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Spatial Discontinuities in Water Rights: Estimating Household Willingness-to-Pay for Unmetered Irrigation Water *

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Abstract: House prices capture the value households place on environmental attributes and amenities. Access to an unlimited water right for irrigating lawns in an arid region is a prized environmental amenity. The distribution of this amenity varies across space, and often houses with these water rights are located in neighborhoods that differ substantially from other neighborhoods. This study aims to disentangle these neighborhood differences to identify the value that households place on unmetered water rights for lawn irrigation. Identification relies on a regression discontinuity design exploiting the variation in unmetered water access that occurs based on historical land use and geographic features. By examining houses on the border of the water rights zones, the analysis isolates houses that only differ by their access to unmetered irrigation water, thereby eliminating potentially correlated variation with this access, such as differences in socioeconomic attributes, local tax rates, school quality, and environmental amenities. The findings indicate that households are willing to pay a premium of 2% for access to unmetered irrigation water. This premium is not driven by factors such as lawn greenness or the curb appeal from more heavily irrigated landscapes.
Keywords: Regression discontinuity design, hedonic analysis, water conservation, irrigation
JEL Codes: D12, L95, Q21, 25

1. INTRODUCTION

Environmental attributes are frequently capitalized into house prices. These amenities can include external attributes at the regional or neighborhood level, but can also include the actual environmental attributes on the property, such as low air pollution or an appealingly landscaped lawn. The provision of these environmental attributes can result from local or regional policy decisions, such as emission testing for air quality, or water rights to facilitate green landscaping. In the arid American West, access to an unlimited water right for irrigating lawns is anecdotally a highly valued attribute. Because these water rights vary across

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space, this study's aim is to isolate and estimate the premium that households are willing to pay for unmetered irrigation water.

Prior research has often found a significant premium for a variety of aesthetics both at the property-level and neighborhood-level. For example, high quality landscaping upgrades are associated with a price premium of 5% (Henry, 1999). Similarly, the association between attractive landscape types and house prices can extend up to a premium of 12% in comparison to less attractive landscaping (Luttik, 2000). Vegetation land cover, specifically trees, has a positive price premium for properties, and this also extends across property lines to neighboring houses (Kadish and Netusil, 2012). Similar research found trees exhibit the highest price premium, but also a well-maintained lawn cover is associated with a price premium for single-family homes (Des Rosiers et al., 2002). Additionally, these premiums may depend on the buyer's household's characteristics (ROSIERS et al., 2007). Further research has found that environmental amenities have the highest premium in areas where the level of the environmental attribute is low (Bourassa et al., 2005). Extrapolating these findings in the context of the aridity and water scarcity in the American West, there may be a high premium for well-watered, green landscaped homes, given the relative scarcity of this resource.

In this paper, I investigate the premium for houses that have access to unmetered irrigation water for their lawns. This access is a result of a distinctive policy in western states where irrigation water is delivered to residential households using "secondary" water systems, which are additional water lines to each residential property. These secondary water systems are frequently remnants of agricultural irrigation systems that were never converted to treated-water systems when the land was developed for residential properties. As a result, these systems have historically remained unmetered, providing unlimited irrigation water for residential lawns at zero marginal cost. The research hypothesis is that houses with access to unmetered secondary water systems will command a price premium in the residential real estate market of the arid American West, with this premium reflecting households' willingness to pay for unrestricted lawn irrigation capabilities.

Neighborhoods with these water rights may differ substantially from neighborhoods without access to secondary water systems, requiring research methods to isolate houses that differ only in their access to these water rights. The premium that households place on access to these water rights is identified by exploiting variation in secondary water access that occurs based on historical land use and geographic features. Examining houses on either side of the border of the water right zones isolate houses that only differ by the access to secondary water, thereby mitigating the effects of variables potentially correlated with secondary access, such as differences in socioeconomic attributes, local tax rates, school quality, and other environmental amenities. The regression discontinuity design (RDD) is a widely-used and developed research method to identify premiums based on variation in house prices across geographical boundaries (Lee and Lemieux, 2010).

These methods result in an estimated premium of 2% on houses with access to unmetered irrigation water. This premium is roughly 40% of the size of the premium found when not considering neighborhood differences and looking at the entire sample of houses with access to secondary water compared to those without. This premium is likely not driven by differences in lushness or greener landscapes that may be associated with unrestricted water access, given that there is no difference in the premium between summer months and the rest of the year. This finding of the premium is robust to multiple specifications and falsification tests using artificial boundaries as a placebo test.

