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The Effects of Water Use on Economic Growth: Investigating California's Surface and Ground Water Use

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Abstract: After many years of drought, California is challenged to manage its water resources to mitigate the socioeconomic impacts of water stress. An important question arises as to whether the economic effects of water use by major sectors are greater for particular geographical and economic regions, taking into account of water sources. Hence, in this paper, we examine the effects of water use by sector, with a particular focus on industrial and agricultural water uses, on employment growth between 2010 and 2016 in California taking ground and surface water use into account. Regional fixed effects model is employed to control for unobservable attributes across six different regions in California. Results suggest that industrial surface water use enhances employment growth in California counties. However, we find that greater surface water withdrawal for industrial use is associated with lower employment growth in agricultural counties. This result is consistent with previous finding that water scarcity constrains economic growth in predominant agricultural regions. Our research will, hopefully, guide policy decisions concerning efficient use and allocation of water and groundwater management considering regional heterogeneity.

Keywords: Groundwater; surface water; economic growth; agricultural counties; California
JEL Classification: Q25; O44

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1. Introduction

Being labeled as "Blue Gold", water is becoming the new concern for many countries throughout the world. The U.S. Census estimates the world population to be 7.4 billion people; and water is not only needed for personal consumption, but also used to produce foods and other goods the population wants and needs. Water is replenishable but depletable resource; more so of the latter in the midst of a growing world population. According to the U.S. Geological Survey (USGS), water is allocated to different business sectors such as (but not limited to) agriculture, industry, mining, and thermoelectric power. The uses in each sector can vary from growing crops to extraction of minerals for the production of high value goods. The need for water has accelerated with the onset of factory farms, commercial farming, and "Big Ag" (i.e., mega agriculture corporations). The push for larger crop yields needs higher water demand. Water withdrawal for irrigation accounts for approximately 70% of global water use (Shiklomanov and Rodda, 2003). As a leading agricultural state, California consumes more than 50% of total water supply for irrigated agriculture (Johnson and Cody, 2015). The importance of water is, therefore, no trivial matter for research. The water shortages in areas of California have left farmers and agriculture corporations to forgo irrigation and let acres of crop to wither. Water shortages can be caused by climate change, over-withdrawal of ground and/or surface water, inefficient allocation of water, pollution, and/or poor water conservation. Each issue poses its own different set of challenges and solutions.

While the contributing factors to water shortages are many, for our present study, we chose to address, mainly, two gaps in the literature: the effects of water use by sector and water source on regional economies. We think that California would be a good starting focus for our research as the state faces severe water scarcity from the persistent drought and heavy irrigation demands. Drawing from Barbier's (2004) finding that water use has heterogeneous effects on economic growth for different nations, we assume that this heterogeneity exists at county level due to unbalanced water distribution and needs across counties. We will also take into account sectoral water uses, as there are substantial differences in marginal benefit of water across sectors depending on water supply (Olmstead, 2014). Our research will also differentiate water withdrawal sources: ground or surface water. Ground water withdrawal requires drilling equipment, pump, and supporting infrastructure such as well casing and pipes. Surface water withdrawal requires pump and different supporting infrastructure such as canals and aqueducts. Groundwater use generally costs more than surface water use due to drilling costs, additional deeper drilling when the water table level drops, and/or drilling new wells when existing wells dry up. Surface water is easier to locate and can be diverted from streams, rivers, or lakes. During severe drought years in western states including California, groundwater accounts for more than 30% of water supply. Some communities in California fully depend on groundwater (CADWR, 2016). The negative effects of groundwater depletion, such as lowering groundwater table, increased costs, reduced surface water supply, land subsidence, and groundwater contamination, potentially hinder economic growth. Since costs of ground versus surface water can differ substantially, we think examination of the impact of water use by water source on a region's economy is warranted.
In this paper, we use an employment growth model to examine the effects of industry and agriculture water use [1] by source (i.e. surface and ground water) on employment growth in California between the years 2010 and 2016, during which drought conditions have worsened. We further explore the effects on counties with higher share of establishments in agricultural sector. To capture region-specific attributes such as climate, socioeconomic conditions, and others, we use region fixed effects to control for the unobservable characteristics that vary across six regions in California.

There is an underlying challenge of sustaining groundwater in California. Groundwater withdrawal for industrial use could mean that the basins are not recharged; thereby, causing or worsening groundwater overdraft. According to California Department of Water Resources' (CADWR) estimate, the State's groundwater overdraft was about 1.5 million acre-feet annually (CADWR, 2003). We would suspect that surface water withdrawal for industrial use lowers employment growth in agricultural counties, because of the keen competition for water. Previous research has found that water constraint hinders economic growth for countries that face moderate or severe water scarcity. This negative effect could be even larger in some key sectors such as agriculture in a country with pressing water stress issue (Barbier, 2004). According to USGS, water use for irrigated agriculture in California accounts for more than 60% of total water withdrawal. Irrigation water use represents approximately 80% of total water for business and residential use. In agricultural counties constrained by water scarcity, more water withdrawal for industrial use could lower the amount of water supply for agriculture. This will likely lead to reduced agricultural productions; thus, negatively affecting the overall economic growth in these agricultural counties.

