DEPARTMENT OF ECONOMICS

Home Cultivation in New Mexico

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Executive Summary

In early April 2021, cannabis consumption for adults 21 and older became legal in New Mexico in April 2021. Home cultivation of up to 6 plants per person and 12 plants per household followed on June 29, 2021. The implications for residential water use were unknown due to a lack of information on the prevalence of home cultivation and the water requirements of growers. On April 2022, the first adult-use dispensaries opened in New Mexico, offering a possible alternative to home-cultivated and illegal cannabis sources, with associated effects on residential water use.

This project studied the effects of legalization of home cultivation on water use in two phases. Phase 1 of this project was completed between September 2021 and August 2022 and used data from the Santa Fe Water Division of the Santa Fe Public Utilities Department and from a small pilot survey on home cultivation experience and preferences. Phase 2 of the study was completed between September 2022 and July 2023 and collected and used data from a much larger survey of New Mexicans. These data were used to update the analyses from Phase 1 and to create an undergraduate research project for use in introductory microeconomics courses at the University of New Mexico (UNM.)

Results from analyses of the water utility data indicated an average monthly increase in water use of 36 gallons per household or 1.27 million gallons overall following legalization of home cultivation. Significant variation in the predicted effects existed across households and increased water use was concentrated in Fall 2021 and April 2022. The analyses also show a substantial increase in water use, presumably from COVID, in 2020. Limiting the conclusions of this study, it is possible that COVID-related increases in water use continued to a more limited degree in 2021 and could be confounding estimates of the effects of home cultivation using the water utility data.

The Phase 1 pilot survey fielded generated 27 responses, disproportionately from experienced growers. Key takeaways included a preference for indoor growing, use of public utility water, and that home-cultivated cannabis can readily compete with dispensary-sourced cannabis on quality and cost.

The Phase 2 survey used target sampling quotas based on New Mexico demographic data from the U.S. Census and generated 532 responses, with the goal of better capturing New Mexican preferences for home cultivation and home cultivation practices than was possible with only 27 responses. Survey results show again that dispensary-sourced cannabis and home-cultivated cannabis are substitutes for many cannabis users. Whether dispensary-sourced or home-cultivated cannabis offer greater societal benefits is not clear, because, while home-cultivated cannabis likely lies in the middle of the quality range of cannabis products available, it generates fewer tax and economic activity benefits than dispensary-sourced cannabis.

Policy recommendations related to water use include educating growers on low-water growing methods, i.e., indoor growing and rainwater collection, and evaluating relative water use between commercial and residential growers. Survey responses suggest that the legality of home cultivation is an important quality check on the profit-motivated commercial market, implying that promoting both types of cannabis production best serves the public interest from a product safety standpoint. More general recommendations include identifying the limitations of current testing requirements for ensuring quality and tracking and publicly sharing the dispensary price and quantity data necessary to understand New Mexico's cannabis market.

Table of Contents

1. White Paper on Home Cultivation and Residential Water Use
    a. Introduction
    b. Data and Methods
        i. Santa Fe Water Utility Data
        ii. Home Cultivation Survey
    c. Results
        i. Santa Fe Water Utility Data
        ii. Home Cultivation Survey
    d. Discussion
    e. Policy Implications and Recommendations
    f. Future Work
    g. References
    h. Appendix Table
2. Undergraduate Data-Driven Research Project
    a. Overview
    b. Materials List
    c. Compressed file with materials – available separately

1. Cannabis Home Cultivation and Residential Water Use: Current Practices and Future Trajectories

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Key words: cannabis, marijuana, home cultivation, water

a. Introduction

In April 2021, adult-use, recreational cannabis became legal in New Mexico. The state's House Bill 2 (The Cannabis Regulation Act) anticipated use by 20% of adults, a rate similar to that of other states with legal adult-use cannabis. Although approved by the legislature and signed by the governor in March and April of 2021, dispensaries did not open until April 2022. Home cultivation, however, became legal on June 29, 2021. With plant counts of up to 6 plants per person or 12 plants per household among individuals, a boom in home cultivation was expected, beginning in 2021.

Home gardening rates in the broader population and medical cannabis personal production licensing rates in New Mexico support that many New Mexicans will cultivate cannabis at home. The National Gardening Association estimates that 35% of U.S. households grow food,[1] i.e., many New Mexicans possess the necessary gardening skills for basic home cultivation of cannabis. Among medical cannabis patients, all certified as suffering from severe, debilitating diseases, rates of personal production licensing ranged from 0.37 licenses per medical patient in the fourth quarter of 2012, the first year for which data are available, to 0.064 licenses in April 2021.[2] Recreational cannabis consumers are likely to be physically healthier than medical cannabis patients and do not have to complete a licensing process, meaning home cultivation by recreational users may exceed the rates seen for personal production licenses through the medical program, especially prior to dispensary entry. The decline in rates of personal production licensing among medical cannabis patients correlates with the availability of medical cannabis dispensaries, so home cultivation rates may be highest prior to dispensary entry in April 2022 with one major caveat – June 29th is a late start to the growing season and may have been too late for outdoor cultivators to grow in 2021 as cannabis plants take 3-6 months to mature. For comparison, California's growing season ranges from as early as April (Dillis et al., 2019) to October (Madhusoodanan, 2019).

Cultivating cannabis requires water and energy with water the dominant resource in outdoor growing and energy the dominant resource for indoor growing. Little research exists on how much water is used by commercial or residential growers. As summarized by a 2017 report on water and energy usage associated with cannabis cultivation in Colorado's Pueblo County, "Searching for credible information on water and energy use in refereed journal articles and from other sources resulted in a significant and frustrating waste of time."[3] The report goes on to report a widespread but largely unsubstantiated estimate of 22 liters or around 6 gallons per day per plant along with their own estimate of ½ gallon per day, based on interviews with six commercial growers. A 2019 article in *Nature* reported commercial outdoor growing uses six gallons of water per day but only for about three months of the five-month California growing

[1] https://www.farmerfoodshare.org/farmer-foodshare/2017/6/15/gardening-boom-1-in-3-american-households-grow-food. Accessed 05/06/2021
[2] https://www.nmhealth.org/about/mcp/svcs/rpa/. Accessed 05/06/2021.
[3] https://mountainscholar.org/handle/10217/192586. Accessed 05/06/2021.

season from June through October, and water conservation methods can reduce commercial per plant water use to only about ½ gallon per plant per day (Madhusoodanan, 2019). This is the first study to estimate water use following home cultivation legalization (HCL) or for home cultivation more generally rather than for commercial cultivation. As our estimates are at the household level, they offer particularly policy-relevant results by accounting for actual household water use.

To evaluate whether or not HCL led to an increase in residential water consumption, the authors of this study obtained data on residential water use in Santa Fe, New Mexico, and conducted surveys on home cultivation preferences. Comparing water consumption prior to and following HCL, this study found evidence of a modest increase in water use following HCL. Survey responses suggest home-cultivated cannabis prevalence is increasing, and growing is most commonly indoors and using public utility water. Dispensary access and pricing affect the attractiveness of home cultivation, suggesting these markets are inextricably linked.

This work supports the goal of the New Mexico Legislature to create a sustainable adult-use cannabis market, while protecting the limited water resources in the state. In addition to its policy relevance, this work contributes to a nascent academic literature on cannabis home cultivation.

b. Data and Methods

We use two primary data sources: water utility consumption data from Santa Fe and survey data collected on New Mexican preferences for home cultivation and associated water use.

i. Santa Fe Residential Water Use Data

This analysis seeks to assess the effect of the June 29, 2021, legalization of home cultivation on water consumption. Thus our "treatment" variable measures whether water consumption occurred before or after June 2021. We cannot ignore the potential influence of the COVID-19 and the associated policy responses, which dramatically affected all aspects of life. Pandemic infection rates were associated with increased interest in home gardening (Lin et al., 2021), the stay-at-home orders have been linked to increased residential water use (Irwin, McCoy, and McDonough, 2021)[4], and the first year of the pandemic showed a large surge in summer and fall residential water consumption in Denver, Colorado (Eastman, et al. 2022). To disentangle the effects of HCL versus COVID, we also measure the effect of COVID-19 on water consumption. We measure the influence of COVID in two ways. In our simple pre/post analyses, we further control for whether water consumption occurred before or after March 2020, which coincides with onset of COVID and the first stay-at-home orders.[5] For our more detailed month-level

[4] New Mexico shut down all non-essential businesses on March 24, 2020. Businesses began reopening May 16, 2020. Some businesses, including restaurants, were periodically closed and opened, e.g., restaurants were closed three times – 03/20/2020 to 05/27/2020, 07/13/2020 to 08/29/2020, and 11/16/2020 to 03/24/2021.

[5] We chose not to include alternative COVID measures, such as vaccination rates or cases, hospitalizations and deaths, due to measurement issues with such variables. Vaccines were initially offered to only certain subsections of

analyses, we track monthly water use beginning in January 2020, in addition to any changes which occurred more proximate to HCL in June 2021. Our sample includes 36 months pre-January 2020, 28 after January 2020, and 9 after June 2021.

We obtained data on monthly household-level water consumption from the Santa Fe Public Utilities Department for the sample period from January 2017 through April 2022.[6] By using overall water consumption rather than attempting to estimate per-plant water use as in prior studies, we are able to measure any changes in water use net of any pre-existing water use from, for example, growing other types of plants. The New Mexico Institutional Review Board deemed these data exempt.