This research makes several important contributions to the literature and policy discussion. Given the water demand pressures from ongoing population growth, combined with projections for future droughts in the American West, understanding the value of water access for households yields critical insights into effectively managing water supplies. The study area is located within the Great Salt Lake water basin, which is under significant pressure due to a warming climate leading to higher rates of evaporation in the lake. Concurrently, rapid population growth has contributed to more water use resulting in less water entering the lake. The Great Salt Lake's decline has spurred many policy debates to more effectively conserve water in the region. As new metering technology has been developed that can measure household-level flows of unfiltered secondary water, a new opportunity to conserve water has been created. All new developments have these household-level meters installed, but as this technology becomes more affordable for retrofits on existing properties, the potential for metering and then charging fees based on use could be forthcoming. By better understanding the price premium captured in house prices, policymakers can better anticipate the potential pushback from households toward water pricing policies, as well as more broadly understanding the value that residents place on irrigation water availability.

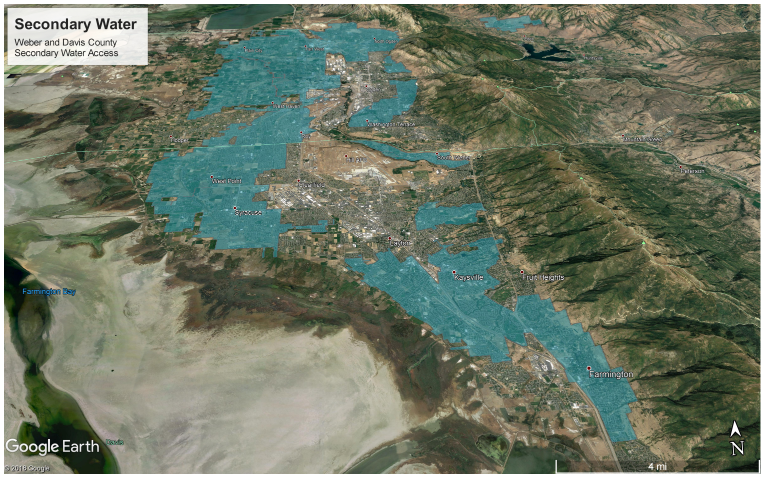
2. BACKGROUND

Unmetered residential irrigation water is a relatively common benefit for properties in American West regions originally developed as farmland. Secondary irrigation water systems were installed for the fields at a lower cost due to gravity-pressured water reservoirs. These irrigation systems were denoted "secondary" because they were installed in addition to the primary culinary water system, which provided potable water for residents in the region. As the population has grown in the American West, many of these farmlands have been converted into residential housing to meet the housing demands. This residential development has included the continued provision of irrigation water to the residential houses. Similar to the original provision of water rights per acre, the intention was to ensure that landholders did not lose any access to water as the farmland was converted to alternate uses.

Prior to 2010, it was not feasible to meter unfiltered secondary water at the property level at a reasonable cost. Therefore, households paid a single flat fee annually for virtually unlimited access to irrigation water through this secondary source. The only binding constraint would be if the reservoir reached certain levels, which would require the water authorities to turn off the secondary water systems to maintain critical levels of culinary water. In Northern Utah, this happened in late summer most recently in 2021 and 2022 due to the ongoing drought causing low reservoir levels.

Recently, individual residential households have begun to have meters installed to understand how this water is being used. Currently, all retrofitted meters in Northern Utah are purely used for informational purposes for the residents, not for pricing based on actual use. The information gathered from these meters is particularly important for drier western states; for example, Utah uses 72% of its water for irrigation (residential and agricultural),

Figure 1: Unmetered Secondary Water Availability for Residential Properties



compared to a national average of 33% (Chidsey Jr et al., 2018).

Future climatic projections anticipate the American West will continue to get hotter and drier, while the populations in these states are growing at the most rapid pace in the United States. This demand shift due to population pressure combined with a decrease in supply due to potentially decreasing precipitation has forced policymakers to determine avenues to sustainably use water. Many potential policies involve getting the right price on water use to prevent overuse. Understanding the value residents place on residential irrigation water is an important first step in the process for sustainably managing water in this region.

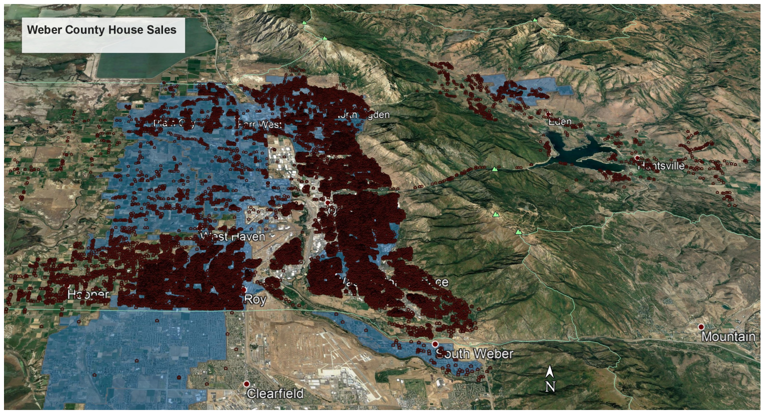
3. DATA

The study area for this analysis is Weber County, Utah. Weber County is a mix of urban and rural areas, 45 minutes north of Salt Lake City. The Ogden-Clearfield Metropolitan Statistical Area covers portions of the county. The county is split across the Wasatch Range with the more rural part of the county residing in the valley to the east of the mountains and the more urban part of the county lying to the west.

