Water Market Participation and Agricultural Land Values

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ABSTRACT *Policies that improve drought resilience have heterogeneous effects on agricultural land values. We examine the value of surface water transfers and groundwater resources in a hedonic analysis of agricultural parcels in California. We find that parcels in irrigation districts, which engage in interbasin surface water transfers, experience an increase in value in subsequent years, but the gains are short-lived and unevenly distributed. Value of groundwater stock is higher in parcels outside irrigation districts. We also find that policies to restrict groundwater-substitution-based transfers, which aimed to reduce groundwater open-access externalities, have not been a deterrent against transfers in all areas.* (JEL Q15, Q25)

1. Introduction

This article seeks to understand how water market participation has affected farmland values. Water markets are institutional and infrastructure arrangements that facilitate transfer of water rights between water users in exchange for monetary compensation. In drought years, water markets can incentivize farmers with lower-valued water uses (e.g., in annual cops such as rice) to transfer or lease their water rights to higher-valued uses (e.g., permanent crops such as orchards, environmental, or urban uses). Successive droughts, large-scale water infrastructure projects that convey water across watersheds, and state policy support have facilitated development of water markets in the western United States. Federal policy support for water markets has expanded in recent years, and trends in water market transactions show an increase in the number of transactions and the volume of water transferred (Brewer et al. 2007; Schwabe et al. 2020). A rich economic literature on hedonic analysis of farmland values has estimated the value of irrigation in agricultural use (Petrie and Taylor 2007; Schlenker, Hanemann, and Fisher 2007; Buck, Auffhammer, and Sunding 2014; Sampson, Hendricks, and Taylor 2019). Research has also focused on the effects of changes in groundwater policies on land values (Ifft, Bigelow, and Savage 2018; Bigelow et al. 2019; Ayres, Meng, and Plantinga 2021), but the effects of differential access to and participation in a surface water market has received little attention. Economic research has focused on the efficiency enhancing role of water markets (Howe, Schurmeier, and Shaw 1986; Olmstead 2010; Leonard, Costello, and Libecap 2019; Rimsaite et al. 2021), but we do not know how those efficiency gains may be distributed among different participants in the market. In this article, we investigate whether agricultural parcels that participate in water markets experience an increase in land value as future water sale revenues are capitalized in land prices.

Since the early days of interbasin water transfers and water market development, there has been a recognition of potential negative externalities of water transfers in source regions (Chong and Sunding 2006; Bourgeon, Easter, and Smith 2008). These may include

Land Economics • February 2024 • 100 (1): 127–147
DOI:10.3368/le.100.1.102122-0091R
ISSN 0023-7639; E-ISSN 1543-8325

Supplementary materials are available online at: https://le.uwpress.org.

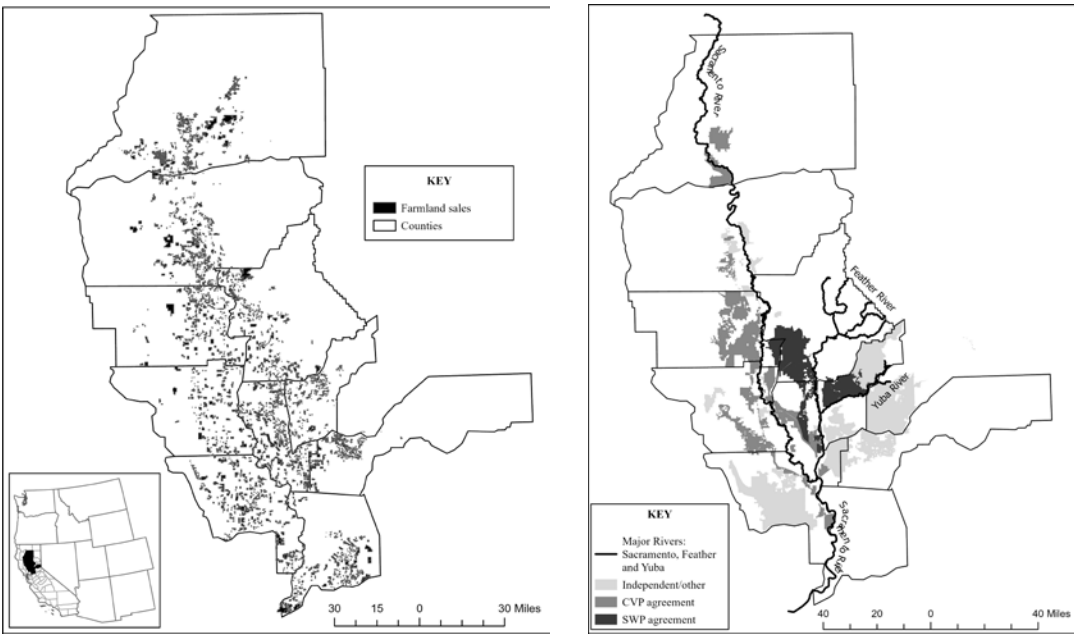
losses to the rural economy from reduced agricultural production, environmental effects from diversion of streamflow, or excessive pumping of groundwater to supplement water transfers. Although there is no disagreement that these effects exist, the incidence, magnitude, and persistence of negative externalities of water transfers are debated (Howitt 2014). In the context of California, state and county policy makers have implemented some policies to reduce these negative effects, which may have restricted water trading (Chaudhry and Fairbanks 2022). Bigelow et al. (2019) found that policies restricting water transfers were associated with lower land values in areas that had the potential to transfer water. We revisit this study area, with different data and model specification, and investigate the effects of transfer restrictions on farmland value.

We use two decades of farmland transaction data from 10 counties in California's Sacramento River valley to conduct a hedonic analysis of water market participation on land values. Hedonic analyses of farmland sales data have long been characterized by small datasets, because farmland markets are thin, with few arm's-length transactions in any given county and year, and because the cost of acquiring sales transaction data over larger regions from real estate data aggregators can be prohibitively high. Prior studies therefore used transactions data for a single state (Guiling, Brorsen, and Doye 2009) or a single county (Ayres, Meng, and Plantinga 2021). Other hedonic analyses of farmland values rely on reports of self-assessed land values collected through surveys (Roka and Palmquist 1997; Ifft, Bigelow, and Savage 2018; Bigelow et al. 2019). Use of survey data can provide more observations than microlevel sales transactions data, but they may raise potential concern over how well survey respondents' assessment of farmland values represent true market prices (Ma and Swinton 2012; Bishop et al. 2020). Zillow's Transaction and Assessment Database (ZTRAX) allows us to circumvent these constraints by providing land transactions data for a large study area that comprises the majority of the sale-side of the statewide water market in California. Moreover, the 20-year time period (2000–2019) of our analysis is long enough to show trends in real estate markets aside from macroeconomic fluctuations and spans multiple drought periods that show greater water market activity. We join ZTRAX data to spatially disaggregated water market data to examine how differential participation in water markets and adoption of water transfer restrictions have affected land value.

This article makes three contributions to the literature. First, to our knowledge, this is the first analysis of capitalization of water market participation in farmland value. Valued at \$3.2 trillion in 2022, farm real estate accounted for 83% of total U.S. farm assets (USDA 2022a). Because it is composed of such a significant portion of the balance sheet of U.S. farms, changes in the value of farm real estate have an important bearing on the farm sector's financial performance and the financial well-being of landowners (Zhang and Nickerson 2015). We focus on irrigated agriculture in California which has some of the highest per acre values in the country (USDA 2022b). Second, because we use spatially disaggregated data among water market participants, we contribute to an understanding of the distributional effects of water markets in the agricultural sector, between farmers who have secure surface water supplies versus those who mostly rely on groundwater. Information on winners and losers from water markets would be useful to reduce barriers to its wider adoption (Leonard, Costello, and Libecap 2019). Finally, as this article revisits the study area of Bigelow et al. (2019), it allows us to contribute to a better understanding of differences between hedonic estimates derived from observed market transactions versus those derived from producer-assessed farmland value.