The original data set included 2,214,106 observations from 35,978 households. We dropped the 98,132 observations reporting zero or less water consumption in a month. In line with the literature (Price, Chermak and Felardo, 2014), we trimmed the bottom and top 1% of our data to remove outliers that might bias our results, which reduced our sample by another 42,215 observations. After these adjustments to the data, the analysis sample included 2,073,751 observations from 35,351 households. The average household in our sample consumed 4,573 gallons of water per month.[7] We use three measures of water consumption as outcome variables. For our main specification, we use 100s of gallons per day to simplify interpretation of the results. We run two robustness checks on this outcome variables. First, we calculate the natural log of water consumption to potentially better account for outliers. (Histograms suggest the natural log of water use is distributed more normally than the total consumption in gallons, which includes large outliers.) Second, we calculate whether or not the household crossed the threshold between lower and higher cost per gallon consumed. (The base residential water consumption charge for September to April is $6.06/1,000 for first 7,000 gallons and

the population, scientific understanding of the ability of the vaccines to prevent infection and transmission evolved over time, increasing availability of home testing affected case counts, and with the onset of Omicron, many COVID-related hospitalizations and deaths were with COVID rather than due to COVID. Policies might offer cleaner measures, but heterogeneity in those affected by and compliant with policies, the short-term (just weeks) nature of many of the policies, and that only subsectors of the economy were affected and at varying rates make it unlikely that specific policies beyond the general lockdowns in summer 2020 drove multi-month cultivation decisions. We present a month-level event study specification, which allows readers to compare our outcomes with COVID-related policies and outcomes occurring simultaneously.

[6] We attempted to obtain water utility data for the City of Santa Fe through April 2023, including addresses that we were going to match with dispensary data to better identify the effect of both legalization and dispensary access on home cultivation. Exploratory analyses of commercial water use were also intended. Negotiations on a data use agreement between UNM and the City of Santa Fe began in February 2023. The most recent update from early July is that the data use agreement has been created and is awaiting signatures from Santa Fe. As a result, we have not been able to access these data, and it is not clear when we will be able to do so.

[7] The United States Geological Survey data indicates that the average New Mexican used 81 gallons of water per day in 2015, the most recent year data are available, making the average in the sample data approximately the average water use for a family of two. National Water Information System: https://nwis.waterdata.usgs.gov/nm/nwis/water_use/. Accessed 07/12/2022.

$21.72/1,000 for gallons thereafter, for May to August is $6.06/1,000 for first 10,000 gallons and $21.72/1,000 thereafter.[8])

To improve our estimates, we include time-invariant, household-specific variables, i.e., household fixed effects, that control for differences between households which do not change during our sample period. We also adjust our estimates for consistent differences in water consumption across months using month-level indicator variables, year-level differences in water consumption, and variation in total monthly precipitation and average monthly high temperatures. The latter two variables are averaged across all reporting weather stations at the city-level, so we further adjust them by "zone", which roughly translates into elevation and allows the effects of these variables to vary with elevation. (Santa Fe elevation averages 7,198 feet above sea level, but can be as low as around 6,348 ft at the airport.) The city is split into 11 different pressure zones ranging from the northeast of the city to the southwest, with higher numbered zones generally corresponding to higher elevation areas. Zone is not available for a subset of households and including it in our regressions reduces our sample size by 2,758 observations (51 households) to 35,300 households and 2,070,993 observations. During our sample period, total monthly precipitation and average monthly high temperatures were 1.07 inches and 61 degrees, respectively.

Lastly, we run specifications assessing whether population density or per capita income affects our results. We obtained these data for each of Santa Fe's 35 Census Tracts from 2019 American Community Survey administered by the U.S. Census Bureau.[9] Population density ranges from 4 persons per square mile to 6,541, while average annual per capita income ranges from $18,309 to $95,198. Table 1 below shows descriptive statistics for the variables.

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Treatment Variables				
HCL	0.16	0.37	0.00	1.00
COVID-19	0.42	0.49	0.00	1.00
Outcome Variables				
Water Use (100's of Gallons)	4,674	6,184	6	68,292
Ln(Water Use)	7.92	1.17	1.76	11.13
High-Use Pricing	0.12	0.32	0.00	1.00
Control Variables				
Total Precipitation (Inches)	1.07	0.89	0.02	3.59
Maximum Temperature (Fahrenheit)	60.88	14.67	38.39	84.22
Month	6	3	1	12
Year	2019	2	2017	2022

[8] https://www.santafenm.gov/water_rates. Accessed 07/26/2022.
[9] Data are available at https://www.census.gov/programs-surveys/acs/data.html. Accessed 07/26/2022.

Population Density (Persons per Square Mile)	2,802	1,741	4	6,541
Per Capita Income (USD)	42,789	19,676	18,309	95,198

Notes: HCL = home cultivation legalization. Data cover period from January 2017 through April 2022 and include 2,070,933 observations from 35,300 households. HCL=Home Cultivation Legalization.

We use two estimation methods. Our first uses Least Squares regressions techniques to estimate the effect of being pre- versus post-HCL on water consumption, controlling for the effect of COVID-19; household-level, time-invariant differences; month-level variation in water use across all households; annual differences in water consumption common to all households; and total precipitation and average high temperature, both adjusted for elevation. Because observations within households may be arbitrarily correlated, we cluster our standard errors at the household level to avoid underestimating our standard errors and overestimating the statistical significance of our results. Our standard errors are further corrected for heteroskedasticity, which means the precision of the estimates varies systematically with the value of the independent variables, leading to inaccurate estimation of the standard errors, and thus, erroneous conclusions about the statistical significance of the estimates.

$$WaterUse_{ht} = \alpha + \beta * HCL_t + \gamma * COVID_t + \vartheta * Weather_t * Zone_h + \tau_y + \theta_m + \omega_h + \varepsilon_{ht}$$

Our outcome variables are measured for household *h* at time *t*, where *t* refers to the month *m* and year *y* in which the water use occurred. Our HCL and COVID variables are measured at the month-year level. We further control for the weather variables, adjusted by elevation (Zone), obtaining main estimates for total precipitation and average daily maximum temperature, as well as relative effects of these weather variables by elevation. As the Zone variable does not vary at the household level and we control for time-invariant household characteristics, the main effect of the Zone variable is perfectly collinear with the household fixed effects and drops out of the equation, leaving only the relative effects of the weather variables by zone, with Zone = 1 the omitted zone. The remaining variables capture a constant term α, the year fixed effects τ_y, the month fixed effects θ_m, the household fixed effects ω_h, and the error term ε_{ht}.

For our second estimation method, we use the following event study specification, in line with work on the COVID-19 pandemic by Bacher-Hicks, Goodman, and Mulhern (2021) and Goda et al. (2022).

$$WaterUse_{ht} = \alpha + \sum_{t=-17}^{-1} \beta_t * PreHCL_t + \sum_{t=1}^{10} \beta_t * PostHCL_t + \varphi * Pre2020_t + \vartheta * Weather_t * Zone_h + \tau_{y(2017-2019)} + \theta_m + \omega_h + \varepsilon_{ht}$$

Our outcome variables do not change, but we substitute a series of month-year-level pre- and post-HCL variables for the HCL and COVID indicator variables, tracing out the entire period from January 2020 through April 2022 with June 2021 as the omitted or baseline period relative to which the other periods' water use is estimated. In other words, in January 2020, *t*=-17; in June 2021, *t*=0; and in April 2020, *t*=10. Observations occurring prior to January 2020 are included in a dummy variable *Pre2020,* capturing that the water use occurred pre-2020. As in our difference-in-differences approach, we adjust the estimates for seasonal differences using month fixed effects, for annual differences in years 2017-2019 using year fixed effects, for precipitation and temperature differences (adjusted by elevation) not captured by the month fixed effects, and for time-invariant household characteristics using household fixed effects. We only include year fixed effects for 2017 through 2019 and drop the year fixed effects for 2020-2022 as all months between 2020-2022 are traced out using the period-level variables.

The β_t's measure how much water use differs from predicted water use in each period t relative to use in June 2021. In other words, but for HCL, predicted water use in each period pre- and post-HCL should be equal to use in June 2021 after adjustment, i.e., the coefficients (β_t's) measuring the difference should be statistical indistinguishable from zero. Differences for predicted values in the pre-period could arise from anticipatory effects or be driven by other events entirely, e.g., COVID-19. Similarly, abnormal water use in the post-period could consistent of immediate and lagged effects of HCL or could be capturing the effects of other events unrelated to the HCL.

ii. Home Cultivation Survey

The Home Cultivation Survey occurred in two phases. The first phase involved an Opinio survey fielded through the *Kurple Magazine* Facebook page (a news publication focused on medical cannabis and headquartered in Albuquerque[10]), while the second phase purchased survey data collected from a compensated, broader sample by Qualtrics. The University of New Mexico Institutional Review Board approved the survey designs.

The pilot home cultivation survey was fielded in Spring 2022. The sample included 27 participants, who responded to 38 questions on home cultivation, ranging from experience to growing methods, and cost- and quality-based preferences for dispensary-sourced versus home-cultivated cannabis. Simple summaries of these data were included in last year's white paper (Stith and Chermak, 2022).

The Qualtrics-based survey was fielded in January and February 2022. The survey sample included 532 participants from New Mexico, who responded to 36 questions on home cultivation. The survey questions were updated versions of the pilot survey questions. The survey was administered online through Qualtrics, which recruits from "website intercepts, member referrals, targeted email lists, gaming sites, customer loyalty web portals, permission-based networks and social media." Thus, the survey participants were compensated but the amount they are compensated depends on the app through which they accessed the survey. The target population was based on U.S. Census 2020 population estimates and research study

[10] https://kurplemagazine.com/. Accessed 08/09/2022.

requirements, but due to voluntary opt-in procedures, ultimately constitutes a convenience sample of New Mexicans. The only exclusionary criterion was being under the age of 21 years. The target sample was restricted to include a maximum of 40% of responses from Bernalillo County[11] to ensure coverage outside this county. In order to better inform the water utility analysis, we also oversampled Santa Fe. Age, gender, and ethnicity quotas were based on the U.S. Census 2021 American Community Survey estimates for the NM population 21 and older and included the following targets: ages 21-34 - 25%, ages 35-54 - 33%, 55+ - 43%; male - 49%, female - 51%; Hispanic or Latino - 46%, Not Hispanic or Latino - 54%.