Secondary water access data were provided by the Weber Basin Water Conservation District (WBWCD) covering Northern Utah. This geographic data contains detailed parcel-level boundaries of the locations of unmetered irrigation water access in this region (Figure 1). Approximately 58% of the residential properties in this area have access to this unmetered secondary water.

The key data used for the analysis was built by linking the geographical boundaries of the secondary water to arms-length transaction data for Weber County, Utah for the years 1999 to January 2020 (Figure 2). This captures relatively recent market trends and water policy, but avoids the shocks to the housing market due to the Covid-19 pandemic, inflation rates following the pandemic, and the interest rate response. The tradeoff is the analysis is not able to provide insights into how the secondary water premium behaves during

Figure 2: Unmetered Secondary Water Availability for Residential Properties



periods of significant market disruption. Utah and many other states in the American West (e.g. Idaho, Wyoming, Montana) are non-disclosure states for property sales, making the acquisition of reliable data challenging because property sales are not required to be reported or recorded in a public database. Property buyers and sellers that do not use a real estate agent can choose to keep the sale price anonymous. As a result, data acquisition must go through MLS provided sources and is not available publicly. Because of the constraints of the available data, the findings of this study should be interpreted cautiously, particularly when extrapolating to other geographic regions.

The data from this study was acquired through the local Multiple Listing Service (MLS), which includes structural and property attributes, transaction price, and address. The analysis includes only single-family residential properties with sale prices between \$30,000 and \$1,500,000, eliminating properties with near zero sale prices. Two measures define neighborhoods in the study. First, neighborhood boundaries were collected using Neighborhood Scout designations. These designations are calculated based on data on crime, school quality, and a variety of demographics. The analysis also uses each boundary between secondary and non-secondary water as an alternative fixed effect. These boundaries often split houses in the same neighborhood and directly control for different areas of the county by looking at the within variation in house prices that occur along each boundary.

Spatial and location variables are calculated using ArcMap and Google Maps API. The variable "view" captures whether the property description specifies if there is a view of the nearby mountains from the property. Travel time in minutes from each property to the main Central Business District, downtown Ogden, was calculated using Google Maps API. ArcMap was used to calculate the elevation of each property, as this region is mountainous and properties higher up the mountains are valued for their views, outdoor access, and cleaner air.

During the time period of this sample, properties in Weber County had a mean sale price of 187,592 and an average size of just over 2,000 square feet, as seen in the summary statistics (Table 1). The average house has approximately 3.2 bedrooms despite the fairly modest square footage, which is likely an artifact of the typically large family sizes of the

Table 1: Summary Statistics

	Mean	St. Dev.	Min	Max
Sold Price ($)	187,592	118,976	30,030	1,475,000
Secondary Water	0.583	0.493	0	1
House Size ('000 sq ft)	2.033	0.975	0.06	13.45
Acreage	0.354	4.613	0	555.5
House Age	33.93	29.91	0	162
Bedrooms	3.223	1.095	1	22
Bathrooms	2.544	1.146	1	10
Downtown Ogden (min)	10.01	5.358	0.046	68.28
Air Conditioning	0.583	0.482	0	1
Deck	0.359	0.539	0	1
Swimming Pool	0.056	0.231	0	1
Fireplace	0.500	0.500	0	1
Elevation ('000 ft)	4.466	0.242	4.213	8.363
View	0.653	0.476	0	1
Cul-de-sac	0.098	0.297	0	1
Corner Lot	0.126	0.332	0	1

predominant religion in the county, The Church of Jesus Christ of Latter-Day Saints. Half of the properties have fireplaces, while slightly over half have air conditioning, and the mean property size is over a third of an acre. The mountains are easily visible throughout the region, and almost two-thirds of the properties have a view of the mountains.

4. METHODS

The standard hedonic pricing method was developed based on the idea that consumers purchase differentiated goods because of the bundle of characteristics in that product (Lancaster, 1966). The equilibrium price therefore reflects the implicit price of each characteristic (Rosen, 1974). This hedonic pricing method is frequently applied to a variety of environmental goods and services (Holmes, 1998; Harrison Jr and Rubinfeld, 1978; Nicholls and Crompton, 2005; Asabere and Huffman, 2009). Hedonic models use the following relationship:

$$\ln p_{ijt} = \alpha + X_{it}\beta + Z_j\delta + \gamma Secondary_i + \eta_t + \epsilon_{ijt} \tag{1}$$

where the natural log of the sales prices, p_{ijt}, of house i at time t in neighborhood j, is a function of a vector of property and location attributes, X_{it}, neighborhood attributes, Z_j, a dummy variable indicating whether or not that house has access to unmetered irrigation water, *Secondary*, and a month/year fixed effect, η_t.