Overall, we find that water transfers are being capitalized into land values in areas that engage in water transfers (inside districts), and areas that do not engage in statewide water markets (outside districts) experience no change in land values associated with water transfers. We find that previous years' transfers are associated with average land values increase in districts at the rate of 1%–2% (\$271–\$361 per acre), for up to three years after the transfers, after which the effect

Figure 1
Study Area: *left*, Farmland Parcels in Filtered ZTRAX Sample; *right*, Location of Districts



dissipates to zero. Our results show that transfers, particularly those conducted in drought years, when water prices offered in water market transactions are likely to be higher, are associated with even higher increases in land values among districts engaging in water transfers. Thus, our results provide suggestive evidence that distribution of gains from water markets, in terms of capitalization in land values, are demarcated along water sellers and nonsellers in the water markets. We also find increase in depth-to-groundwater is valued differently in areas depending on their relative dependence on groundwater and water transfers; an additional decline in 1 ft. in depth-to-groundwater is associated with a decrease in land value of 0.3% ($54 per acre) in outside-district parcels, while inside-district parcels that tend to have access to surface water sources show a statistically insignificant effect of increase in depth-to-groundwater. Finally, our results show that presence of water transfer restrictions are associated with lower land values, which is similar to the results found in previous hedonic research using self-reported farmland values in the same study area. Overall, these findings have important policy relevance due to the new groundwater laws in California. The Sustainable Groundwater Management Act (SGMA) came into force in 2020–2022 and created California's first statewide mandate requiring local water agencies to regulate groundwater extraction and improve groundwater sustainability. In some regions, the new laws may increase transactions in water markets.

2. Study Area and Institutional Context

The study area is California's Sacramento Valley, which is a major agricultural area. Sacramento Valley refers to the 10-county region in northern Central Valley of California (Figure 1).[1] A major factor that distinguishes Sacramento Valley from the rest of California's agricultural land base to the south is its relative water abundance. A large share of the surface water used for irrigation in the southern and central portion of the state originates

[1] The 10 counties are Shasta, Tehama, Glenn, Butte, Colusa, Sutter, Sacramento, Placer, Yolo, and Yuba.

from snowmelt in the Cascades/Sierra Nevada, which collects in the Sacramento Valley. Through a network of reservoirs and canals, the federal Central Valley Project (CVP) and California's State Water Project (SWP) supply water to many irrigation and water districts in the Sacramento Valley and other parts of the state. This region has relatively abundant supplies of groundwater, which is a primary supply for many farms as well as domestic users.

Irrigation and Water Districts

In the western United States, "special districts," particularly irrigation and water districts, are the predominant organizational structure that hold the majority of senior surface water rights, deliver water to individual users, and facilitate water transfers during droughts. Irrigation and water districts (referred to from here on simply as "districts") provide focused surface water–based irrigation-related services to landowners within defined geographic boundaries.[2] According to a national census of irrigation organization, more than 2,500 districts in the western United States deliver more than 40 million acre-feet of irrigation water directly to farms. In 2018, about 60% of irrigated acreage in the western United States was serviced by a district, and water delivered by districts constituted about 67% of all water used for irrigation by farms (Potter, Hrozencik, and Wallander 2023). As it pertains to our analysis, a key feature of districts is that they provide their members access to water distribution and conveyance system in the state. In drought years, the projects' conveyance infrastructure is also used to transfer water from sellers in the Sacramento Valley to buyers in the south, thus enabling district member farmers to participate in interbasin water transfers.

Given our large study area, we expect heterogeneity in districts' water market participation. Districts differ in their size, water rights, location relative to water buyers and thus conveyance costs, local soil and groundwater conditions, and crop mix. Thus, districts may have different expectations about potential benefits and costs of participating in water transfers, and the extent of their participation in water transfers may differ. For example, districts with mostly annual lower-valued crops such as rice or alfalfa may have lower opportunity cost of fallowing farmland than those with permanent tree crops (Chaudhry and Fairbanks 2022). Furthermore, districts' institutional forms may not be prepared for the challenges of internal reorganization for engaging in a water market (Rosen and Sexton 1993; Libecap 2011; Griffin 2012). Historically, districts arose in the early late nineteenth and twentieth centuries to solve collective action problems among district members for financing capital needs for surface water irrigation infrastructure (Hundley 2001; Ostrom 2011; Hanemann 2014), and internal management and regulatory processes for participation in water market may impose too high transactions costs on some districts (Leonard, Costello, and Libecap 2019).[3] In some cases, the home county of the district may require additional permits for certain kinds of transfers.

Surface Water Markets and the Role of Groundwater Substitution Permit Requirements

Owing to their relative water abundance and senior water rights, Sacramento Valley districts are sellers in the statewide water markets. Spurred by the drought in 1987–1992, water marketing increased in 1991 in California and generally becomes more active in drought periods. Farmers lease or temporarily transfer their surface water supplies by fallowing their cropland (a practice known as crop-idling [CI]), or pumping groundwater to continue agricultural production while leasing surface water rights (a practice known as groundwater substitution [GWS]). Since the early 1990s, CI and GWS have become two

[2] Irrigation and water districts were enabled via different special district acts, but for our purposes we treat them the same.

[3] District management, which is often composed of elected members, may decide to participate in water transfers outside the district. District management negotiates the transfer price and volume, conducts environmental reviews that may be necessary for the transfer approval process, and all the required internal reorganization within the district membership to execute the transfer.

of the main modes of water transfers in California's statewide water market (Hanak and Stryjewski 2012).

Until the implementation of the SGMA in 2020–2022, aside from a few adjudicated groundwater basins in southern California, there have been few state restrictions on groundwater volume pumped. Groundwater has been an open-access resource in most of the state and the "no-injury" clause intended to protect third parties from unmitigated harm only applies to surface water. Water transfers of the early 1990s relied heavily on groundwater substitution, which led to increased groundwater pumping and a subsequent drop in the groundwater levels in some areas. This created political momentum in many rural communities in California against groundwater-substitution-based water transfers. By the mid- to late 1990s, 22 of the California's 58 counties issued ordinances that directed districts to obtain permits from their respective home county governments to execute a groundwater export or substitution-based transfer out of the basin (Hanak 2003). While districts could transfer their surface water allocations by fallowing land with necessary state or federal approvals as needed, county ordinances on GWS-based transfers add an additional layer of approvals for completing a water transfer. County ordinances were thus policy-induced transactions costs imposed specifically on GWS-based transfers to mitigate groundwater-related negative externalities on outside-district farms that relied on groundwater as their primary source of irrigation. As Hanak (2003) has documented in detail, immediately after these ordinances were passed, county-level GWS permit requirements became a highly effective deterrent for GWS-based transfers. Research on the determinants of GWS permit requirements across California found that counties with GWS permit requirements had higher residential dependence on groundwater and more irrigated farmland, and while a higher share of on-farm employment increased the likelihood of adoption, counties with a higher share of value-added activities related to agriculture (e.g., agricultural processing activities rather than on-farm employment) were less likely to adopt GWS permit requirements (Hanak 2005). However, no previous research has linked agricultural land values to the presence of the GWS permit requirements.

More than two decades since the implementation of GWS permit requirements, it is an empirical question how county ordinances are being implemented and how they correlate with actual GWS-based transfers from the area. In the short term, these ordinances were a defensive strategy by groundwater-dependent users to protect themselves from harmful effects of water transfers, but in the long run, transfer behavior may have adjusted. Available data on mode of water transfers (see Section 4) shows that GWS permit requirements have not been equally prohibitive for GWS-based transfer across all counties in the sample.

3. Conceptual Model and Empirical Strategy

Conceptual Model

Farmland value is composed of expected net present value of economic returns to land as given by

$$V_{it} = E_t \sum\nolimits_{s=t}^{\infty} \frac{R_A(\boldsymbol{A}_{is})}{(1+\delta)^{s-t}}, \qquad [1]$$

where V_{it} is the value of agricultural parcel i in year t, R_A is the return from agricultural production, and $\boldsymbol{A}_{is}$ is a vector of parcel-specific variables that affect agricultural productivity (Palmquist 1989).[4] $\boldsymbol{A}_{is}$ includes access to irrigation water supplies, soil quality, proximity to roads, urban areas, slope and elevation of the parcel, and so on. Research on hedonic value of water has found that value of irrigation water is bundled with value of land, although water availability is measured differently depending on the institutional context (Petrie and Taylor 2007; Buck, Auffhammer, and Sunding 2014; Brent 2017; Sampson, Hendricks, and Taylor 2019).