Table 2: Sample Statistics

Variable	**Full Sample (N=532)**	**Cannabis Consumers (N=337)**	**Home Cultivators (N=100)**
Panel A: Demographics			
Albuquerque	0.46	0.44	0.45
Santa Fe	0.16	0.15	0.14
Other Locations	0.38	0.41	0.41
Rural	0.15	0.15	0.12
Age 21-39	0.38	0.46	0.57
Age 40-64	0.42	0.42	0.38
Age 65+	0.20	0.12	0.05
Female	0.64	0.62	0.50
Male	0.35	0.37	0.49
Non-Binary	0.01	0.01	0.01
Native American	0.06	0.07	0.11
Black	0.06	0.07	0.11
White	0.70	0.67	0.55
Multi-Race	0.04	0.04	0.04
Asian	0.02	0.02	0.01
Other Race	0.12	0.13	0.18
Hispanic	0.39	0.44	0.62
Non-Hispanic	0.61	0.56	0.38
Low Income	0.51	0.54	0.47
Middle Income	0.31	0.32	0.38
High Income	0.18	0.13	0.15
Panel B: Cannabis Consumption and Home Cultivation			
Cannabis Consumer	0.63	1.00	1.00

[11] Bernalillo County includes most of the broader Albuquerque metro area, by far the largest population center in the state at 672,508 of the state's 2,113,344 population (U.S. Census Bureau, July 2022 estimates, https://www.census.gov/quickfacts/bernalillocountynewmexico, accessed 07/05/2023.)

Home Cultivator	0.19	0.30	1.00
Home Cultivator - Past	0.12	0.20	0.66
Home Cultivator - Future	0.40	0.63	0.90
Indoor Growing	0.11	0.18	0.59
Summer Growing	0.13	0.20	0.67
Public Water Use	0.11	0.18	0.60
Indoor - Future	0.23	0.36	0.51
Public Water - Future	0.26	0.41	0.53
Commercial Grow - Future	0.20	0.30	0.50
Panel C: HC and Dispensary Comparisons			
HC better than Dispensary	0.15	0.18	0.24
Dispensary and HC substitutes	0.20	0.20	0.23
Dispensary Prices Affect HC	0.43	0.61	0.80

Notes: HC = home cultivation. All variables are {0,1} and are based on underlying responses to the survey instrument described in the text.

Table 2 shows descriptive statistics for the sample in Panel A. The first column reports the proportion for the full sample, the second column is restricted to cannabis consumers, and the third column is restricted to current home cultivators. Forty-six percent of the sample were from Albuquerque, 16% from Santa Fe, and 38% from other locations within the state with 15% reporting living in a rural location rather than a city, small town, or suburb. Respondents were asked their age with 38% reporting being between 21 and 39, 42% reporting being between 40 and 64; and 20% reporting being 65 or older. Respondents were majority female (64%), White (70%), and Non-Hispanic (61%). Fifty-one percent reported an income less than 40,000 USD per year with 18% reporting incomes of 100,000 USD or more. Cannabis consumers were younger, less White, and more Hispanic than the full sample. Home cultivators are younger, less likely to live in a rural area or be White, and more likely to be male, Hispanic, and middle income than both the full sample and cannabis users more generally.

We explore outcomes related to cannabis use, home cultivation (current, past and future), growing methods, and tradeoffs between home cultivating and sourcing cannabis from a dispensary. Panel B shows that 63% of our sample consumes cannabis, 19% currently home cultivate, 12% cultivated previously and 40% intend to do so in the future. The majority of those reporting home cultivating home-cultivated indoors, cultivated during the summer months of June, July and/or August, and used public water. Rates of indoor growing and public water use were lower among future home cultivators, but these methods still constituted the majority of the responses. Twenty-percent of the sample reported intending to apply for a commercial cultivation license in the future. Cannabis use and home cultivation are clearly correlated with future home cultivation. About 50% of home cultivators expect to apply for a commercial grow license in the future.

Panel C of Table 2 shows how respondents felt dispensary-sourced cannabis compared with home-cultivated cannabis. 15% felt home-cultivated cannabis was superior in quality while 3, 20% reported access to dispensaries affecting their likelihood of home cultivation, and 43% expected dispensary prices to affect their desire to home cultivate. Not surprisingly, home cultivators had a more favorable view of home-cultivated versus dispensary-sourced cannabis, however, they are also the most likely (at 80%) to report their propensity to home cultivate is affected by dispensary prices.

A simple linear probability model was used to analyze associations between respondent characteristics our outcome variables.

$$Y_i = \alpha_1 + \alpha_2 * X_i + \varepsilon_i$$

In the equation above, Y_i represents our {0,1} outcome variables: cannabis consumption, home cultivation (current, past, and future), growing methods (indoors, summer, public water use), commercial cultivation expectations, and comparisons between dispensary and home cultivated cannabis. Our independent variables, represented by X_i, include age categories, race, ethnicity, family income, and rural. For our regressions regarding cannabis use and future home cultivation or commercial cultivation, we use the full sample. In our regressions analyzing current home cultivation and growing methods, we include only home cultivators. The regressions analyzing tradeoffs between dispensary and home cultivated cannabis are restricted to cannabis consumers. We use standard errors robust to heteroskedasticity throughout. In terms of the power of our analyses, i.e., our ability to identify an effect, we are limited by our sample size to only identifying as statistically significant coefficients larger than 0.0608 for the full sample, 0.0765 for the cannabis user sample, and 0.14 for the sample of home cultivators (power = 80, alpha=0.05).

c. Results

i. Santa Fe Residential Water Use Data

We begin our analysis of the effect of HCL by graphing the raw data by month for the pre-COVID (January 2017 – January 2020), COVID (February 2020 – April 2022), and HCL (July 2021 – April 2022) periods, as shown in Figure 1.

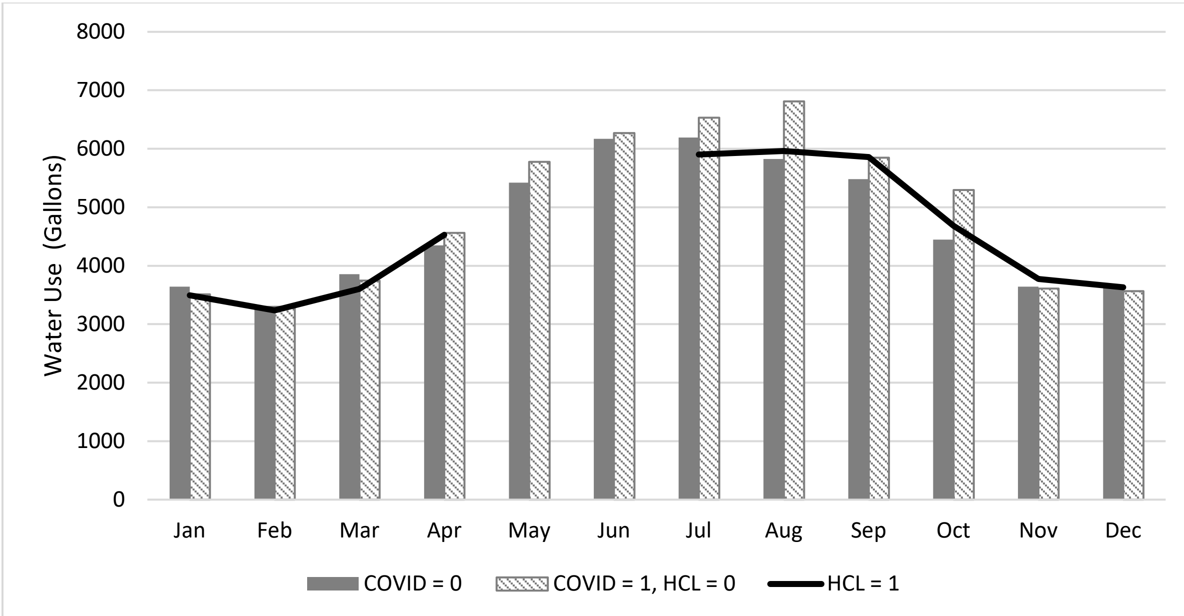

Figure 1: Residential Water Consumption by Time Period – Raw Data

Notes: HCL = home cultivation legalization. The graph depicts average monthly household water consumption in gallons for three periods: COVID = 0 and HCL = 0 from January 2017 through January 2020, COVID = 1 and HCL = 0 from February 2020 through June 2021, HCL = 1 and COVID = 1 from July 2021 through April 2022.

Throughout seasonality is evident with higher water consumption in the summer and fall. During the winter months, COVID water use is lower than pre-COVID, but during the summer months, COVID water use is distinctly higher. Water use after HCL tracks similar to prior periods during the winter months but falls between pre-COVID and post-COVID water use during the summer months.

Table 2 shows the results from the regressions for our three outcome variables.