Following a regression discontinuity design framework (Holmes, 1998; Black, 1999; Hahn et al., 2001; Micheli et al., 2019), there are potentially omitted variables at the house or neighborhood level which may bias the results. First, these could include school quality or public good provision at the spatial scale of those public goods, changing discretely over space at these boundaries. Second, these include omitted variables that may smoothly vary across space, such as air quality. Using Black's (1999) identification strategy, the vector of neighborhood variables are replaced with a set of boundary dummy variables that indicate houses within a set buffer around the boundary for secondary water. Three buffers are specified: less than 1,000 feet, less than 500 feet, and less than 100 feet, the last of which essentially captures houses on either side of streets split apart by the boundary for secondary water.

The advantages of this methodology are twofold. First, these methods account for any unobservable omitted variables that are shared by houses in each buffer on either side of the secondary water boundary. Any omitted variable that is discrete, such as public good provisions and school catchment zones, is unlikely to correspond to secondary boundaries, and any omitted variable that varies smoothly across space is mitigated by the houses in close proximity to each other on either side of the boundary. Second, this is conceptually appealing and easy to interpret for policymakers as the analysis is essentially comparing the means of the house prices across the boundary after controlling for house characteristics, which is interpreted as the premium that households are willing to pay for secondary water.

5. RESULTS

5.1. Running Variables

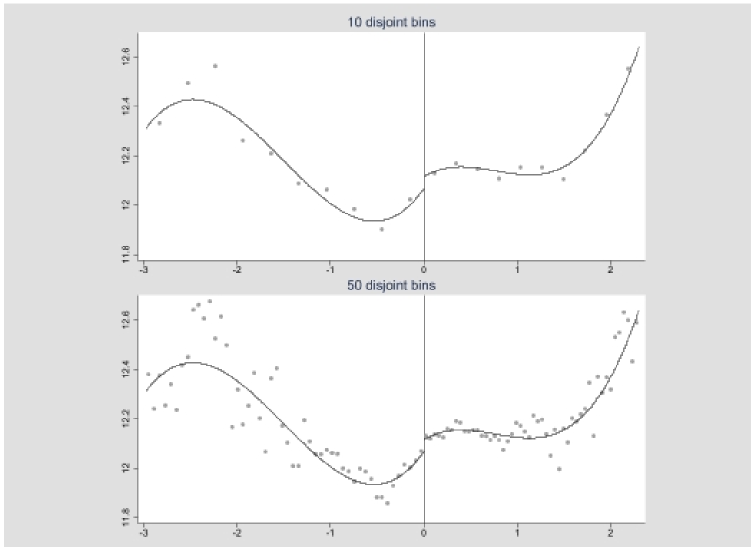
Prior to estimating the regression equation, the distance from the border for the unmetered irrigation water is calculated as the running variable to visualize the relationship between house prices and the geographic border. Positive values of the running variable indicate houses with access to secondary water, while negative values indicate houses that do not have access. Using binned scatter plots with two different bin sizes (10 and 50) balances detail and smoothness in the graphical representation for a 3rd degree polynomial fit. In both cases, a discontinuity is visually apparent at the threshold, indicating a border discontinuity in house prices (Figure 3).

Plots were also created to investigate whether the covariates are balanced to ensure that the observed discontinuity in house prices is due to the access to unmetered irrigation water rather than other observable factors. Scatter plots of the covariates are suggestive that there are not substantial discontinuities on either side of the boundary line (Figure 4). Smooth transitions across the border indicate that the estimated premium for houses with access to unmetered irrigation water is not confounded by discontinuities in these important covariates.

5.2. Regression Results

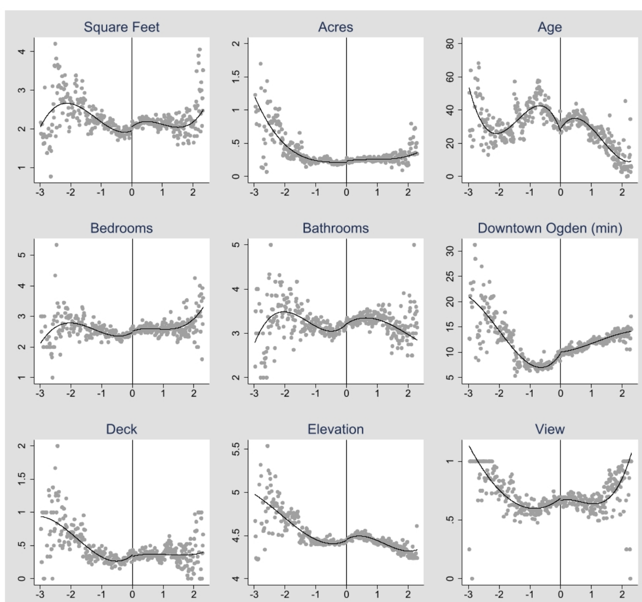
The regression model presented in Section 4 yields estimates for the premium of unmetered irrigation water access (Table 2). To address potential spatial correlation among error terms within the RDD specifications, boundary segment fixed effects are included in each regression, and the standard errors are clustered by the boundary segment (Gonzalez, 2021). Column 1 includes results from the full sample of properties, while Columns 2-4 include results from the various buffers around the secondary water boundary. House and parcel size follow the

Figure 3: Regression Discontinuity Plots



Notes: Plots for house prices and distance to secondary boundary. Fitted to a third-degree polynomial.