In our study area, location of the parcel inside or outside a district determines the portfolio of water rights attached to the parcel;

[4] $R_A(\boldsymbol{A}_i)$ is the result of solving renter's and landowner's profit maximization problems as shown in Palmquist (1989).

district parcels have surface water allocations and may supplement their irrigation water supplies with groundwater sources, while outside-district parcels are dependent on groundwater for irrigation supplies. District parcels can lease surface water rights to off-farm buyers via a water market, which may add to the economic returns of land. We restrict attention to temporary water transfers and ignore the possibility of permanent transfers that retire agricultural land from production. For farms inside districts expected returns from water transfers include an additional stream of returns as follows:

$$V_{it}^{ID} = E_t \sum_{s=t}^{\infty} \left(\frac{R_A(\boldsymbol{A}_{is}^{ID})}{(1+\delta)^{s-t}} + \frac{R_W(\boldsymbol{W}_{is}; GWS_c)}{(1+\delta)^{s-t}} \right). \quad [2]$$

In equation [2], value of parcel i inside a district, V_{it}^{ID}, reflects the expected discounted stream from agricultural production (the first term) plus the expected discounted stream of returns from water transfers (the second term). $R_A(\boldsymbol{A}_{is}^{ID})$ captures returns from agricultural production as described earlier, and $\boldsymbol{A}_{is}^{ID}$ includes parcel-specific variables that affect agricultural productivity mentioned earlier, including the portfolio of surface water rights and the stock of groundwater below a parcel. $R_W(\boldsymbol{W}_{is})$ denotes returns from water transfers, and $\boldsymbol{W}_{is}$ includes the parcel-specific variables that affect returns from water transfers, such as home district's participation in water transfers, drought conditions in year t which may increase returns from water transfers, and so on. If in year t, transfers are undertaken by land fallowing, the first term $R_A(\boldsymbol{A}_{it}^{ID}) = 0$, but returns from water transfers are positive, $R_W(\boldsymbol{W}_{it}) > 0$. If transfers are undertaken by groundwater substitution in year t, both terms would be positive as farmer receives revenues from water transfers while also engaging in agricultural production. We assume that farmers choose to participate in water transfers to maximize total returns from agricultural production and water transfers.[5] Finally, returns from transfers may also be affected by the GWS permit requirement of district's home county, denoted by GWS_c, although the net effect may be uncertain. These permit requirements introduced transactions costs in water transfers and may reduce the returns from water transfers for inside-district parcels. But if these permit requirements are being used to reduce open-access externalities of groundwater, for example, allowing groundwater aquifers to recharge, then restrictions to lease water could benefit inside-district parcels.

Previous research has shown that the net effect of changes in groundwater institutions on land values may depend on aquifer characteristics, degree of open access, and the effectiveness of the policy instruments used to reduce open-access externalities (Edwards 2016; Ayres, Meng, and Plantinga 2021). In our context, as mentioned in Section 2, GWS_c were not based on comprehensive groundwater management but was used as a mechanism for resolving conflicts between those who wished to trade in water and the broader community. As Bigelow et al. (2019) show, GWS_c were associated with lower land values in the early years after these permit requirements were instituted, although the effect dissipated over time.

We assume that farms inside districts can lease their surface water allocations in regional water markets and farms outside districts cannot do so because of lack of access to water conveyance infrastructure to participate in water markets.[6] Farm values outside districts, denoted by V_{it}^{OD}, is the discounted stream of agricultural returns is expressed as

$$V_{it}^{OD} = E_t \sum_{s=t}^{\infty} \frac{R_A(\boldsymbol{A}_{is}^{OD}; GWS_c)}{(1+\delta)^{s-t}}, \quad [3]$$

where $R_A(\boldsymbol{A}_{is}^{OD})$ captures returns from agricultural production, and $\boldsymbol{A}_{is}^{OD}$ refers to

[5]We abstract away from farmers' periodic decision to transfer water and/or grow crops. Profit-maximizing farmers have incentives to fallow crops that generate the least profit per acre-foot. In general, such crops tend to be low-value, highly mechanized commodities that generate the lowest on-farm employment and the least value added through further processing (Hanak 2003). See Chaudhry and Fairbanks (2022) or Griffin (2016, ch. 9) for a single-period, profit-maximizing exchange framework.

[6]Outside-district parcels may engage in water trades between neighboring parcels or parcels connected via streams or river channels, but without the large-scale infrastructure of CVP and SWP, such trades are necessarily spatially local and smaller in volume. Therefore, without loss of generality, we ignore the role of these local trades in affecting land values for outside-district parcels.

parcel-specific variables outside districts, including groundwater stock available to parcel *i*. Outside-district parcels do not have any monetary returns from water transfers, but they may experience negative externalities from water transfers. In particular, outside-district parcels may experience lower groundwater levels from GWS-based transfers from their region. If a county permit requirement GWS_c is implemented optimally to eliminate open-access externalities, it may protect outside-district parcels' groundwater stock from negative externalities and thus may boost (or mitigate a decline in) land value.

Comparing equations [2] and [3] suggests testable hypotheses regarding water transfers and land values. We expect that water transfers are associated with higher land values inside districts and negative or zero effects outside districts. Furthermore, we expect that a district's actual participation in transfers is associated with an increase in the district land values. We also expect outside-district parcels to have a higher value of groundwater resources compared with inside-district parcels. While the effect of GWS_c is uncertain, we pay attention to its evolution over time in the inside- and outside-district parcels.

Empirical Strategy

We specify two econometric models to investigate how water transfers have affected land values in Sacramento Valley, an area that has been a seller of water in water markets. Our first econometric model is as follows:

$$ln(p_{it}) = \alpha + \beta_k WT_{c(t-k)} + \gamma GWS_c + \boldsymbol{\theta GW_{it}} + \boldsymbol{\rho_1 X_{1i}} + \tau Y_t + \varepsilon_{it}. \qquad [4]$$

In equation [4], the dependent variable is log of inflation-adjusted per acre land value of parcel *i* in year *t*. The right-side variables include WT_{ct-k}, which is the total volume of transfers from county *c* in previous year; $t-k$, where *k* takes on values 1, 2,…, 5 in different specifications. Transfers are undertaken by districts, and WT_{ct-k} aggregates volume of water transferred by all districts in county c in year $t-k$. Coefficient β_k measures the marginal effect of water transfers in year $t-k$ on land value. GWS_c is an indicator variable that equals one when parcel *i* is in a county that has a permit requirement for GWS-based transfers and zero otherwise. $\boldsymbol{GW_{it}}$ denotes annual parcel-level groundwater characteristics, spring groundwater elevation, and the coefficient of variation in groundwater elevation in the previous five years. $\boldsymbol{X_{1i}}$ includes parcel-level variables such as parcel area, elevation, slope, river frontage, distance to roads, distance to urban areas, percentage building footprint, soil quality, and county dummy variables that capture time-invariant effects at the county level; finally, τY_t are annual year dummy variables. Following our conceptual model, econometric model 4 is estimated for all parcels and separately for parcels inside and outside districts to track differential effect of all variables on land values inside and outside districts.

Districts hold heterogeneous water rights and vary in location, size, local soil and groundwater conditions, and crops planted and may have different expectations about potential benefits and costs of participating in water transfers. We propose our second econometric model to examine the effect of transfers disaggregated at the district level as follows:

$$ln(p_{it}) = \alpha + \delta_k (WT_{d(t-k)} \times D_{t-k}) + \boldsymbol{\theta GW_{it}} + \boldsymbol{\rho_1 X_{1i}} + \boldsymbol{\rho_2 X_{2d}} + \tau Y_t + \varepsilon_{it}. \qquad [5]$$

In equation [5], $WT_{d(t-k)}$ is the total volume of transfers from district *d* in previous years, $t-k$, where *k* takes on values 1, 2, 3 in different specifications. D_{t-k} is an indicator variable that equals one if the year $t-k$ was a dry year and zero otherwise. Coefficient δ_k measures the marginal effect of water transfers in drought years on the value of all district parcels. $\boldsymbol{X_{2d}}$ are district-level variables including total area of the district and the type of water district (federal, state or independent). Remaining variables are the same as in model 4. Model 5 focuses only on inside-district parcels and examines whether farmland values inside a district capitalize water transfer revenues based on own-district transfer behavior.