Table 3: Regression Results

	(1) Water Use (100s of gal)	(2) Water Use (100s of gal)	(3) Ln(Water Use)	(4) High-Use Pricing
HCL	-0.913***	-0.799***	-0.025***	-0.005***
	(0.143)	(0.014)	(0.003)	(0.001)
COVID		1.162***	0.033***	0.013***
		(0.177)	(0.004)	(0.001)
Observations	2,070,993	2,070,993	2,070,993	2,070,993
R-squared	0.125	0.125	0.112	0.058
Number of households	35,300	35,300	35,300	35,300
Outcome Mean	0.000	46.740	7.919	0.119

Notes: HCL = home cultivation legalization. Each column represents a separate regression. The outcome variables are total water consumption in 100's of gallons, the natural log of total water consumption in gallons, and whether or not the household crossed into high-use pricing. HCL changes from zero to one in July 2021; COVID changes from zero to one in March 2020. All regressions control for precipitation, maximum temperature, zone x precipitation, and zone x maximum temperature, and include month, year, and household fixed effects. Standard errors clustered at the household level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The estimates in Columns 1 and 2 can be directly interpreted as changes in 100's of gallons of water consumed. In Column 1, the effect of HCL is measured without controlling for COVID. A negative coefficient corresponding to a reduction of 91.3 gallons is evident. However, the magnitude of the coefficient is too large due to the positive impact of COVID on water use in 2020. After controlling for the large surge in water use during summer 2020, i.e., comparing the HCL period with the pre-COVID period, we estimate an HCL coefficient of -0.799, which indicates a reduction of 80 gallons per month from HCL, while the COVID coefficient indicates an increase of 116 gallons. Although the coefficients together suggest an increase of 36 gallons per month in the HCL period, we cannot reject that the joint effect differs from zero (p=0.091) at standard levels of statistical significance (p≤0.05). Although not precise, this analysis suggests an aggregate effect of approximately 36 gallons times 35,300 households or 1,270,800 gallons. In Column 3, the HCL coefficient of -0.025 can be interpreted as showing that legalization of home cultivation reduced average monthly water consumption by 2.5 percent or 117 gallons per month.[12] This reverses an increase of 3.4 percent or 159 gallons during COVID. The combined coefficients for HCL and COVID are not statistically significantly different from zero (p=0.146). Although the outcome variable may better account for outliers in the natural log specification in Column 3, the model's explanatory power (R-squared) is lower than for the model using hundreds of gallons in Column 1. The fourth column's results show that HCL is associated with a 0.5 percentage point reduction in the likelihood of crossing into higher price-per-gallon consumption, with approximately 12 percent of households crossing the price threshold each month. COVID was associated with a 1.3 percentage point increase in the likelihood of crossing into higher price-per-gallon consumption. Jointly, the probability of crossing into higher price-per-gallon consumption was lower following HCL relative to COVID, but remained elevated relative to pre-pandemic levels (p<0.001). Combining the information in Columns 1 and 3, one can derive a rough estimate of $10,228 increase in monthly payments from households post-HCL relative to pre-COVID.[13] Dividing by the number of households yields an average per household increase in monthly payments of $0.29.

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[12] The average effect of HCL on the natural log of water consumption is calculated as [exp(β)-1], where β is the reported coefficient.

[13] $ChangeAggregateMonthlyWaterUse = [(BaselineHighUsePricing + ChangeHighUsePricing) * N\ Households * Price\ per\ 1{,}000\ gallons * IncreaseWaterUsePostHCL] + [(1 - HighUsePricedProportion) * N\ Households * Price\ per\ 1000\ gallons * IncreaseWaterUsePostHCL] =$

In Table 4, we interact the HCL variable with Population Density in thousand persons per square mile and with per capita income in ten thousand USDs in order to evaluate whether the small, marginally statistically significant aggregate estimate is masking underlying variation in the effects by population density and per capita income. We adjust the original population density and per capita income variables by 1,000 and 10,000, respectively, to improve interpretation of coefficients given small effect sizes.

Table 4: Regression Results Interacting Population Density and Per Capita Income

	(1) Water Use (100s of gal)	(2) Ln(Water Use)	(3) High-Use Pricing
HCL	-2.252***	-0.049***	-0.015***
	(0.569)	(0.015)	(0.004)
COVID	1.161***	0.033***	0.013***
	(0.177)	(0.004)	(0.001)
HCL x Population Density (1,000 persons per sq. mile)	0.184**	-0.001	0.001**
	(0.087)	(0.002)	(0.001)
HCL x Per Capita Income (10,000 USDs)	0.219***	0.006***	0.001***
	(0.084)	(0.002)	(0.001)
Observations	2,070,993	2,070,993	2,070,993
R-squared	0.126	0.113	0.058
Number of households	35,300	35,300	35,300
Outcome Mean	46.740	7.919	0.119

Notes: HCL = home cultivation legalization. Each column represents a separate regression. The outcome variables are total water consumption in 100's of gallons, the natural log of total water consumption in gallons, and whether or not the household crossed into high-use pricing. HCL changes from zero to one in July 2021; COVID changes from zero to one in March 2020. All regressions control for precipitation, maximum temperature, zone x precipitation, and zone x maximum temperature, and include month, year, and household fixed effects. Standard errors clustered at the household level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

In Table 4, we explore heterogeneity in the effects of HCL by population density and by per capita income. The main coefficients for HCL and COVID can be interpreted as baseline levels to which the coefficients for the interaction effects should be added. Despite the prior that cannabis cultivation requires sufficient space, census tracts with denser populations experienced more water use post-HCL, even after controlling for weather differences. Per capita income was

$\left[(0.119 + 0.0.013 - 0.005) * 35{,}300 * \$21.72 * 36\frac{gallons}{1000}\right] + \left[(1 - 0.119 - 0.013 + 0.005) * 35{,}300 * \$6.06 * \frac{36gallons}{1000}\right] = 0.127 * \$27{,}602 + 0.873 * \$7{,}701 = \$10{,}228.$

also associated with greater water use post-HCL. It may be that these variables are proxying for other factors affecting the decision to home cultivate, such as race and education which are highly correlated with income. Adding the HCL and COVID coefficients, baseline water use is 1.091 gallons lower post-HCL. For HCL to not decrease water use, based on the point estimates in Column 1 above, population density would have to be more than 5,930 persons per square mile, which is not true of any Census Tract in Santa Fe or income would have to be at least $49,818, which is true for 9 of the 35 Census Tracts in Santa Fe. A combination of high enough population density and income would also yield positive effects. Figure 2 below shows estimates of the effect of HCL on water use by Census Tract, where we base our estimates on Census Tract-level population density and per capita income. Clearly, substantial heterogeneity exists across Census Tracts as shown in Figure 2 below. Most Census Tracts experience an increase in water use, but a handful of counties experience a decrease post-HCL. The magnitudes also vary substantially across counties from a decrease of 60 gallons near the airport (Census Tract 1304) to an increase of 100 gallons in the large rural area on the northwest side of the city near the pueblos (Census Tract 10204).

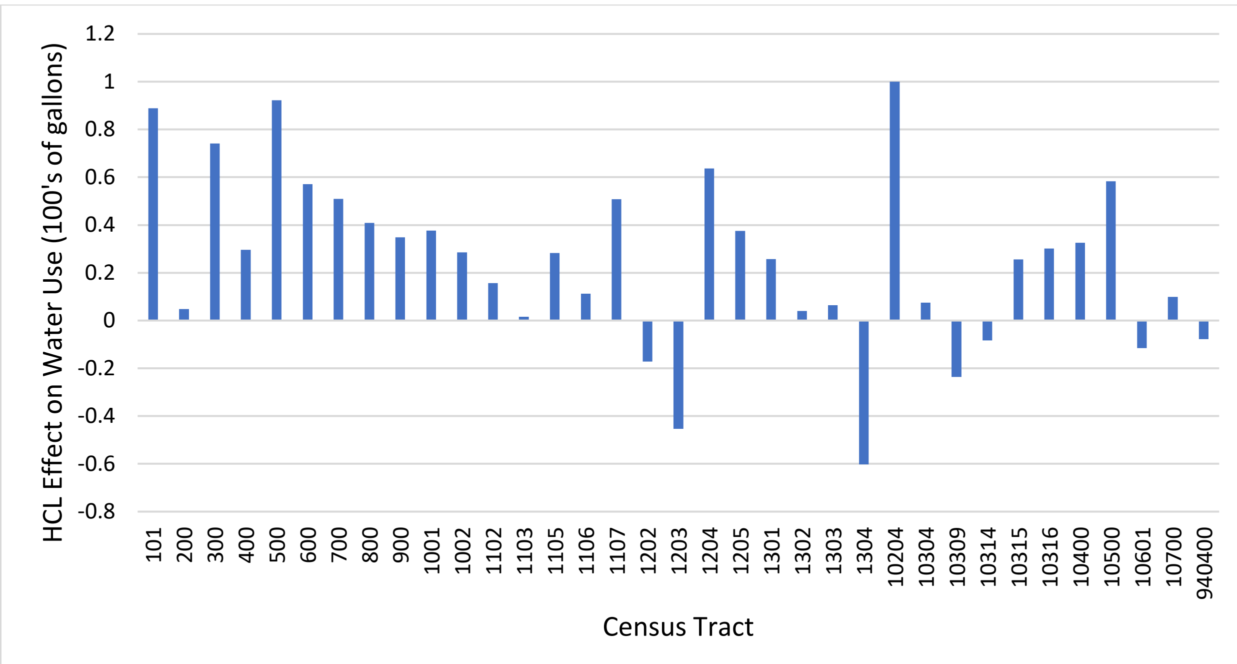

Figure 2: Census Tract-Level Changes in Water Use Based on Population Density and Per Capita Income

Notes: HCL = home cultivation legalization. The estimated HCL effect on water use (in 100's of gallons) by Census Tract are calculated from the coefficients reported in Table 3 as follows: $-2.252 * (HCL = 1) + 1.161 * (COVID = 1) + 0.184 * persons\ per\ sq.\frac{mile}{1000} + 0.219 * per\ capita\frac{income}{10000} = Water\ Use\ Change\ (100's\ of\ gallons)$.