Figure 4: Regression Discontinuity Covariate Plots



Notes: Regression discontinuity covariate plots for distance to secondary boundary. Fitted to a third-degree polynomial.

expected relationship; bedrooms, bathrooms, air conditioning, and fireplaces are all highly valued across all specifications. Swimming pools are a negative amenity, likely due to the high maintenance and upkeep costs, particularly given the low summer night temperatures necessitating the heating of the pools. Geographically, corner lots and houses in cul-de-sacs are highly valued, as are houses at higher elevations and those with a view of the mountains.

Across all properties, there is a 3.7% premium for houses with secondary water. This premium tends to decline as the buffer around the boundary shrinks, which likely illustrates the biased estimates for the premium for secondary water access in Column 1. Column 4 presents the results on either side of the boundary for secondary water access, yielding an estimate of the premium for this access of 1.98%.

5.3. Neighborhood Effects

Similar results are presented with the full samples and three buffers using neighborhood fixed effects rather than boundary fixed effects (Table 3). The results are similar in magnitude across the specifications, with a slightly larger point estimate for the premium across all properties (7.8%). However, when restricting the analysis to those within the three buffers, there is a similar statistically significant premium for secondary water access between 2.48% and 2.01% depending on the buffer size.

6. ROBUSTNESS

6.1. Seasonal Analysis

The main analysis may reflect both the value of access to unmetered irrigation water, but also it may reflect potential differences in landscaped spaces for houses with unmetered irrigation. It is plausible that houses with access to secondary water may exhibit more lush, well-maintained landscaping during the summer months. This region of the country typically has hot, dry summers, and without irrigation lawns will quickly turn brown and die off. If houses have to use paid for, culinary water to irrigate their lawns, they may use less water and have browner lawns as a result. This difference in landscaping appeal (Gourley, 2021) could be driving the observed price premium, rather than the water rights themselves. Further, if neighboring lots or greenspaces are lusher, this proximity to high quality urban greenery could positively impact house prices (Morancho, 2003; Netusil et al., 2014; Li et al., 2015; Walls et al., 2015; Sachs et al., 2023). If either of these mechanisms lead to higher house prices, this could bias the results leading to an overestimate of the premium for secondary water.

The greenery effect can be disentangled from the premium for secondary water access by conducting a robustness check that excludes all transactions that occurred during the summer months (June, July, and August) from the analysis. The rationale for this approach is that landscape differences between properties with and without unmetered water will be most pronounced during the hottest, driest months of the year. During cooler seasons and wetter seasons of the year, there will be less visual disparity in “greenness” of the lawns and the premium in those months will reflect the access to the water right, rather than differences

Table 2: Regression Results Using Boundary Fixed Effects. Dependent Variable is Natural Log of the Real House Price

Variable	All Houses	<1000ft	<500ft	<100ft
Secondary Water	0.0368***	0.0395***	0.0304***	0.0198**
	(0.003)	(0.004)	(0.005)	(0.010)
House Size ('000 sq ft)	0.1510***	0.1060***	0.1007***	0.1576***
	(0.007)	(0.011)	(0.015)	(0.027)
House Size Squared	0.0078***	0.0143***	0.0146***	0.0091
	(0.001)	(0.002)	(0.003)	(0.006)
Acreage	0.0011*	0.0275	0.0877***	0.1766***
	(0.001)	(0.018)	(0.027)	(0.036)
House Age	-0.0039***	-0.0037***	-0.0039***	-0.0038***
	(0.000)	(0.000)	(0.000)	(0.000)
Bathrooms	0.0287***	0.0238***	0.0256***	0.0263***
	(0.001)	(0.002)	(0.003)	(0.008)
Bedrooms	0.0697***	0.0603***	0.0570***	0.0492***
	(0.002)	(0.003)	(0.004)	(0.009)
Downtown Ogden (min)	0.0074***	0.0087***	0.0114***	0.0095***
	(0.000)	(0.001)	(0.001)	(0.002)
Air Conditioning	0.0796***	0.0703***	0.0813***	0.0763***
	(0.002)	(0.004)	(0.005)	(0.012)
Deck	0.0214***	0.0160***	0.0067	0.0208**
	(0.002)	(0.003)	(0.005)	(0.009)
Swimming Pool	-0.1137***	-0.0552***	-0.0477***	0.0418
	(0.005)	(0.008)	(0.013)	(0.047)
Fireplace	0.0741***	0.0625***	0.0499***	0.0145
	(0.002)	(0.004)	(0.005)	(0.013)
Elevation ('000ft)	0.0421***	0.1027***	0.1011***	0.0764*
	(0.006)	(0.012)	(0.015)	(0.044)
View	0.0590***	0.0577***	0.0498***	0.0290**
	(0.002)	(0.004)	(0.005)	(0.012)
Cul-de-sac	0.0152***	0.0180***	0.0246***	0.0487***
	(0.003)	(0.005)	(0.006)	(0.014)
Corner Lot	0.0187***	0.0232***	0.0163***	-0.0100
	(0.003)	(0.004)	(0.006)	(0.013)
Constant	11.3196***	11.0503***	11.0085***	10.8637***
	(0.033)	(0.089)	(0.102)	(0.217)
Observations	74,375	22,454	11,385	1,906
R-squared	0.7417	0.7502	0.7462	0.7733
Boundary FE	Yes	Yes	Yes	Yes
Month/Year FE	Yes	Yes	Yes	Yes