4. Data

Data Sources, Construction of ZTRAX Filtered Sample, and Other Variables

Our primary parcel-level dataset comprises land transactions data for 2000–2019 across 10 California counties obtained from ZTRAX. We restrict the ZTRAX data in several ways. First, we select observations with high and medium confidence for arm's-length transactions as documented by Nolte et al. (2024 [this issue]). Second, we restrict the sample to irrigated agricultural parcels by using the California's Department of Water Resources crop inventory land use maps that delineated irrigated agricultural areas. Third, the location of each ZTRAX parcel was identified vis-à-vis irrigation or water district boundaries. Fourth, for parcels outside the district boundaries (but inside irrigated agricultural areas as shown in crop layers), data on location of agricultural groundwater wells were used as a further check to remove unirrigated parcels.[7] Fifth, following Zhang and Nickerson (2015), we used U.S. Census data to identify the location of urban areas in study area. We used 2010 and 2020 U.S. Census Bureau definition of urbanized area (population ≥ 50,000) and urban clusters (2,500 ≤ population < 50,000) to measure the distance of each parcel to the closest urbanized area and urban cluster and counted total population within 25 miles of each parcel as proxies for urban influence on parcel price. As expected, parcels closer to urbanized areas are higher in value. We removed parcels located less than 500 m from urbanized area and less than 50 m from urban clusters in our final sample to mitigate the effect of urban proximity on our results. Finally, we removed parcels smaller than two acres as well as obvious outliers in land values (price per acre > $200,000 or price per acre < $99). Figure 1 (left) shows the location of sample parcels in the study area. All of these steps in constructing the ZTRAX filtered sample are described in further detail in Appendix A. Appendix Tables A5–A10 present details on the distribution of the ZTRAX filtered sample across sample counties, districts, and land use classes.

We filtered spatial data on all water agencies in the study area to create a set of agricultural irrigation and water districts that are also linked to the state (SWP) or federal (CVP) surface water conveyance infrastructure (see Appendix A for details on the district filtering procedures adopted).[8] Figure 1 (right) shows the location of districts in the study area. Each parcel in the ZTRAX sample was placed in its respective county and labeled "inside district" if it was situated in a district boundary or "outside district" if it was located outside a district.

Data on districts' water transfers for 2008–2019 were obtained from California's Department of Water Resource's historical water transfer data.[9] We focus on temporary or one-year transfers (also called leases). Water transfer data identify districts that transferred water in each year, volume of transfer (acre-feet), mode of transfer (CI or GWS), as well as duration (one year or long term) of transfer. To augment the district transfer data for earlier years, 1995–2007, data collected by the Public Policy Institute of California (PPIC) were added, although the PPIC data do not have information on mode of transfer.[10] Annual water transfer data were matched with ZTRAX parcel data by matching district names. To estimate econometric model 4, water transfers by all districts in a county were added for each year to calculate the total volume transferred from the county.[11]

California's Central Valley has a network of groundwater monitoring wells that record depth-to-groundwater for agricultural wells.[12] Spring season data for agricultural wells for

[7] Data on location of all agriculture wells are from the OSCWR database.

[8] See https://gis.data.ca.gov/datasets/45d26a15b96346f1816d8fe187f8570d_0/about.

[9] See https://info.water.ca.gov/wtims/proposalservice/publicsearch.

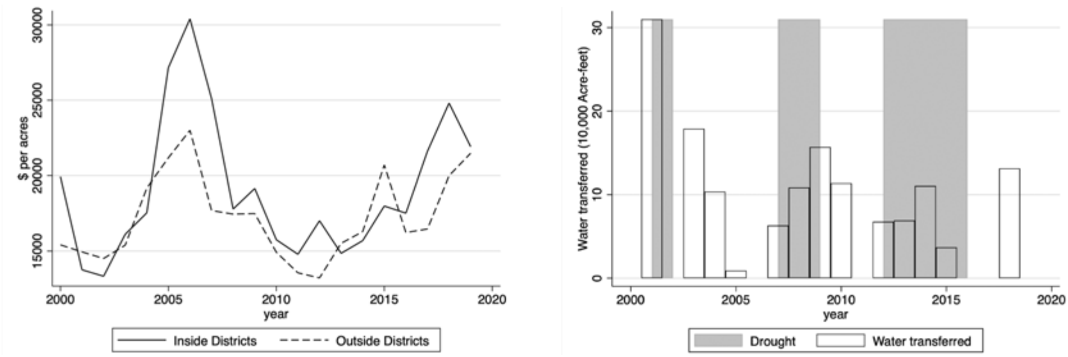
[10] We gratefully acknowledge Ellen Hanak (Public Policy Institute of California) for sharing these data with the lead author of this article.

[11] There are 12 (out of a total of 66) districts that lie across multiple county borders. In constructing transfers from the county, we attributed water transfer volume of cross-county districts to the county where most of the district area lies. On average, 86% of the area of the cross-county districts lie in one county, so attribution decision was straightforward.

[12] Periodic groundwater measurements and location of groundwater wells were obtained from https://data.cnra.ca.gov/dataset/periodic-groundwater-level-measurements.

Figure 2

Trends in Land Values and Water Transferred, 2000–2019: *left*, Mean Farmland Price (2001 prices) by District Membership; *right*, Water Transferred by Districts



1991–2019 were used in an ordinary kriging spatial interpolation procedure to develop groundwater surfaces. This procedure was applied to the log-transformed data to normalize the data distribution, suppress outliers, and improve data stationarity, as outlined in Pauloo et al. (2020). Optimized kriging model fits for each year were applied to reduce error and uncertainty. Spring season depth-to-groundwater data were extracted for each parcel in the ZTRAX data. Depth-to-groundwater serves as a proxy for energy costs associated with pumping groundwater, and we expect a greater depth-to-groundwater to lead to higher energy costs of pumping groundwater. Following Bigelow et al. (2019), we construct coefficient of variation in depth-to-groundwater in the five years before parcel sale to proxy groundwater volatility. Higher groundwater volatility is expected to have lower land values if farmers are risk-averse.

Data on county GWS permit requirements were obtained from state and county documents (CDWR and BoR 2019) and verified for earlier years using Hanak (2003). Drought occurrence was obtained from the water year's classification index, which measures drought incidence in river basins based on river runoff data. We use drought classification of "dry" or "critical" as an indication of drought. During the period of analysis is 2000–2019, there are 11 drought years.[13]

[13] Drought year classification was obtained from https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST.