To better tease out the relationship between HCL, COVID, and residential water consumption, we use our second specification to generate the event studies in Figures 3-5. The reported outcomes are the average effect of being in that period relative to June 2021, the last month before HCL, adjusted for month-, year- (for 2017-2019), and household-level characteristics, precipitation, and high temperature.

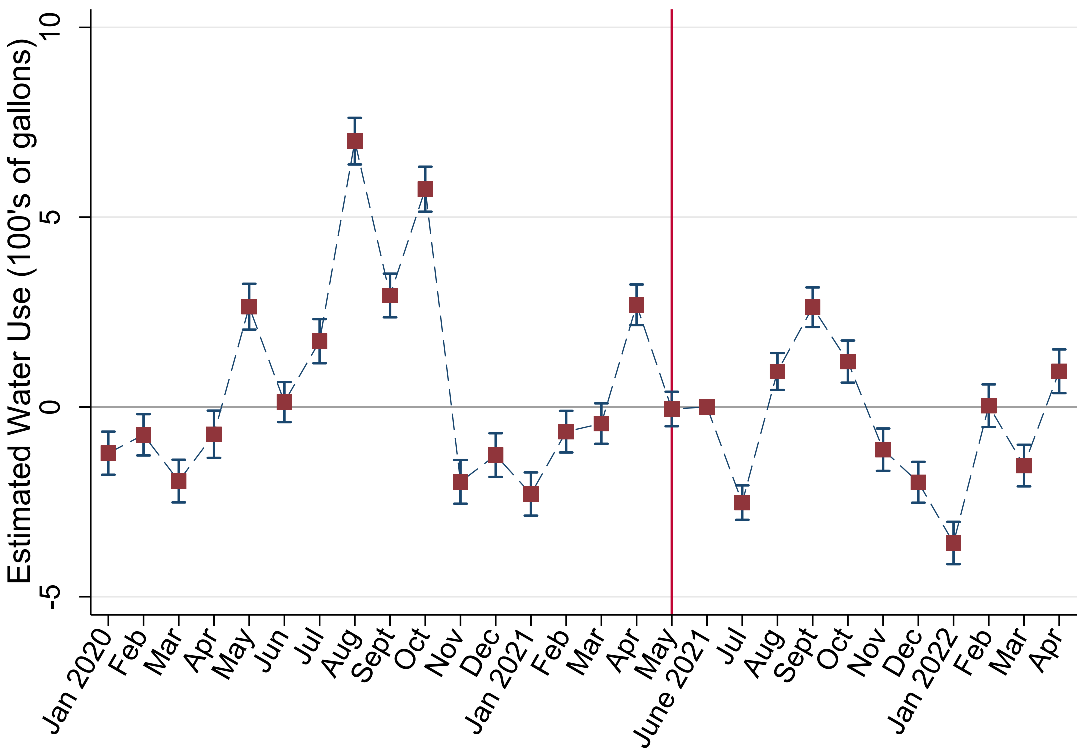

Figure 3: Event Study of Effect of HCL on Water Use (100's of gallons)

Notes: HCL = home cultivation legalization. The y-axis measures change in water use in 100's of gallons relative to June 2021, the month prior to HCL. Periods prior to January 2020 are coded as occurring pre-2020. The underlying regressions control for precipitation, high temperature, zone x precipitation, and zone x high temperature, as well as month, year (2017-2019), and household fixed effects. Standard errors are clustered at the household level with 95 percent confidence intervals reported in the graph.

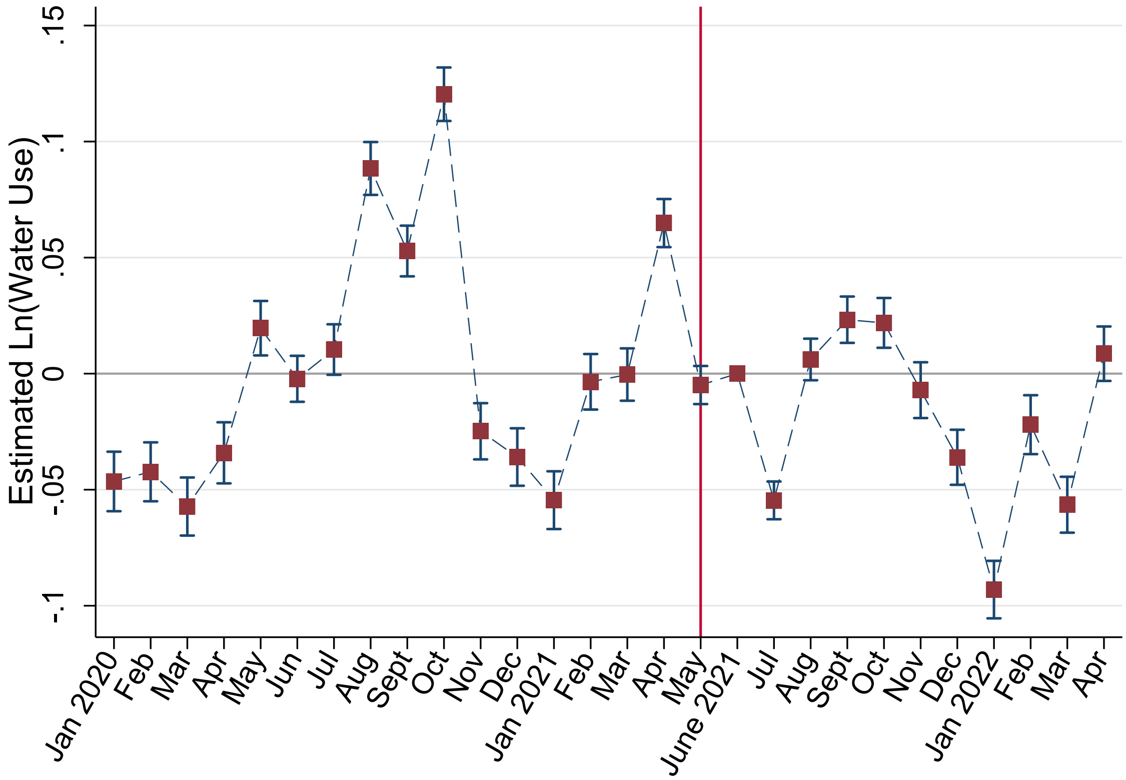

Figure 4: Event Study of Effect of HCL on Natural Log of Water Use

Notes: HCL = home cultivation legalization. The y-axis measures change in the natural log of water use relative to June 2021, the month prior to HCL. Periods prior to January 2020 are coded as occurring pre-2020. The underlying regressions control for precipitation, high temperature, zone x precipitation, and zone x high temperature, as well as month, year (2017-2019), and household fixed effects. Standard errors are clustered at the household level with 95 percent confidence intervals reported in the graph.

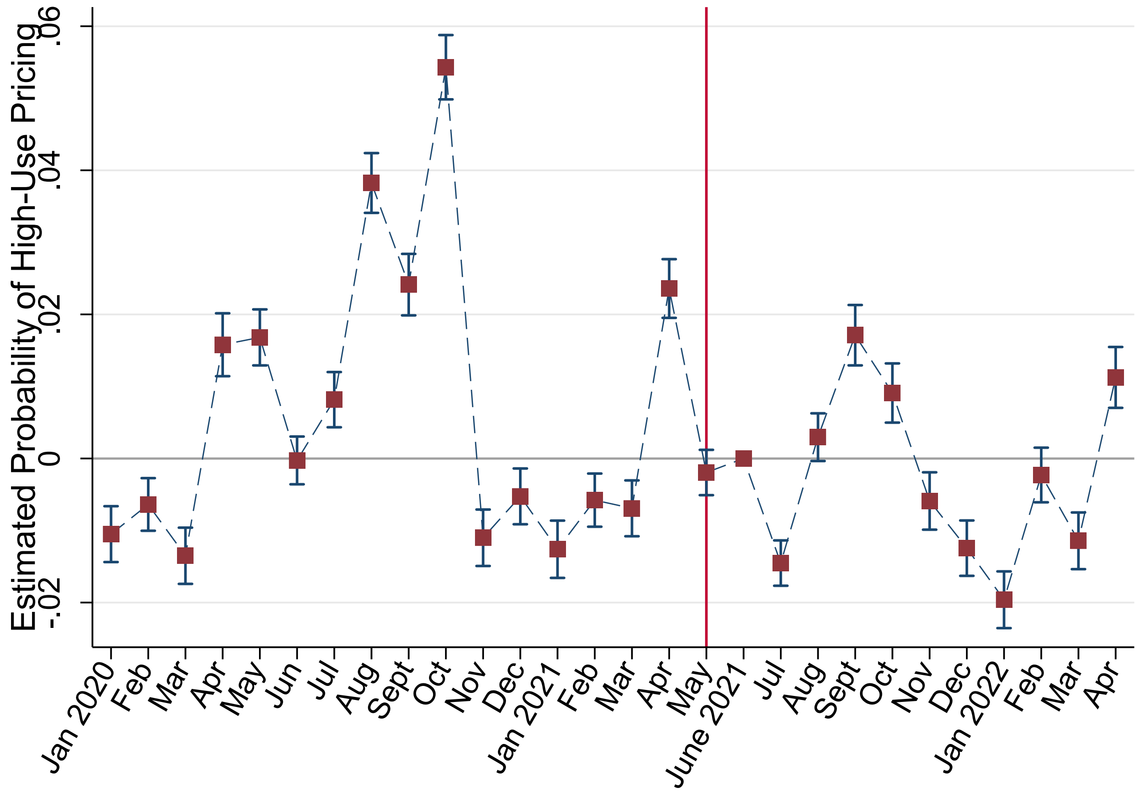

Figure 5: Event Study of Effect of HCL on the Probability a Household Crosses into Higher Priced Use

Notes: HCL = home cultivation legalization. The y-axis measures the probability that a household exceeded the price threshold relative to the probability that they did in June 2021, the month prior to HCL. Periods prior to January 2020 are coded as occurring pre-2020. The underlying regressions control for precipitation, high temperature, zone x precipitation, and zone x high temperature, as well as month, year (2017-2019), and household fixed effects. Standard errors are clustered at the household level with 95 percent confidence intervals reported in the graph.