Notes: Standard errors clustered at each boundary segment. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Regression Results Using Neighborhood Fixed Effects. Dependent Variable is Natural Log of the Real House Price

Variable	All Houses	<1000ft	<500ft	<100ft
Secondary Water	0.0078***	0.0248***	0.0235***	0.0201**
	(0.003)	(0.004)	(0.005)	(0.011)
House Size ('000 sq ft)	0.1632***	0.1200***	0.1090***	0.1617***
	(0.007)	(0.010)	(0.015)	(0.025)
House Size Squared	0.0068***	0.0132***	0.0144***	0.0094
	(0.001)	(0.002)	(0.003)	(0.006)
Acreage	0.0017**	0.0343	0.0975***	0.1895***
	(0.001)	(0.021)	(0.027)	(0.033)
Age	-0.0038***	-0.0038***	-0.0039***	-0.0041***
	(0.000)	(0.000)	(0.000)	(0.000)
Bathrooms	0.0246***	0.0206***	0.0226***	0.0231***
	(0.001)	(0.002)	(0.003)	(0.008)
Bedrooms	0.0677***	0.0598***	0.0572***	0.0471***
	(0.002)	(0.003)	(0.004)	(0.008)
Downtown Ogden (min)	0.0114***	0.0113***	0.0115***	0.0096***
	(0.000)	(0.001)	(0.001)	(0.002)
Air Conditioning	0.0681***	0.0629***	0.0796***	0.0771***
	(0.002)	(0.004)	(0.005)	(0.012)
Deck	0.0233***	0.0174***	0.0084*	0.0211**
	(0.002)	(0.003)	(0.005)	(0.009)
Swimming Pool	-0.1057***	-0.0700***	-0.0723***	0.0417
	(0.005)	(0.008)	(0.012)	(0.042)
Fireplace	0.0750***	0.0642***	0.0493***	0.0118
	(0.002)	(0.004)	(0.006)	(0.012)
Elevation ('000ft)	0.0379***	0.0545***	0.0565***	0.0539
	(0.007)	(0.014)	(0.018)	(0.046)
View	0.0615***	0.0555***	0.0496***	0.0355***
	(0.002)	(0.004)	(0.005)	(0.011)
Cul-de-sac	0.0108***	0.0160***	0.0229***	0.0360**
	(0.003)	(0.005)	(0.006)	(0.014)
Corner Lot	0.0159***	0.0239***	0.0186***	-0.0136
	(0.003)	(0.004)	(0.006)	(0.014)
Constant	11.1422***	11.1068***	11.0899***	11.0645***
	(0.033)	(0.062)	(0.082)	(0.202)
Observations	74,375	22,454	11,385	1,906
R-squared	0.7343	0.7431	0.7419	0.7741
Boundary FE	Yes	Yes	Yes	Yes
Month/Year FE	Yes	Yes	Yes	Yes

Notes: Standard errors clustered at each neighborhood. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Regression Results Using Non-Summer Month Sales. Dependent Variable is Natural Log of the Real House Price

Variable	All Houses	<1000ft	<500ft	<100ft
Secondary Water	0.0363***	0.0404***	0.0343***	0.0220*
	(0.003)	(0.004)	(0.006)	(0.011)
Observations	53,027	16,041	8,103	1,379
R-squared	0.7430	0.7491	0.7489	0.7985
Control Variables	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes
Month/Year FE	Yes	Yes	Yes	Yes

Notes: Control variables include the complete set of variables presented in Table 2. Standard errors clustered at each boundary segment. *** p<0.01, ** p<0.05, * p<0.1.

in curb appeal of the properties.