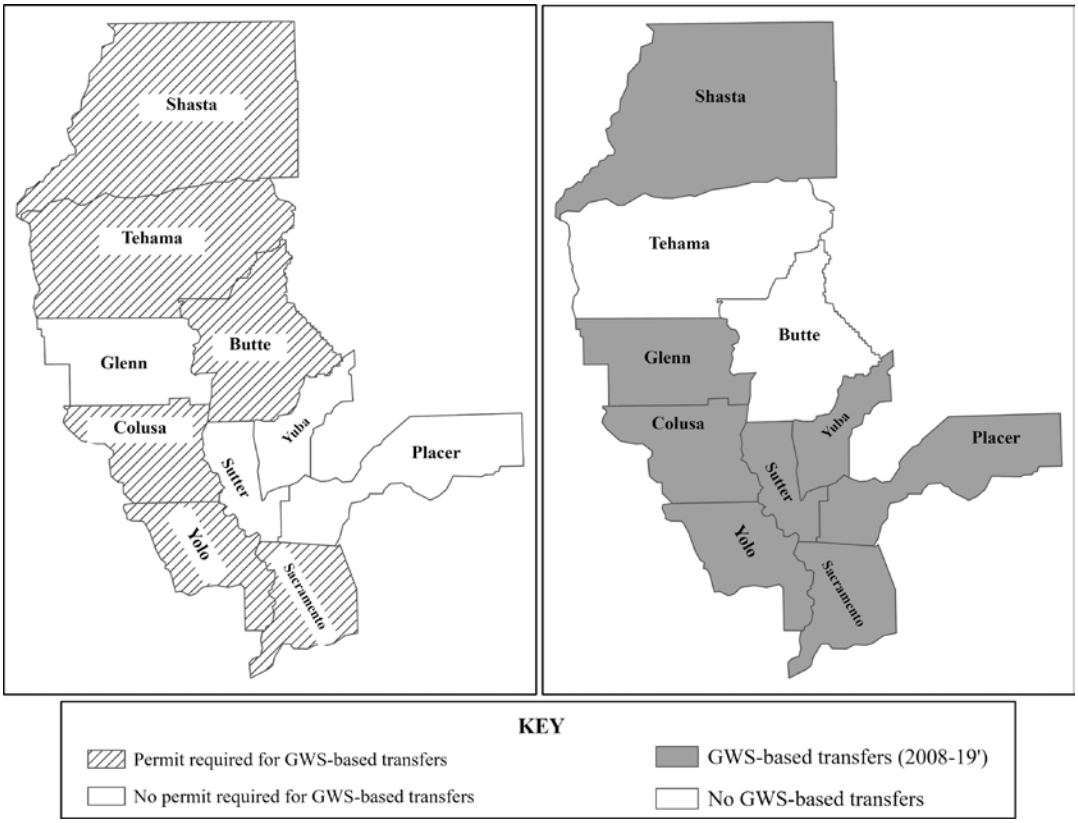
Data Summary and Trends

The final sample used in the analysis has 10,218 ZTRAX parcel transactions, of which 5,740 (56%) of the parcels are outside districts and 4,478 (44%) are inside districts. In the full sample, mean farmland per acre price is $17,882 (2001 prices) and median price is $10,923. Outside districts, mean farmland per acre price is $17,081.05 (median $10,602), while inside districts, mean farmland per acre price is $18,922.39 (median $11,304).[14] Figure 2 (left) shows mean farmland prices

[14] Farmland prices differ considerably by land use, as observed in 2014 land cover data. As shown in Appendix Table A6, mean land value is about $6,870 per acre in rice cropped areas and $15,077 per acre in field crops, whereas in areas in high-value permanent crops is considerably higher. Per-acre value in fruit and orchards is $23,072. Moreover, prices fluctuate over years in our sample. As Figure 2 (left) shows, prices peaked in 2006–2007, plunging to lows in 2011, and then climbing again in 2012. In Bigelow et al. (2019), mean self-assessed land values in the same study area was $7,339 per acre for 2001–2009, which is closer to land use in rice crops in our sample. In more recent reports, average irrigated agricultural land value is reported at $15,000 per acre in 2019 (USDA 2022b). In general, self-assessed values are expected to be different from market data because of sample selection (lower value properties may not be sold) as well as self-assessment errors by survey respondents (Bishop et al. 2020). As an additional rough data validation, we used the final sample to compare acreage transacted with total irrigated acreage as reported in the USDA Census of Agriculture. Appendix Table A5 presents the average annual area transacted in the ZTRAX sample, and the total irrigated acres as reported by the 2017 USDA Census of Agriculture. Although each county percentage acreage varies, the final sample has about 2% of the agricultural area in the 10-county region, although it fluctuates for each county and across years. This resonates with Nickerson

Figure 3

Spatial Distribution of Groundwater Substitution (GWS) in Study Area: *left*, Counties Requiring a GWS Permit; *right*, Counties Where GWS-Based Transfers Occurred in 2008–2019



disaggregated by the district membership. See Appendix Tables A2–A4 for detailed summary statistics.[15]

Patterns in district-level water market participation reveals that 31 of the 66 districts (46%) participated in the water market and transferred water out of the Sacramento Valley at least once during 2000–2019, and the remaining 36 (54%) districts have never participated in transfers. Figure 2 (right) shows that volume of water transferred increases in dry years, as expected.[16] Depth-to-groundwater increases in drought periods, as pumping increases to supplement surface water supply shortages, and recovers in wetter periods (see Appendix Figure B3).[17]

Figure 3 shows counties in the study area that have a GWS permit requirement and counties where GWS-based transfers have been documented since 2008. Figure 3 (left) shows that of the 10 counties in the sample, six required a permit to conduct a GWS-based transfer and four do not (CDWR and BoR 2019). GWS permit requirements have been in place before the period of analysis, 2000–2019. Figure 3 (right) uses available data on districts' mode of water transfer for

and Zhang (2014) who show that around 2% of the farmland in an agricultural market is sold in a year.

[15] Appendix Tables A2–A4 show summary statistics of all variables used in the analysis, separately for all data, outside and inside districts, respectively.

[16] Appendix Figure B2 also shows that the trends in the number of districts participating in the transfer also varies. District participation in the water market increases in drought years.

[17] Appendix Figure B3 shows trends depth-to-groundwater in the study area disaggregated by district membership and GWS permit requirement.

2008–2019 to show the occurrence GWS-based water transfers indicating that GWS permit requirements are not equally prohibitive for GWS-based transfer. In particular, districts in Yolo, Shasta, and Colusa Counties have a permit requirement and have approved permits to allow for GWS-based transfers. CI transfers are overwhelmingly from Butte County, and GWS-based transfers are predominantly in Yuba, Yolo, and Sutter Counties.

5. Results

Transfers at the County Level and Land Values

Table 1 reports the results of the model in equation [4]; columns (1)–(3) present results for $WT_{c(t-1)}$ for the full sample, outside-district, and inside-district subsamples, respectively. Columns (4)–(9) show results for adding longer lags in water transfer variables, $WT_{c(t-k)}$, added one at a time in each column. Table 2 provides a summary of estimated marginal effects of $WT_{c(t-k)}$ for k = 1,…, 5, and depth-to-groundwater.

In the full sample, the estimated coefficient of previous year's transfers, $WT_{c(t-1)}$, is 1.1%. All else equal, an increase of 10,000 acre-feet of water from all districts in the county is associated with an increase in land value of 1.1% ($197 per acre) one year later. Estimated coefficient of depth-to-groundwater in the full sample is negative and statistically significant at 10%: a 1-ft. increase in depth-to-groundwater is associated with reduction in land values by 0.25% ($45 per acre). Results for outside-district subsample, reported in Table 1, column (2), show that water transfers have a statistically insignificant effect on land values outside districts. The estimated coefficient of depth-to-groundwater is statistically significant: a 1-ft. increase in groundwater depth is associated with reduction in land values outside districts by 0.3% ($57 per acre). This makes sense because outside-district parcels are more dependent on groundwater than farms inside districts have senior surface water rights and use groundwater as a backstop. Column (3) shows the results for inside-district farms. The estimated coefficient of previous year's transfers is positive and significant. An increase of 10,000 acre-feet of water is associated with a 1.43% increase in land values inside districts ($271 per acre). This shows that the positive and significant coefficient in the full sample was entirely driven from the inside-district subsample. Coefficient for depth-to-groundwater is statistically zero in the inside-district subsample.

Table 1, columns (4)–(6), shows the results of model 4 estimated for water transfers two years prior to parcel sale, $WT_{c(t-2)}$. In the full sample, the estimated coefficient of $WT_{c(t-2)}$ is statistically insignificant. Transfers from districts in the county two years ago are associated with 1.83% ($346 per acre) increase in land values inside districts, but again, no effect outside districts. Table 1, columns (7)–(9), shows results for water transfers three years before parcel sale, $WT_{c(t-3)}$. In the full sample, the estimated coefficient of $WT_{c(t-3)}$ is statistically insignificant for the full sample, as well as for outside-district parcels. For the inside-district sample, an additional 10,000 acre-feet of water transferred is associated with an increase of 1.91% in land values ($361 per acre). Results for longer lags, k = 4, 5, show statistically insignificant estimates for transfer volumes.[18] The results for depth-to-groundwater show a very robust pattern across all lags of water transfers. For parcels outside districts, the coefficient of depth-to-groundwater is negative and statistically significant. An increase in depth-to-groundwater by 1 ft. is associated with a reduction in land value of 0.3% ($56–$57). For parcels inside districts, the estimated coefficient of depth-to-groundwater is negative but statistically indistinguishable from zero.

Estimates of coefficient of GWS permit requirement, γ, are very interesting. All else equal, average land values are lower in counties that have instituted a permit requirement for GWS-based transfers. As Table 1, column (1), shows, in the entire sample, counties that have a permit requirement for GWS-based transfers have 34% ($6,044 per acre) lower land values than counties that do not have this requirement. Columns (2) and (3) show that

[18] Summary results are reported in Table 2, and full results are reported in Appendix Table B1.