All three figures show much higher levels of water consumption in summer 2020 than any time before or thereafter. This coincides with a period in which COVID lockdowns were most prevalent. An inexplicable higher level of water use occurs in April 2021, around the time of the passage of HB2. In July 2021, the first month in which cannabis home cultivation for adult use was legal, water use is abnormally low. August, September, and October 2021 show water use that exceeds water use in June 2021, but is lower than during the first summer of COVID. (Appendix Table A1 reports the estimated coefficients underlying these regressions.) These results are in line with the overall results, that water use increased post-HCL relative to pre-COVID, but was lower than during COVID, and show that the increase in water use was driven by water use in September, October, and November of 2021 as well as possibly April 2022. September generally marks the end of the harvest season, suggesting that the increase in October and November may be driven by indoor grows begun at the end of June 2021 approaching maturity approximately 3-5 months after planting. A 3-5 month growing season falls within estimates of 3-8 months from a popular cannabis information aggregator.[14]

ii. Home Cultivation Survey

Tables 5-7 explore the associations in our home cultivation survey sample. As shown in Table 5, cannabis use declines with age, is higher among Hispanics, and is lower among those from households earning 100,000 USD or more per year. Current home cultivation is less common among the oldest cohort and females and more common among Hispanics. Past home cultivation shows a similar pattern, but higher income individuals are marginally statistically significantly more likely to have previously home cultivated than lower income cohorts. Future home cultivation is also less common among the oldest cohort and more common among Hispanics, but there are no gender distinctions and Whites are statistically significantly less likely to intend to home cultivate than other races. Rural has no effect on cannabis consumption or home cultivation. Higher rates of home cultivation among males is consistent with surveys of home cultivation practices prior to recreational legalization (Azofeifa et al., 2021) and in Canada prior to legalization of extracts, when only flower was available to recreational users (Cristiano et al., 2022.) Perhaps reflecting differences between New Mexico and Canada, Wadsworth et al. (2022) did not find differences by age, gender, or ethnicity, but did find differences by rural status.

Table 5: Associations between Demographic Characteristics, Cannabis Use, and Home Cultivation

	(1) Cannabis User	(2) HC Current	(3) HC Past	(4) HC Future
Age 40-64	-0.109**	-0.031	-0.040	-0.057
	(0.046)	(0.055)	(0.048)	(0.059)
Age 65+	-0.336***	-0.165**	-0.144***	-0.214**
	(0.061)	(0.071)	(0.055)	(0.091)
Female	-0.059	-0.109**	-0.088**	-0.057
	(0.043)	(0.052)	(0.044)	(0.054)
White	-0.063	-0.086	-0.026	-0.150***
	(0.046)	(0.057)	(0.048)	(0.056)
Hispanic	0.106**	0.191***	0.201***	0.121**
	(0.043)	(0.052)	(0.045)	(0.055)
Income - Middle	-0.005	0.076	0.051	0.002
	(0.046)	(0.054)	(0.045)	(0.057)
Income - High	-0.176***	0.077	0.138*	-0.024
	(0.060)	(0.075)	(0.070)	(0.084)

[14] Leafly: 4 Stages of Marijuana Growth. https://www.leafly.com/learn/growing/marijuana-growth-stages Accessed. 08/03/2022.

Rural	0.005	-0.044	-0.019	0.048
	(0.057)	(0.063)	(0.052)	(0.073)
Constant	0.810***	0.344***	0.180***	0.758***
	(0.058)	(0.072)	(0.056)	(0.076)
Observations	532	337	337	337
R-squared	0.099	0.104	0.110	0.071

Notes: HC = home cultivation. Age groups are relative to Ages 21-39; Female is relative to male and nonbinary; White is relative to other races; Hispanic is relative to non-Hispanic, income levels are relative to low income, and rural is relative to urban/suburb/small town. Column (1) includes the full sample; Columns (2) to (4) include only cannabis users. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6 explores current home cultivation practices in the first three columns, restricting the sample to only current home cultivators. Partly due to our small sample size, we find few associations. However, it appears that the oldest cohort is least likely to grow indoors, middle income home cultivators are least likely to grow in the summer, and the middle age cohort is least likely to use public utility water. The second set of columns explores future home cultivation expectations using the full sample and finds that older cohorts are less likely to intend to grow indoors, use public water, or grow commercially. The youngest cohort is the most likely to anticipate applying for a commercial license. Whites are less likely to expect to grow indoors or to apply for a commercial license. Hispanics are the more likely to anticipate applying for a commercial license than non-Hispanics. Not surprisingly, current home cultivation greatly increases the likelihood of anticipating future home cultivation. The R-squareds suggest that demographic variables explain between 14.5 percent and 20.5 percent of the variation in our future home cultivation variables and between 5.2% and 7.2% of the variation in home cultivation practices among current home cultivators.

Table 6: Associations between Demographics and Growing Practices

	(1) Indoor Grow	(2) Summer Grow	(3) Public Utility Water	(4) Future Indoor Grow	(5) Future Public Water Use	(6) Future Commercial Grow
Age 40-64	0.059	-0.027	-0.206*	-0.029	-0.072	-0.136***
	(0.111)	(0.109)	(0.113)	(0.043)	(0.044)	(0.041)
Age 65+	-0.365*	-0.128	-0.118	-0.181***	-0.121**	-0.210***
	(0.212)	(0.250)	(0.266)	(0.043)	(0.052)	(0.039)
Female	-0.013	0.074	0.080	-0.048	0.046	-0.041
	(0.100)	(0.094)	(0.107)	(0.056)	(0.056)	(0.050)
White	-0.004	-0.055	0.045	-0.112*	-0.041	-0.100*
	(0.101)	(0.098)	(0.105)	(0.058)	(0.060)	(0.057)

Hispanic	0.056	-0.054	0.052	-0.011	0.048	0.128**
	(0.107)	(0.104)	(0.109)	(0.055)	(0.057)	(0.053)
Income - Middle	-0.172	-0.194*	-0.027	-0.045	0.047	-0.023
	(0.111)	(0.103)	(0.113)	(0.059)	(0.060)	(0.054)
Income - High	0.102	-0.074	0.023	-0.125	-0.042	-0.070
	(0.143)	(0.140)	(0.156)	(0.076)	(0.082)	(0.068)
Rural	0.010	0.093	-0.110	-0.076	-0.105	0.062
	(0.160)	(0.165)	(0.161)	(0.069)	(0.071)	(0.069)
Home Cultivator				0.185***	0.148**	0.231***
				(0.062)	(0.062)	(0.059)
Constant	0.648***	0.799***	0.611***	0.343***	0.266***	0.279***
	(0.146)	(0.145)	(0.148)	(0.061)	(0.060)	(0.058)
Observations	100	100	100	532	532	532
R-squared	0.072	0.061	0.052	0.145	0.111	0.205

Notes: HC = home cultivation. Age groups are relative to Ages 21-39; Female is relative to male and nonbinary; White is relative to other races; Hispanic is relative to non-Hispanic, income levels are relative to low income, and rural is relative to urban/suburb/small town. Column (1) to (3) includes only home cultivators; Columns (4) to (6) include all cannabis users. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7 shows the results comparing dispensary and home-cultivated cannabis. Older adults and Hispanics were less likely to report home-cultivated cannabis as superior to dispensary cannabis, while home cultivators generally were more likely to believe their cannabis was superior to that sold in dispensaries. None of the coefficients are statistically significant for our dispensary access effect on home cultivation. The R-squared in both the first two columns are quite small as well, suggesting that the independent variables are not explaining much of the variation in our outcome variables. Our model for the effect of dispensary prices on the likelihood of home cultivation performs better with an R-squared of 10.3 and clearer associations. Those ages 40-64, women, and middle-income were less likely to have their home cultivation decision affected by dispensary prices. Whites and current home cultivators were the more likely to report effects from dispensary prices than non-Whites and non-home cultivators.

Table 7: Associations between Demographics and Preferences for Home-Cultivated v. Dispensary-Sourced Cannabis

	(1) HC Higher Quality	(2) HC Likelihood Affected by Dispensary Access	(3) HC Likelihood Affected by Dispensary Prices
Age 40-64	-0.031	-0.013	-0.097*
	(0.049)	(0.048)	(0.058)

Age 65+	-0.120*	0.055	-0.112
	(0.064)	(0.077)	(0.087)
Female	-0.004	0.006	-0.095*
	(0.044)	(0.045)	(0.053)
White	0.007	-0.019	0.093*
	(0.047)	(0.050)	(0.055)
Hispanic	-0.104**	0.014	-0.028
	(0.046)	(0.046)	(0.055)
Income - Middle	0.014	0.053	-0.130**
	(0.047)	(0.048)	(0.057)
Income - High	0.031	0.028	-0.073
	(0.069)	(0.067)	(0.079)
Rural	0.056	0.029	-0.056
	(0.063)	(0.062)	(0.070)
Home Cultivator	0.108**	0.039	0.289***
	(0.052)	(0.049)	(0.055)
Constant	0.208***	0.155**	0.639***
	(0.067)	(0.062)	(0.081)
Observations	337	337	337
R-squared	0.040	0.011	0.103

Notes: HC = home cultivation. Age groups are relative to Ages 21-39; Female is relative to male and nonbinary; White is relative to other races; Hispanic is relative to non-Hispanic, income levels are relative to low income, and rural is relative to urban/suburb/small town. Column (1) to (3) includes only home cultivators; Columns (4) to (6) include all cannabis users. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

d. Results Summary and Discussion

The Santa Fe water use data indicate a possible increase in residential water use in response to HCL. Households in Santa Fe are spending about $0.29 more per month on average for an additional 36 gallons and Santa Fe Water Utility can expect just over $10,228 more per month. Responses from the survey on home cultivation indicate increasing interest in home cultivation over time, with many future home cultivators intending to use public utility water, suggesting that the current water utility results are a lower bound on the effects of HCL. However, they also report being more likely to grow indoors than current home cultivators, potentially decreasing overall water use. The commercial cannabis market will be an important determinant of how residential water use for home cultivation evolves. Many cannabis consumers and even home cultivators report that home-cultivated and dispensary-sourced cannabis are substitutes and that their propensity to home-cultivate is determined in part by dispensary proximity and pricing. The relative use of water in home cultivation versus commercial cultivation is unknown, depending whether a lack of expertise leads to over- or under-watering.