The regression models from Table 2 are re-run using this restricted dataset. If the price premium observed earlier in the main analysis is primarily driven by greener lawns in summer months, there would be a substantially reduced or non-existent premium in this model. However, if the premium persists, this is evidence that the access to unmetered secondary water is valuable, not merely the visual reflection of that access manifested through greener landscapes.

The results are statistically and numerically similar using this restricted sample (Table 4). Despite losing slightly more than 25% of the observations (unsurprisingly, a disproportionately large number of sales happen in the summer months compared to the other seasons), the point estimates and statistical significance of the estimates are similar across the entire geographic region, and each of the three boundary restrictions, and the point estimates are actually slightly larger in magnitude on this restricted sample, suggesting that the majority of the premium is not driven by seasonal variation in landscape quality. Additionally, restricting the sample to each individual season (spring, summer, autumn, winter) yields a statistically significant and premium between 2-3% for each specification (results available from the author upon request).

A second approach to model this phenomenon is through interacting the secondary water variable with a summer dummy variable that indicates whether the property sale occurred during a summer month. Estimates from this interaction in the RDD are similar to the previous estimated premium for secondary water (Table 2). Houses sold during the summer months on average sell for higher prices than houses sold during other times of year. This reflects the well-known seasonality of the property market. The estimated premium for secondary water remains sizeable and statistically significant. Notably, there is no evidence of an additional premium for secondary water during the summer months. Even when transactions are made outside of the peak irrigation months, buyers still are willing to pay a substantial premium for properties that offer unmetered water access. Both sets of results in this section support the main findings in this paper, that households place a substantial

Table 5: Regression Results Testing for Higher Premiums for Secondary Water During Summer Month Sales. Dependent Variable is Natural Log of the Real House Price

Variable	All Houses	<1000ft	<500ft	<100ft
Secondary Water	0.0371***	0.0403***	0.0348***	0.0210**
	(0.003)	(0.004)	(0.006)	(0.010)
Summer	0.0199***	0.0257***	0.0352***	0.0699***
	(0.004)	(0.006)	(0.008)	(0.020)
Secondary*Summer	-0.0013	-0.0030	-0.0136	-0.0226
	(0.005)	(0.007)	(0.010)	(0.025)
Observations	74,375	22,454	11,385	1,906
R-squared	0.7406	0.7483	0.7441	0.7688
Control Variables	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes
Month/Year FE	Yes	Yes	Yes	Yes

Notes: Control variables include the complete set of variables presented in Table 2. Standard errors clustered at each boundary segment. *** p<0.01, ** p<0.05, * p<0.1.

value on access to unmetered secondary water, and this value is not merely due to immediate aesthetic benefits such as differences in curb appeal that would be more prominent in the summer than during other seasons.

6.2. Heterogenous Effects

While the estimated premium of having access to secondary water is relatively consistent across the various specifications, the valuation of secondary access may vary across property types. Interaction effects are estimated between secondary water access and property characteristics to identify differences in the premiums across different properties. Table 6 presents the results of interactions between secondary water access and lot size, as well as secondary water access and house size. While findings are consistent for the full sample, for conciseness Table 6 shows results using properties within 500 feet and 100 feet of the boundary.

There is no statistically significant difference in premium for larger lots, indicating that purchasers of larger properties do not value the premium differently than smaller properties, despite the theoretical prediction that it would be less costly to irrigate smaller properties using primary culinary water. This finding may reflect that larger lots are more expensive, and thus these consumers may be less price sensitive to relatively small expenditures like water bills. Consistent with this hypothesis, buyers of larger houses exhibit a diminished premium for secondary access than those of smaller houses. These findings suggest that further investigation into the heterogenous effects of secondary water access could yield important insights into the relationship between individuals or property characteristics and the valuation of water infrastructure.

Table 6: Regression Results Examining Whether the Premium for Secondary Water Varies Across Property Types. Dependent Variable is Natural Log of the Real House Price

	Impact of lot size		**Impact of house size**	
Variable	<500ft	<100ft	<500ft	<100ft
Secondary Water	0.0275*	0.0223**	0.0750**	0.0756*
	(0.012)	(0.011)	(0.016)	(0.032)
Secondary*Acres	0.0115	-0.0314		
	(0.047)	(0.065)		
Secondary*Sqft			-0.0231**	-0.0327*
			(0.008)	(0.015)
Observations	11,385	1,906	11,385	1,906
R-squared	0.7462	0.7734	0.7466	0.7741
Control Variables	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes
Month/Year FE	Yes	Yes	Yes	Yes

Notes: Control variables include the complete set of variables presented in Table 2. Standard errors clustered at each boundary segment. *** p<0.01, ** p<0.05, * p<0.1.

6.3. False Boundary Analysis

A key identifying assumption in this model is the absence of spatially varying unobservable factors that are correlated with the boundary between areas with and without secondary water access. These unobservables, which could range from historical land use patterns, street layouts, distance to amenities, or socioeconomic sorting across space, could bias the estimates of the premium for secondary water.