Table 1
Land Values and Transfers at the County Level

Variable	All Parcels (1)	Outside Districts (2)	Inside Districts (3)	All Parcels (4)	Outside Districts (5)	Inside Districts (6)	All Parcels (7)	Outside Districts (8)	Inside Districts (9)
Water transferred from all districts in county in $t-1$ ($WT_{c(t-1)}$)	0.0110***	0.0141	0.0143**						
	(0.00306)	(0.0130)	(0.00584)						
Water transferred from all districts in county in $t-2$ ($WT_{c(t-2)}$)				0.00993	−0.0131	0.0183*			
				(0.00592)	(0.00787)	(0.00840)			
Water transferred from all districts in county in $t-3$ ($WT_{c(t-3)}$)							0.00687	−0.0155	0.0191**
							(0.00619)	(0.0171)	(0.00671)
Depth-to-groundwater in spring in $t-1$ (feet below land surface)	−0.00254*	−0.00333**	−0.00190	−0.00259*	−0.00330**	−0.00197	−0.00258*	−0.00330**	−0.00193
	(0.00136)	(0.00120)	(0.00166)	(0.00134)	(0.00117)	(0.00167)	(0.00132)	(0.00120)	(0.00167)
Coefficient of variation in spring depth-to-groundwater in previous 5 years	0.00630	0.00783	0.00242	0.00649	0.00786	0.00198	0.00664	0.00769	0.00214
	(0.00530)	(0.00618)	(0.00264)	(0.00536)	(0.00610)	(0.00210)	(0.00539)	(0.00614)	(0.00275)
County has a permit requirement for GWS-based transfer ($GWS_c = 1$)	−0.338***	−0.108*	−0.167	−0.352***	−0.185**	−0.173	−0.368***	−0.203**	−0.190
	(0.0733)	(0.0588)	(0.117)	(0.0836)	(0.0625)	(0.120)	(0.0796)	(0.0845)	(0.110)
Constant	9.542***	9.408***	9.224***	9.559***	9.512***	9.222***	9.576***	9.534***	9.232***
	(0.189)	(0.142)	(0.145)	(0.201)	(0.142)	(0.153)	(0.200)	(0.161)	(0.150)
Parcel controls	x	x	x	x	x	x	x	x	x
Year	x	x	x	x	x	x	x	x	x
County	x	x	x	x	x	x	x	x	x
Observations	10,200	5,730	4,470	10,200	5,730	4,470	10,200	5,730	4,470
Adjusted R-squared	0.366	0.383	0.391	0.366	0.383	0.392	0.366	0.383	0.392

Note: Robust standard errors are in parentheses. Errors are clustered at the county. Parcel controls include elevation, slope, river frontage, distance to paved roads, travel time to major cities, distance to urbanized area (population > 50,000), distance to urban cluster (population > 2,500 and < 50,000), total population within 25 square miles, % building footprint between 500 m and 5,000 m, building square footage, and soil quality. GWS = groundwater substitution.

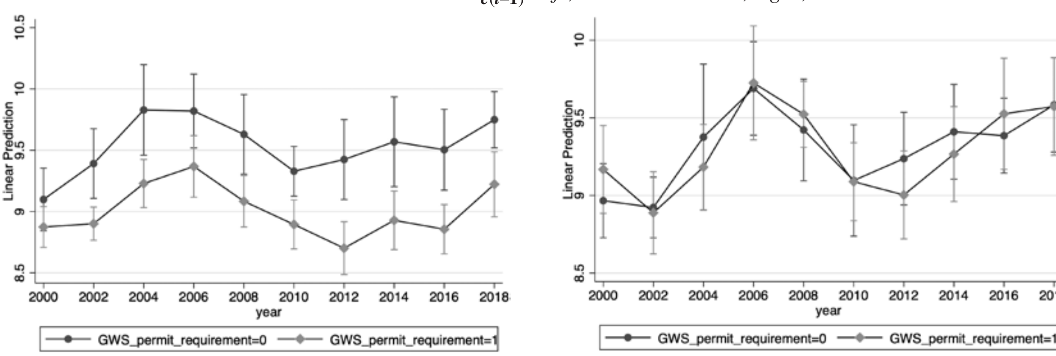
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 2
Estimated Marginal Effects of Water Transferred and Depth-to-Groundwater

	Water Transferred (10,000 Acre-Ft.)			Depth-to-Groundwater (Ft.)		
In Model with:	All Data	Outside Districts	Inside Districts	All Data	Outside Districts	Inside Districts
Water transferred from all districts in county in $t-1$ ($WT_{c(t-1)}$)	0.0110*** ($197) (0.00306)		0.0143** ($271) (0.00584)	−0.00254* (−$45) (0.00136)	−0.00333** (−$57) (0.00120)	
Water transferred from all districts in county in $t-2$ ($WT_{c(t-2)}$)			0.0183* ($346) (0.00840)	−0.00259* (−$46) (0.00134)	−0.00330** (−$56) (0.00117)	
Water transferred from all districts in county in $t-3$ ($WT_{c(t-3)}$)			0.0191** ($361) (0.00671)	−0.00258* (−$46) (0.00132)	−0.00330** (−$56) (0.00120)	
Water transferred from all districts in county in $t-4$ ($WT_{c(t-4)}$)				−0.00257* (−$46) (0.00133)	−0.00331** (−$57) (0.00121)	
Water transferred from all districts in county in $t-5$ ($WT_{c(t-5)}$)				−0.00258* (−$46) (0.00133)	−0.00332** (−$57) (0.00121)	

Note: Robust standard errors are in parentheses below the estimate; $ values calculated at means. Errors are clustered at the county.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Figure 4
Linear Prediction of Model 4 with $\boldsymbol{WT_{c(t-1)}}$: *left*, Outside Districts; *right*, Inside Districts



this difference in land values is entirely driven by the outside-district parcels. For parcels outside districts, farmland values are lower by 11% ($1,931 per acre) if they are in a county that has a permit requirement for GWS-based transfers. Inside-district parcels, however, show statistically insignificant effects of being in a GWS permit county. We explore these results further by interacting the GWS permit requirement with years and examining predicted values over time. Linear predictions are plotted in Figure 4, which shows clear differences in land values along the GWS permit requirement margin. Outside districts, GWS permit requirement is associated with lower agricultural land values (Figure 4, left), while inside districts the difference is statistically zero (Figure 4, right). In counties with a GWS permit requirement, outside-district parcels tend to have lower land values. GWS permit requirements have been in place since before our period of analysis, and these results allude to the reasons these requirements were instituted in the first place: groundwater-dependent parcels, in relatively lower land value areas, lobbied for these requirements as a defensive strategy to protect their irrigation supplies from groundwater-based transfers in neighboring districts. We find no evidence that water transfers have negatively

Table 3
Land Values and Transfers at the District Level

Variable	Inside Districts (1)	Inside Districts (2)	Inside Districts (3)
Water transferred from home district in year prior to parcel sale ($WT_{d(t-1)}$)	−0.0265		
	(0.0504)		
Year $t-1$ = drought year ($D_{t-1} = 1$)	0.510***		
	(0.127)		
($WT_{d(t-1)} \times D_{t-1}$)	0.174*		
	(0.0869)		
Water transferred from home district in 2 years prior to parcel sale ($WT_{d(t-2)}$)		−0.402**	
		(0.155)	
Year $t-2$ = drought year ($D_{t-2} = 1$)		0.457***	
		(0.106)	
($WT_{d(t-2)} \times D_{t-2}$)		0.385**	
		(0.145)	
Water transferred from home district in 3 years prior to parcel sale ($WT_{d(t-3)}$)			−0.143
			(0.103)
Year $t-3$ = drought year ($D_{t-3} = 1$)			0.557***
			(0.155)
($WT_{d(t-3)} \times D_{t-3}$)			0.169
Depth-to-groundwater in spring in $t-1$ (feet below land surface)	−0.00133	−0.00108	−0.00143
	(0.00170)	(0.00169)	(0.00172)
Coefficient of variation in spring depth-to-groundwater in previous 5 years	−0.00142	−0.000978	−0.00126
	(0.00356)	(0.00432)	(0.00390)
Constant	9.932***	9.922***	9.924***
	(0.544)	(0.555)	(0.543)
Parcel controls	x	x	x
Year	x	x	x
District controls	x	x	x
Observations	4,459	4,459	4,459
Adjusted R-squared	0.410	0.413	0.410

Note: Robust standard errors are in parentheses. Errors are clustered at the county. Parcel controls include elevation, slope, river frontage, distance to paved roads, travel time to major cities, distance to urbanized area (population > 50,000), distance to urban cluster (population > 2,500 and < 50,000), total population within 25 square miles, % building footprint between 500 m and 5,000 m, building square footage, and soil quality.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

affected outside-district parcels. It is possible that GWS permit requirements helped screen more harmful water transfers. In Section 6, we elaborate on these results and compare them with those of Bigelow et al. (2019).