Although a range of policy-relevant implications arise from our results, we cannot rule out the influence of other factors, especially COVID, on the precision and generalizability of our results. Significant variation in water use exists across households and across Santa Fe more generally. Complicating the identification of causal effects, COVID caused an enormous perturbation in water use patterns in 2020 and it is possible that a spillover or continued COVID effect could be driving the results in 2021 rather than HCL. Reducing the risk of contamination from spillover COVID effects, the COVID context changed substantially between the summers of 2020 and 2021. Although case counts and hospitalizations did not differ significantly across summers in 2020 and 2021, during the first summer stay-at-home orders were prevalent, while by summer 2021, most of those who wanted to be vaccinated were vaccinated and businesses were open. Labor market analyses (e.g., Goda et al. (2022)) show a general trend towards a resumption of normal labor market outcomes, suggesting that individual policies and COVID-related cases, hospitalizations, and deaths may have done little to perturb a general trend back to normal over the course of the pandemic. Data from the New Mexico Department of Health show peak cases in November 2020 and January 2022, peak deaths in December 2020, December 2021 and February 2022, which, apart from November 2020, are not months with particularly high-water use.[15]

Another major limitation of the water use data is the lack of household-level information. While we do control for household fixed effects to capture time-invariant household characteristics, we are do not have household-level information on factors such as age, race, number of household members, employment status, education, and income. Although we are unable to analyze these variables at the household level, we are able to evaluate Census Tract-level differences in the effect of HCL. We focused on population density to approximate lot size and per capita income to capture financial resources and because income is correlated with employment status, education, and health. Unfortunately, the positive coefficient on population density does not have an obvious explanation. Less space seems unlikely to drive increased water use, so factors such as more private wells in less densely populated areas or increased population density in more fertile growing areas might be driving the effect. Similarly, the positive coefficient on per capita income could be directly due to greater availability of resources or might arise because per capita income is correlated with other factors, e.g., health and education. Ultimately, Census Tract-level heterogeneity can only capture the general context in which a household lives and not the precise circumstances of an individual household. Another issue with the lack of individual information is that it limits our ability to generalize the results beyond Santa Fe, as we do not know which underlying household factors specific to Santa Fe could be driving the results. Comparing the fourteen home cultivators from Santa Fe in our sample from the broader sample, they do appear to skew younger, less female, more Native American, and higher income. They had more prior growing experience and were more likely to grow indoors and during the summer, but were less likely to use public utility water. Santa Fe home cultivators were the most likely to respond that

[15] New Mexico Department of Health COVID Dashboard. https://cvprovider.nmhealth.org/public-dashboard.html. Accessed 08/09/2022.

home-cultivated cannabis is of higher quality than dispensary-sourced cannabis, while simultaneously showing the greatest price effects from dispensaries. If anything, it appears that these may be fairly sophisticated growers and predictive of effects we might see going forward in the broader sample, e.g., a shift towards indoor growing with potential associated reductions in water use.

The Home Cultivation Survey data are limited by the small number of home cultivators in the sample and the opt-in nature of the survey design, but offers suggestive evidence of potential trajectories in cannabis home cultivation in the future. In particular, the main reported barrier to home cultivation, lack of know-how, can easily be addressed; more respondents intend to grow cannabis in the future than grow now; and home cultivated cannabis is a cheaper, potentially higher quality product as compared to dispensary-sourced cannabis. Expected growing methods point towards lower water-use methods, i.e., indoor growing, but the majority of water used for home cultivation is likely to come from public water utilities. Home-cultivated cannabis and dispensary-sourced cannabis are likely to continue to be substitutes with the former acting as a quality and price check on the commercial market. A majority of all respondents believe dispensary-sourced cannabis is no better or even worse than home-cultivated cannabis and a majority of cannabis consumers report that dispensary prices affect their likelihood of home cultivating. Our survey results further indicate that areas with younger populations, more males, and more Hispanics are likely to see the most home cultivation, with younger and Hispanic respondents most interested in transitioning into commercial cultivation in the future. These results suggest that home cultivation may serve as a sort of training program for future commercial growers. Given widespread views that dispensary-sourced cannabis is not particularly high quality, increased growing expertise and associated higher quality products in the industry might be a positive spillover from HCL.

While no other studies of home cultivation have used water utility data, several other studies have used survey methods to attempt to understand home cultivation. These studies explore demographics differences in preferences for home cultivation but do not address growing methods or water use and were fielded either in Canada (Wadworth et al., 2022), in Canada prior to legalization of extracts at the end of 2019 (Cristiano et al., 2022), or in the United States prior to recreational legalization (Azofeifa et al., 2021). Work on commercial cultivation is unlikely to be especially informative because home cultivators face different restrictions with respect to production, e.g., they are only permitted to cultivate a small number of plants but have fewer restrictions on water sources. For example, while both residential and commercial cultivators can use public utility water, only residential growers can use domestic, non-commercial wells. Most commercial grows in Northern California use commercial wells (Dillis, et al., 2019). Thus, by using residential water utility data and analyzing a relatively large sample of New Mexicans post-HC legalization, the study offers an important contribution to the academic literature in terms of understanding home cultivation, growing practices, and water use.

e. Policy Implications

The data analyzed suggest that home cultivation occurs in New Mexico and it is likely to increase in the future, even if dispensary access is widespread. Home cultivation could lead to an increase in water use, but overall impacts through April 2022 were relatively small at less than 1% of average monthly use. Dispensary entry after the water utility sample period may have reduced home cultivation-related water use, as many of our respondents report that home-cultivated and dispensary-sourced cannabis are substitutes, but expectations about increased future growing suggest that dispensaries will not fully crowd out home cultivation. The interconnection between markets for home and commercially cultivated cannabis mean that the overall effect of cannabis legalization on water resources used by all cannabis cultivators in New Mexico will remain unknown. Furthermore, as this study serves as the only data point on home cultivation water use and even studies of commercial water use are few, this study offers insights but not conclusions as to the final effects of cannabis legalization on water in New Mexico. The popularity of indoor growing methods likely mitigates the potential impact of home cultivation, but the use of public utility water has important policy implications for public water use, with the needs of home cultivators only one of many demands on local water supplies. In fact, the popularity of indoor growing may be partly due to the risk of restrictions on outdoor water use in response to drought conditions as happens frequently throughout New Mexico, especially during the summer months.

While policymakers might prefer that cannabis be sourced through regulated dispensaries for public health and tax revenue reasons, dispensaries seem unlikely to drive out home cultivation for the foreseeable future and should provide an important safety, price, and quality check on the commercial market. Dovetailing with the findings from our surveys, perceptions in the popular press in April 2022 were that prices in New Mexico continue to be relatively high as compared Colorado and quality is comparatively lower (Hooper, 2022; Porter, 2022), i.e., dispensaries are not seen as offering a particularly high value product, even compared to dispensaries in competing markets, despite regulations. More recent price data are not available from the Cannabis Control Division, only aggregate sales by city,[16] but consumer-sourced online data from Price of Weed shows high quality cannabis retails at $283 per ounce in New Mexico, lower than most states, including Arizona ($297) but higher the $241 charged per ounce in Colorado. In general, more mature markets appear to display lower prices. Both home cultivation and Colorado are likely to continue to encourage New Mexican dispensaries to increase the quality of their products and decrease their prices, ultimately improving the cannabis consumer experience and the economic efficiency of the market. These effects need not be negative for state revenues – enough new dispensary customers will outweigh any negative tax effects from lower prices.

Policy Recommendations:

1. Educate and encourage growers to use low-water growing methods, with indoor growing a clear option for conserving water.

[16] https://www.rld.nm.gov/cannabis/for-media/press-releases/. Accessed 07/27/2022.

2. Develop training programs to facilitate transitioning from home cultivation to licensed micro-production with training on optimal water use procedures.
3. Continue to monitor the evolution of New Mexico's cannabis market with respect to the interplay between unregulated home-cultivated cannabis and dispensary-sourced cannabis and the relative water use of each approach to cannabis cultivation.
4. Consider expanding testing protocols to incorporate a broader range of contaminants. While New Mexico tests for 16, California tests for 66 and Oregon for 59 (Atapattu and Johnson, 2020.)
5. Educate consumers on cannabis quality dimensions beyond THC. Widespread medical use underscores the importance of ensuring consistently high-quality, safe cannabis is sold by New Mexico dispensaries.
6. Ensure that the Cannabis Control Division tracks detailed data on prices and quantities sold overall and by product type and makes this data available to researchers. Such data are crucial for understanding substitution patterns between home-cultivated and dispensary-sourced cannabis and the implications for water use across types of products sold.

f. Future work

Our state funded work concludes with this white paper. However, we anticipate extending the research in multiple directions with the goal of generating several publications. We intend to publish a paper on the effects of HCL on water use. If we are able to obtain the Santa Fe data, we will include them in the analysis, hopefully better disentangling the effects of HCL and COVID on water use. Were we to obtain access to the commercial data as well, we would be able to generate the first study on the relative water use of commercial versus residential cannabis cultivation. As no existing work has studied substitution between home-cultivated and dispensary-sourced cannabis, we intend to write such a paper as well. From the undergraduate data project, we intend to generate a publication for the *Journal of Economics Education*. The feasibility of the current project was beta-tested in Spring 2023, is currently undergoing further testing this Summer 2023, and in order to evaluate the effect of the data project on undergraduate learning, we intend to beta-test the project once more, including surveying several sections of Microeconomics Principles on their knowledge of data-informed research pre- and post-exposure to the project in Fall 2023. As a final research product, we intend to write a short letter on the startling effects of the COVID pandemic on residential water use in Summer 2020.

