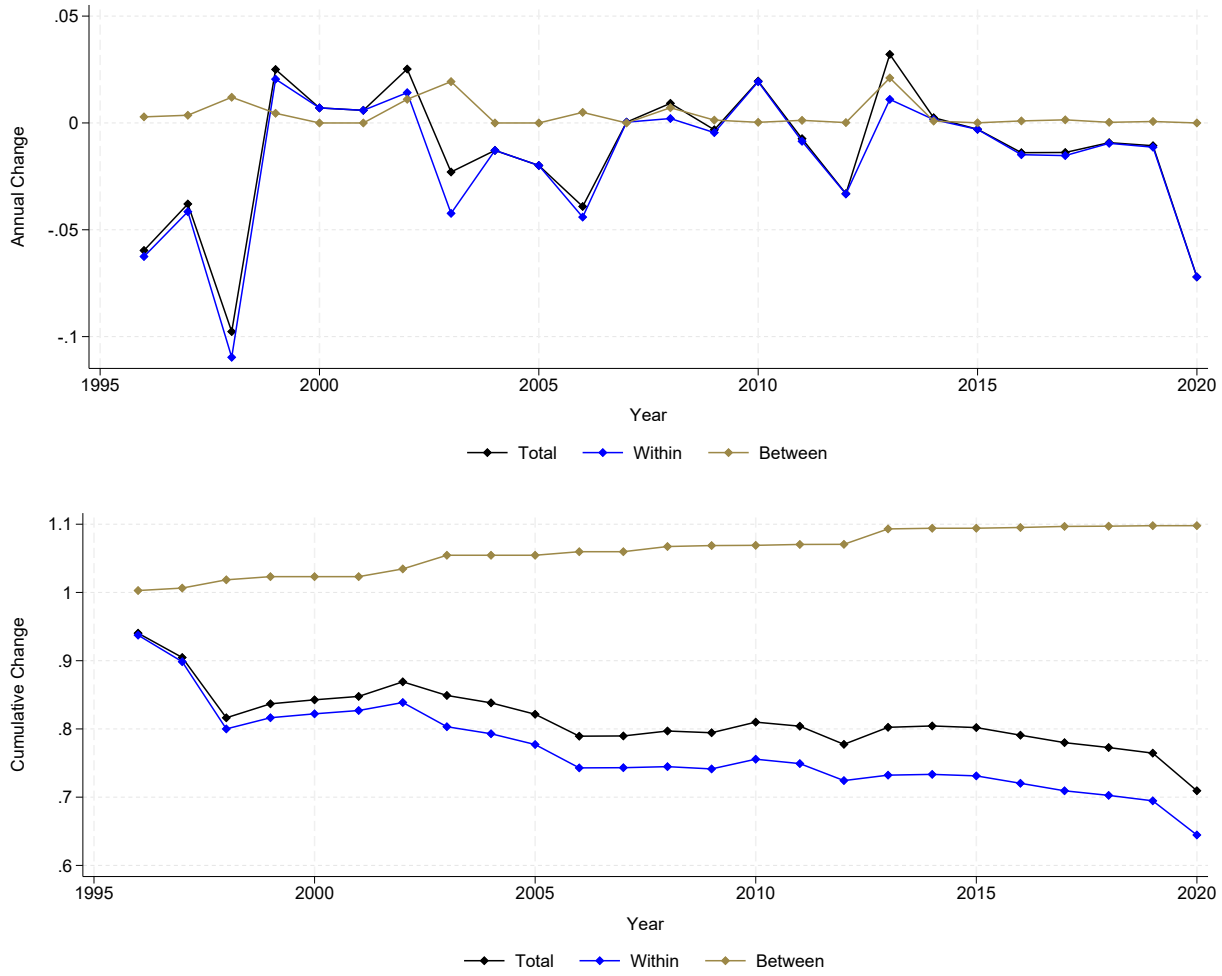
A Appendix

Figure A.1: Decomposition of Top Ownership Share - No Rampdown



NOTES: The top and bottom panels show decompositions of interannual changes in the average wealth of top BAP holders according to Gomez (2023). In both cases, the black line is the total change, blue reflects the *within* term, and the brown line the *between* term. These figures do not account for rampdown of BAP rights, i.e., they reflect ownership of nameplate BAP.

Figure A.2: Decomposition of Top Ownership Share - Rampdown



NOTES: The top and bottom panels show decompositions of interannual changes in the average wealth of top BAP holders according to Gomez (2023). In both cases, the black line is the total change, blue reflects the *within* term, and the brown line the *between* term. These figures account for rampdown of BAP rights, i.e., they reflect ownership of FPA, or pumpable water.