Transfers at the District Level and Land Values

Restricting the sample to within-district parcels and disaggregating annual transfers conducted at the district level, we estimate empirical model in equation [5]. Table 3 presents results of including $WT_{d(t-k)}$, $k = 1$, 2, and 3 in each column.

Column (1) shows that the effect of transfers from the district, $WT_{d(t-1)}$, in the year prior to parcel sale, varied by drought conditions in that year. If the year prior to parcel sale was a drought year, an additional 10,000 acre-feet transferred by the district was associated with an increase in land value by 17.4% ($3,292).[19] Transfers in nondrought years had a statistically insignificant effect on land values in the district. Column (2) shows the results of model 5 for transfers from the district two years prior to parcel sale, $WT_{d(t-2)}$. Results in column (2) show that depending on the drought conditions, transfers from the district two years before had an opposite effect on land values. Transfers are positively associated if undertaken in drought years, but if undertaken in a nondrought year, they are negatively associated with land values.

[19] Because of space constraints, the table summarizing estimated marginal effects of model 5 is moved to Appendix Table B2.

An additional 10,000 acre-feet transferred in a nondrought year were associated with a reduction in district land values by 40.2% ($7,607) two years later, but an increase of 38.5% ($7,285) if the water transfers were made in a drought year.

These results suggest an interesting pattern of association between water transfers by districts and land values inside districts. Compared with averages across all districts in the county, as presented earlier in results of model 4, own-district transfers have a higher marginal effect on land values, yet the increase only lasts two years and then dissipates. Moreover, effect varies by drought conditions in the year of transfer. A plausible explanation of these results is that water prices received by district farmers for engaging in transfers are likely to be higher in dry years as demand for water increases, transfers in dry years may be associated with higher transfer revenues and hence greater return, as shown in equation [2]. As demand for water in the water market decreases in a nondrought year, prices offered to districts for water transfers may be lower. Results for transfers at the district level suggest that nondrought years transfers may not as profitable for district parcels as transfers in drought years.

Other economically significant results from model 5 include the statistical insignificance of depth-to-groundwater and coefficient of variation in depth-to-groundwater in all specifications. This is not entirely surprising, since district parcels generally have senior surface water rights and use groundwater to supplement surface water supplies.[20]

6. Discussion: Comparing Results of Self-Reported and Market Transactions

A comparison of our findings with Bigelow et al. (2019) may shed some light on model specification and data used in each study, with some lessons for future work. This comparison makes a compelling case for the usefulness of replicating previous analyses with different data, particularly in rapidly changing policy contexts.

Bigelow et al. (2019) used a rotating panel data of farmers' self-reported land values over 1999–2009 for a hedonic analysis of groundwater-substitution restriction. Following previous literature, such as Hanak (2003), Bigelow et al. (2019) interpreted the presence of a GWS permit requirement as a deterrence to GWS transfers and used drought periods as a proxy for timing of water sale opportunity for parcels inside districts. These temporal and cross-sectional variations were exploited by Bigelow et al. (2019) to disaggregate trends in farmland values and provided insight into differential effects of GWS permit requirement on trends in land values. They found that during 2001–2002, the first drought period after the implementation of GWS permit requirements, when they could potentially deter drought-induced water transfers, there was a 34% ($2,057 per acre) decline in farmland value in counties that had a GWS permit requirement. Disaggregating trends for inside- and outside-district sample of agricultural parcels, Bigelow et al. (2019) found no effect of GWS permit requirement inside districts but a lower land values in outside-district parcels by 46% ($3,318 per acre). These results were interpreted as suggestive evidence that GWS permit requirements imposed short-term costs on interbasin water transfers from the region.

Our analysis is in the same 10-county study area of Sacramento Valley, although our period of analysis is longer, 2000–2019 compared with 1999–2009 in Bigelow et al. (2019). We have used pooled cross-sections of market transactions of farmland parcels and annual data on districts' water transfers rather than location of the parcel inside a district as a proxy for water transfers. In general, results of hedonic analyses of market transactions and self-reported values cannot be expected to be same. In particular, there are differences in sample selection, that is, the set of parcels transacted may not be representative of the agricultural parcels in the area although a random sample of farmers for self-assessment

[20] Results for district controls included in vector $X2$d how tha. t, all else equal, larger districts have higher land prices; an increase of 1% in average land value is associated with an additional 1,000 acres in district size. Also, the differences in land values in state, federal, and independent districts are statistically indistinguishable from zero.

may do a better job of building a representative sample of agricultural parcels in regional land market. On the other hand, market transactions better capture the long run agricultural profitability of parcels while farmers opinions may be systematically biased due to behavioral biases such as salience of recent events or simply lack of knowledge or experience with land transactions (Bigelow et al. 2020). Despite the differences in our data and models, we find some important parallels in the direction of our results. Overall, in line with Bigelow et al. (2019), we find lower land values in GWS permit counties, specifically in outside-district parcels. Another interesting and important comparison between both studies is the estimate of depth-to-groundwater. These studies found that inside districts, increase in depth-to-groundwater had statistically insignificant effect on land values inside districts and a negative and statistically significant effect outside districts. This comparison provides support for the modeling decision of separating lands with secure surface water rights (inside districts) from those with primary dependence on groundwater (outside districts) in hedonic analyses of water transfers and groundwater variables. This concurrence in the direction of the results is potentially significant for applied economics work that often relies on self-assessed data for hedonic analysis, particularly for agricultural land values.

The magnitude of the estimates in both studies are quite different. For instance, our results show that in the full sample, counties with a GWS permit requirement have, on average, 34% lower ($6,044 per acre) land values than counties that do not have this requirement, compared with a lower estimate of $2,057 per acre in Bigelow et al. (2019). Also, we found that outside-district agricultural parcel values were lower by 11% ($1,931 per acre), whereas Bigelow et al. (2019) found that outside-district parcels were lower by $3,318 per acre, a higher estimate. The magnitude of the estimates of depth-to-groundwater is quite different as well; $233 per foot in Bigelow et al. (2019) and $45 per foot in our estimate in the full sample. These differences in magnitudes may be important to consider if results are being used to develop specific costs estimates or compensation policies.

Another important difference in results is that while Bigelow et al. (2019) found that the difference in values in outside-district parcels along the GWS permit margin reduced over time, we found that not to be the case. As Figure 4 shows, the difference is that land values in outside-district parcels is large and perhaps getting larger over the years. To do an "apples-to-apples" comparison, we estimated our model 4 for 2000–2009; that is, for almost the same time period as Bigelow et al. (2019). Results show that, on average, GWS permit counties have 40% lower land values in the full sample but an opposite effect on inside- and outside-district parcels.[21] Parcels outside districts have 24% higher value if they were in GWS permit counties, whereas parcels inside districts have 45% lower values if they are in GWS permit counties.

Overall, these comparisons suggest the possibility of an evolution in land values associated with the implementation of GWS permit requirements in the 20+ years since their enactment. In 2000–2009, the first decade after GWS permits were implemented, permit requirements may have been a strong signal to district farmers from the county against GWS-based transfers and restricted transfers out of the region, particularly in the first drought after the restrictions were passed, a result that Bigelow et al. (2019) captured. But over time, as our results show, GWS permit requirements have not been a binding constraint against transfers; GWS-based transfers have occurred, and thus short-term response to the permits has subsided. Our interpretation of the GWS permit variable is that it captures the longer-term structural differences in local agricultural economies. Our results provide support to the idea that GWS permit were instituted as a defensive strategy in areas where land values among nonsellers in the water market were lower. We find no evidence of negative effects of water transfers on outside-district parcel land values or of GWS permit requirements on inside-district parcels. It is possible that some of the harmful transfers

[21] Full results of model 4 estimated for 2000–2009 are shown in Appendix Table B3.

may have been screened by GWS permit requirements, which helped protect these lands from excessive groundwater depletion and economic loss. Finally, it is important to note that without temporal variation in GWS permit requirements, neither study makes a causal claim regarding the effect of GWS permits on land values.