To test for the presence and potential impact of these spatially varying unobservables, I employ a falsification test using artificial boundaries following a well-developed strategy in analyses that rely on a geographical discontinuity RDD (Becker et al., 2016; Buggle, 2016; Conklin et al., 2020; Oto-Peralías, 2020). If the main results are driven by the water boundary itself, rather than an underlying spatial trend, then there should not be any effect when false secondary water boundaries are used for the analysis.

False boundaries represent moving the actual boundary 750 and 2000 feet into the non-secondary areas and also by moving the boundary 750 and 2000 feet into the area with secondary water, respectively. These new boundaries are likely to be correlated with unobservable factors that vary across space in similar ways to the secondary water access points, but properties across these false boundaries all have the same access (or non-access) to secondary water.

For each of these false boundaries, the RDD analysis is replicated, treating houses on one side of the boundary as if they have access to unmetered irrigation water and houses on the other side of the boundary as if they do not have access. If the original results are robust, there should not be any price discontinuities across these false boundaries.

Table 7: Regression Results Using Artificial Boundaries Moved Into the Secondary Water Areas. Dependent Variable is Natural Log of the Real House Price

Variable	False Boundary 750ft <500ft	False Boundary 750ft <100ft	False Boundary 2000ft <500ft	False Boundary 2000ft <100ft
Secondary Water - Artificial Boundary	0.0004	0.0081	0.0019	0.0076
	(0.004)	(0.008)	(0.005)	(0.011)
Observations	13,669	2,824	8,019	1,616
R-squared	0.7473	0.7793	0.7366	0.7585
Control Variables	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes
Month/Year FE	Yes	Yes	Yes	Yes

Notes: Control variables include the complete set of variables presented in Table 2. Standard errors clustered at each boundary segment. *** p<0.01, ** p<0.05, * p<0.1.

Results from all four artificial boundaries can be found in Tables 7 and 8. Columns 1 and 3 in both tables restrict the analysis to buffers within 500 feet on either side of the artificial boundary. Columns 2 and 4 present the analyses with 100-foot buffers of the artificial boundaries. Table 7 presents results where the artificial boundary was moved 750 feet and 2000 feet into the secondary area, while Table 8 presents the results where the artificial boundary was moved 750ft and 2000ft respectively into the non-secondary areas. All regression discontinuities fail to identify a statistically significant premium associated with differences in the artificial boundary.

7. CONCLUSION

Environmental attributes are capitalized into the sale price of houses, allowing policymakers the ability to understand the premium households are willing to pay for a specific environmental good or service. Access to an unlimited water right for irrigating lawns is a highly valued attribute in the arid American West.

I estimate the value of access to unmetered irrigation water through a regression discontinuity design which isolates differences in house prices on either side of a boundary separating those with access and those without. The remaining difference in mean house value across this boundary after controlling for property attributes is the valuation of this access.

Households are willing to pay a premium of approximately 2% for access to secondary irrigation water. This result indicates that access to secondary water is highly valued, approaching the value of an additional bathroom for houses in the sample. This finding is indicative of the value of secondary water access in Northern Utah. While the context may be similar to other regions in the arid American West, direct extrapolation outside the study area must be done cautiously absent further research on a broader geographic region.

Several promising avenues exist for future research on this topic. These include, but

Table 8: Regression Results Using Artificial Boundaries Moved Into the Non-Secondary Water Areas. Dependent Variable is Natural Log of the Real House Price

	False Boundary 750ft		**False Boundary 2000ft**	
Variable	<500ft	<100ft	<500ft	<100ft
Secondary Water - Artificial Boundary	0.0023	0.0024	0.0040	-0.0218
	(0.006)	(0.013)	(0.007)	(0.015)
Observations	7,830	1,595	6,026	1,415
R-squared	0.7604	0.7892	0.7842	0.8007
Control Variables	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes
Month/Year FE	Yes	Yes	Yes	Yes

Notes: Control variables include the complete set of variables presented in Table 2. Standard errors clustered at each boundary segment. *** p<0.01, ** p<0.05, * p<0.1.

are not limited to extending the analysis to other geographic regions, identifying temporal changes in the premium through variation in drought periods, investigating the influence of different demographic characteristics on the size of the premium, and exploring whether access to secondary water influences landscaping decisions, such as xeriscaping vs traditional lawns.

Such research directions are especially relevant given the ongoing policy debate about effective measures to conserve water in dynamic regions that are experiencing demand pressures from population growth, and supply pressures due to climate change reducing the supply of water. As new technology facilitates better measurement of irrigation water using the secondary water lines, households may expect to pay the full price of this previously highly subsidized benefit to homeowners in certain neighborhoods. Furthermore, knowledge of these values is critical to understanding potential pushback from households toward water pricing policies based on use, as well as understanding the value that residents place on irrigation water availability.

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