Lastly, this study points toward an important area for future work - why are regulations, significant competition among dispensaries, and pressure from home cultivation and Colorado are not ensuring that dispensaries consistently sell high quality products? In other words, why is it that expert growers hired by dispensaries are unable to grow consistently better cannabis than many home cultivators? Are current testing protocols inadequate to ensure that products sold are free from contamination, e.g., from pesticides, mold, mites, or even just seeds, or that the industry itself lacks expertise on dimensions of quality beyond tetrahydrocannabinol (THC) potency? The lack of optimal quality in the industry suggests that other dimensions, e.g., water use, may also not be optimal.

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h. Appendix Table

Table A1: Event Study Regression Results

	(1) Water Use (100s of gal)	(2) Ln(Water Use)	(3) High-Use Pricing
January 2020	-0.046***	-1.218***	-0.010***
	(0.007)	(0.290)	(0.002)
February 2020	-0.042***	-0.734***	-0.006***
	(0.006)	(0.278)	(0.002)
March 2020	-0.057***	-1.953***	-0.014***
	(0.006)	(0.287)	(0.002)
April 2020	-0.034***	-0.720**	0.016***
	(0.007)	(0.318)	(0.002)
May 2020	0.020***	2.641***	0.017***
	(0.006)	(0.308)	(0.002)
June 2020	-0.002	0.128	-0.000
	(0.005)	(0.269)	(0.002)
July 2020	0.010*	1.732***	0.008***
	(0.006)	(0.297)	(0.002)
August 2020	0.088***	7.003***	0.038***
	(0.006)	(0.313)	(0.002)
September 2020	0.053***	2.937***	0.024***
	(0.006)	(0.294)	(0.002)
October 2020	0.120***	5.737***	0.054***
	(0.006)	(0.302)	(0.002)
November 2020	-0.025***	-1.973***	-0.011***
	(0.006)	(0.294)	(0.002)
December 2020	-0.036***	-1.269***	-0.005***
	(0.006)	(0.294)	(0.002)
January 2021	-0.055***	-2.294***	-0.013***
	(0.006)	(0.290)	(0.002)
February 2021	-0.004	-0.652**	-0.006***
	(0.006)	(0.280)	(0.002)
March 2021	-0.000	-0.438	-0.007***
	(0.006)	(0.272)	(0.002)
April 2021	0.065***	2.691***	0.024***
	(0.005)	(0.273)	(0.002)
May 2021	-0.005	-0.054	-0.002
	(0.004)	(0.232)	(0.002)
July 2021	-0.055***	-2.521***	-0.015***

	(0.004)	(0.232)	(0.002)
August 2021	0.006	0.934***	0.003*
	(0.005)	(0.248)	(0.002)
September 2021	0.023***	2.627***	0.017***
	(0.005)	(0.266)	(0.002)
October 2021	0.022***	1.195***	0.009***
	(0.005)	(0.283)	(0.002)
November 2021	-0.007	-1.127***	-0.006***
	(0.006)	(0.285)	(0.002)
December 2021	-0.036***	-1.985***	-0.012***
	(0.006)	(0.275)	(0.002)
January 2022	-0.093***	-3.584***	-0.020***
	(0.006)	(0.285)	(0.002)
February 2022	-0.022***	0.033	-0.002
	(0.006)	(0.286)	(0.002)
March 2022	-0.056***	-1.545***	-0.011***
	(0.006)	(0.280)	(0.002)
April 2022	0.009	0.940***	0.011***
	(0.006)	(0.293)	(0.002)
Observations	2,070,993	2,070,993	2,070,993
R-squared	0.113	0.126	0.059
Number of households	35,300	35,300	35,300
Outcome Mean	46.740	7.919	0.119

Notes: Each column represents a separate regression. The outcome variables are total water consumption in 100's of gallons, the natural log of total water consumption in gallons, and whether or not the household crossed into high-use pricing. June 2021 is the omitted period. All regressions control for precipitation, maximum temperature, and zone x precipitationand include month, year, and household fixed effects. Standard errors clustered at the household level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

2. Undergraduate Data Research Project: Measuring Prevalence, Preferences, and Production Methods of Cannabis Home Cultivators in New Mexico

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a. Overview

In addition to the research on cannabis legalization and water use, we used the survey data to generate an undergraduate data analysis project available to all instructors of introductory microeconomics classes. The project supports our undergraduate teaching mission by meeting three goals: (i) improve the data analysis skills and economic understanding of our undergraduates, (ii) connect the general education teaching curriculum to real issues occurring in New Mexico, and (iii) provide a shared educational resource that is quickly adopted into any classroom of microeconomics principles. The project asks students to act as economics research analysts for the state of New Mexico. Their task is to analyze a random sample of the survey data and apply economic concepts to understand better the prevalence, preferences, and production methods of home cultivation in New Mexico, the relationship between home cultivation and dispensaries, and how various scenarios may impact markets.

From the students' perspectives, the project comprises two main components. First, students analyze a small sample of data (ten observations) by following step-by-step tutorials. The goal is to ensure that students of all skill levels become familiar with the dataset and basic data analysis. The second component gives students a random sample of 150 observations. They are tasked with analyzing the data to answer questions about survey respondent characteristics, current and future home cultivation incidence, why and how home cultivators choose to cultivate, and various relevant scenarios that reinforce economic concepts.

From the instructors' perspectives, the project provides an alternative learning resource that supports the teaching curriculum while exposing students to research on New Mexico issues. In addition, the project is quickly adopted into any class size or delivery method—(i) all project materials are accessible through the department's *Undergraduate Teaching Resources* shared folder, (ii) a comprehensive instructor's manual is provided, (iii) each question is aligned to an economic concept (e.g., QX: [Demand—Substitutes Goods]), (iv) questions are in automatically-graded formats (e.g., numerical answer, fill-in-the-blank), and (v) each instructor generates their own random draw from the entire dataset (with solutions automatically updated), creating a project unique to their class.

The project is being piloted in a Summer 2023 Microeconomics Principles course. Students will be surveyed on their experience and feedback will be used to finalize the project for use in the Fall 2023 semester. The materials that comprise the undergraduate data project are listed below. To avoid making the main document excessively long, we have made the underlying materials available in a compressed companion file.

b. Data Project Materials

0. NM HC Cannabis Instructor’s Manual

1. NM HC Cannabis Market Analysis - About

2.1 Practice with Data Instructions

2.2 Sample Data

2.3 Practice with Data Quiz Questions

3.1 NM HC Cannabis Market Analysis Instructions

3.2 Market Analysis Data Sample

3.3 Market Analysis Quiz Questions

c. Compressed Zip File – available upon request

Project Team Members:

Sarah Stith is an expert on the medical and regulatory effects of cannabis legalization with twenty-one cannabis-related, peer-reviewed publications. She has had her work cited in testimony before the U.S. Congress, has testified herself on the subject before the New Mexico Legislature's Economic Development and Policy Committee, and has experience managing policy-related grant work for the Social Security Administration. Dr. Stith has conducted research related to New Mexico's medical cannabis program with a focus on particularly vulnerable New Mexicans, including chronic pain patients and veterans with PTSD. Her work has been cited in both the national press, e.g., *U.S. News and World Report* and *Forbes*, and local news outlets, e.g., *KRQE, KKOB,* and the *Santa Fe New Mexican*.

Swarup Paudel, a PhD candidate in economics at the University of New Mexico, specializes in health and public economics. Before joining the PhD program, Swarup gained experience as a Business Analyst at Aetna Healthcare in Chicago. In this role, he worked on their websites and mobile app, focusing on the administration of clients' FSA, HSA, HRA, and COBRA accounts. Swarup also holds an MS in economics from the University of Nebraska. His research interests revolve around examining the impact of the COVID-19 pandemic on various social and economic aspects of households. Additionally, he conducts research on the demand for prenatal care among expectant mothers in developing countries, with the aim of identifying the barriers and determinants that influence healthcare-seeking behavior.

Janie Chermak is a resource economist with expertise in water and energy issues and chair of the UNM Department of Economics. She has a dozen articles that focus on water or energy in the southwest. She has testified numerous times before the New Mexico Legislature's Water and Resources Committee and Economic Development and Policy Committee. She has substantial experience managing interdisciplinary, policy grants, including serving as the economics lead for three New Mexico EPSCoR grants, which focused on water and energy in New Mexico.

Cristina Reiser is an accomplished educator and scholar with over a decade experience of teaching undergraduates. She specializes in pedagogical approaches within the field of economics, learning assessment, and innovative curriculum design. Dr. Reiser's contributions have been acknowledged through multiple merit-based awards, including university and national recognition of her courses, ECURE and SEP fellowships, and UNM College of Arts and Science Learning Improvement Awards. Currently, her focus lies on ways to empower students from diverse backgrounds to succeed in economics by integrating economics research training into the general education curriculum and by promoting inclusivity through evidence-based interventions.