7. Robustness Checks

In constructing our filtered sample of ZTRAX parcels and specification of the econometric model, we made several assumptions. We check the robustness of our main results by changing some of these key assumptions. Specifically, we present results for (1) disaggregating water transfers by mode of transfer, (2) dropping parcels farther from urban boundaries, and (3) replacing county fixed effects with zip-code fixed effects. Tables for these results are provided in Appendix B.

We have data for mode of water transferred; that is, CI, GWS, or a combination of both, for each district for 2008–2019. We adapt econometric model 5 and replace $WT_{d(t-k)}$ with volume of water transferred for each mode as a separate explanatory variable.[22] Results help illuminate whether the association between total annual water transfers and land values differs by mode of water transferred. Appendix Table B4 shows that CI-based transfers during droughts are associated with the highest increase in land values in subsequent years, whereas GWS-based transfers have a statistically insignificant association with land values. Some districts transferred via a combination of GWS and CI, and such transfers also show a positive association with later land values. Overall, in our study area CI transfers may be associated with larger increase in returns from water transfers relative to opportunity costs of forgone agricultural production, and GWS, while still profit-maximizing for water sellers, is associated with increased groundwater pumping costs and county-level transactions costs in obtaining permits for such transfers.

Next, we explore the sensitivity of our main results to urban influence in our ZTRAX sample. It is well established that agricultural parcels closer to urban areas have higher land values and may affect results of hedonic analysis (Zhang and Nickerson 2015; Ortiz-Bobea 2020). We drop parcels in successively larger zones of proximity to the urban boundary to test the robustness of our results to reducing the urban proximity of our sample. We drop parcels within 2,500 m (1,163 observations dropped), 5,000 m (1,691 observations dropped), and 10,000 m (2,054 observations dropped) from an urban boundary. Estimated coefficients of volume of water transferred and depth-to-groundwater in model 4 are summarized in Appendix Tables B5 and B6. In line with our main results, we observe that transfers from all districts in the county are associated with a statistically significant increase in inside-district parcel values and a statistically insignificant association with value of outside-district parcel. The magnitude of the estimated coefficient in land values associated with $WT_{c(t-1)}$ is higher in the smallest sample, from 1.43% ($271 per acre) inside districts in the main results to 2.5% ($369 per acre) inside districts in the smallest sample, but like our main results, the effect diminishes to zero four years after transfers. Increase in depth-to-groundwater is associated with a significant decline in land values in outside-district parcels and negative but a statistically insignificant effect in inside-district parcels (Appendix Table B6), which is also in line with our main results. The magnitude of the coefficient is larger in the smallest sample, but the estimated marginal effect is lower due to lower land values in the smaller sample. Compared with –0.33% (–$57 per acre) in our main results to –0.45% ($49 per acre) for an additional decline in 1 ft. of groundwater. For model 5, results of dropping urban parcels also shows robustness to dropping parcels closer to urban boundaries. Coefficients

[22] Results for separating mode of water transfer in county-level model 4 were inconclusive. Water transfers from a county are a mix of CI and GWS, and highly positively correlated with each other in a year, so it is difficult to tease apart the marginal effects of each mode in county-level transfer model. We exploited spatial heterogeneity in the occurrence of GWS transfers post-2007 and found that presence of any GWS transfers (in all but Butte and Tehama Counties) had a statistically insignificant association with outside-district land values.

of water transferred from the district during drought years are positive and statistically significant in line with our main results, and the effect is short-lived as well, dissipating to zero three years after transfers were conducted (Appendix Table B7). In summary, the pattern of the main results is robust to reducing urban proximity of the sample.

As a final robustness check, we replace county fixed effects in our main model with parcel zip codes. In our sample, each county has 15–20 zip codes, which offers more granular spatial controls for each parcel, controlling for unobserved parcel-level variation not captured in parcel and county controls. Estimated coefficients of volume of water transferred and depth-to-groundwater in model 4 are summarized in Appendix Tables B8 and B9. Again, we observe that in line with our main results, transfers from all districts in the county are associated with a statistically significant increase in inside-district parcel values and a statistically insignificant effect is in the outside-district parcels. The magnitude of the increase in land values in the smallest sample is 1.42% inside districts for $WT_{c(t-1)}$ is close to what we observed in our main results, 1.43%, and again the effect diminishes to zero four years after transfers. With zip code controls, the marginal value of increase in depth-to-groundwater is negative but statistically insignificant in all models. For model 5 as well, Appendix Table B10 summarizes the main results; overall, results for water transfer variables are qualitatively similar to the main results. Land values increase in years subsequent to water transfers, particularly if transfers were conducted in drought years.

8. Summary and Conclusions

This study has shed some light on capitalization of water transfer benefits in the agricultural sector. Economics research has focused on the efficiency enhancing role of water markets (Howe, Schurmeier, and Shaw 1986; Leonard, Costello, and Libecap 2019), but here we focused on how those efficiency gains may be distributed among different participants in the water market. Focusing on agricultural users in a region that has been a seller of water in water markets, our results show that water market participation is valued positively by sellers. Water transfer revenues are being capitalized in farmland values, with lands inside irrigation and water districts that engage in out-of-watershed transfers, experiencing 1%–2% ($271–$361 per acre) increase in land values. However, these gains are short-lived, lasting for up to three years after transfers were undertaken and then dwindling to zero. We also found that these gains were largely driven from transfers undertaken in drought years, rather than in nondrought years, which makes sense because water prices tend to be higher in drought years. Value of parcels outside district boundaries; that is, nonsellers in the water market do not show any effects of transfers but respond to changes in depth-to-groundwater. Increase in depth-to-groundwater is associated with decrease in land values; an additional decline in 1 ft. in depth-to-groundwater was associated with a 0.3% decrease in land values ($54 per acre). As found in previous literature, increase in depth-to-groundwater has a negative effect only on outside-district lands, which tend to be more dependent on groundwater. We examined GWS permit requirements, a defensive strategy used by some counties in the study area. Our results support the notion that relatively lower-valued, groundwater-dependent, outside-district landowners may have used this policy as a precautionary strategy to protect themselves from physical externalities of water transfers. We found no evidence of decline in land values associated with of water transfers outside districts, even as GWS-based transfers are occurring, which is consistent with the idea that the permit requirements may have screened relatively more harmful transfers over time. Comparison of our results with previous work that used self-reported land values shows parallels in the direction of the results but some important differences in their magnitude and persistence over time, which suggests some trade-offs to be considered by researchers in their choice of data source for hedonic analysis.

Implementation of SGMA is likely to increase the demand of water from Sacramento Valley, with potentially an expansion of interbasin water transfers. Future research should focus on how Groundwater Sustainability Agencies (GSAs) adopt different approaches and policies regarding water transfers, for example, some GSAs may grandfather county GWS restrictions, whereas others may modify or abandon them entirely. A more careful examination of the overlapping jurisdictions of newly formed GSAs with the older institutional forms of districts and counties could allow inroads into modeling causal relationships between water policies and land values. Future research may use data on groundwater basin boundaries, made recently available in the process of SGMA implementation, to conduct a more rigorous assessment of capitalization of externalities of water transfers among nonsellers in water markets, particularly in delineating the spatial extent of the physical externalities of water transfers in outside-district parcels. In this article, we only considered distributional effects of water transfers within agricultural sectors; considering the effects on other groundwater-dependent users, such as rural residential users relying on shallow domestic groundwater wells, could be a fruitful and important direction for future research.

Acknowledgments

We gratefully acknowledge Ellen Hanak at the Public Policy Institute of California for sharing PPIC's water transfer data with the lead author of this article. We also acknowledge the comments and suggestions received from participants in the ZTRAX special issue workshops and seminar participants at California State University, Fresno. Comments and suggestions received from two anonymous reviewers and the journal editor were immensely useful in improving the article. All mistakes are the sole responsibility of the authors. Data are provided by ZTRAX. More information on accessing the data can be found at http://www.zillow.com/ztrax. The results and opinions are those of the authors and do not reflect the position of Zillow Group.

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