2. Literature Review

Water withdrawals come from two sources: groundwater, and surface water. According to USGS (2017), groundwater is defined as water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust. Surface water is defined as water that is on the Earth's surface, such as in a stream, river, lake, or reservoir. Surface water is replenished faster than ground water because unlike ground water, surface water does not need to seep through the ground. Thus, groundwater is a relatively more finite resource because of the slow process of replenishing the underground aquifer.

Sekhri (2014) examined the impacts of groundwater depletion on rural poverty in India. She found that withdrawing groundwater beyond the depth of 8 meters significantly increases poverty rate in rural India that depends on groundwater irrigation. Withdrawing from deeper wells could involve higher water acquisition costs and/or poorer water quality for irrigation. Beyond the direct effects of water shortage and groundwater depletion on agricultural sector, the ripple effects (e.g., on non-Ag services and retail businesses) could amplify the overall negative effects on local and regional economies. Holland et al. (2007) examined the effects of water shortage on economic returns of potato production, and the chain effects on the regional economies using case study in four Columbia Basin counties in Washington State. The authors found that relying on "deep well" irrigation threatens agricultural production. Using input-output model, the authors found significant loss in the regional economies in terms of employment loss and declines in regional income due to water shortage and its impact on the agricultural sector.

Due to the slow replenishing of groundwater sources, overdrafting of aquifers has been shown to have negative economic impacts. Anantha (2013) researched the effects of over withdrawals of ground water upon local farmers in India. One of the findings was that groundwater overexploitation is detrimental mostly to small farmers in the agricultural region in India. As dependency on groundwater expands, negative consequences on individuals and businesses begin to grow. For example, California's largest aquifer is located in the California's Central Valley, one of the most important and largest agricultural regions in the nation, and this aquifer provides water for not only irrigation, but also for municipal, and industrial uses. Groundwater overdraft, which occurs in a growing number of groundwater basins in California, has negative impacts on multiple sectors and regional economies as a whole (Moran et al., 2014).

Another line of literature has looked at the marginal value of water per industry. Strzepek et al. (2006) studied 13 different industries based on the International Standard Industrial Classification (ISIC) code throughout 66 regions. The authors found that marginal value of water varied largely across the 13 industries. The value of output was highest in the petroleum extraction sector per unit of water use, while marginal value of water in the agricultural sector was the lowest. Even within the same sector, marginal values of water could differ substantially depending on water supply. Marginal values of groundwater use range from $27 to $3,267 per acre-foot across counties in Arizona (Brewer et al., 2008). Compared to agricultural water use, urban water use tends to have higher marginal value and could reach up to $21,000 per acre-foot (Griffin and Boadu, 1992).

Generally speaking, water is allocated from the low-valued to high-valued uses based on the market mechanism.

Given that marginal value of water varies across sectors and regions, it is not surprising to see heterogeneous impacts of sectoral water use on regions that have different industrial compositions and regional comparative advantages. When inspecting the demographics of California, there are stark differences in the population. For example, when comparing Fresno County (in California's Central Valley), and Santa Clara County (home to Silicon Valley), Fresno has 19.5 percent of its population with a Bachelor's degree or higher compared to Santa Clara's 47.3 percent.[2] Different compositions of working-age population by educational attainment are partially associated with industrial compositions in these two counties. Silicon Valley has been home to high-tech companies and electronic industry, while Fresno is one of the leading agricultural counties in the nation. Thus, sectoral water use is expected to have different impacts across counties in California. In addition to the literature on marginal values of water across sectors, several researchers have empirically examined price elasticity of water demand from residential, industrial, to agricultural water use (e.g. Klaiber et al., 2014; Nauges and Whittington, 2010; Olmstead et al., 2007; Griffin, 2006; Scheierling et al., 2006). To adapt to climate change, water pricing policies should take water scarcity into account. The literature also suggests that markets allocate scarce water resources to the highest valued use (Olmstead, 2014; Brookshire and Ganderton, 2004). However, there is a lack in research on water allocation and its effects on the regional economies. Barbier (2004) theoretically and empirically analyzed the effects of water withdrawal upon economic growth across countries and found that the relationship between water withdrawal and annual growth of per capita income follows an inverted-U shape. The author concluded that water withdrawal does not hinder economic growth for countries with abundant water resources, while more water use negatively affects economic growth for countries with limited water supply. Barbier (2004) suggested that future research examining water use and economic growth at a disaggregated level should capture heterogeneity across regions and sectors. Hence, investigating the effects of the water use at the finer spatial scale (e.g. regions or counties) especially in the area with severe drought could add to the literature on water use and economic growth. Furthermore, exploring the effects by sector could grant researchers the ability to see the heterogeneous effects of water on economic growth across sectors that have different marginal benefit of water use.

Water stress and its negative impacts on regional economies could be intensified by climate change. Extreme weather events continue to happen with greater frequency and intensity. A total number of 567 counties in the year 2014 were declared as primary disaster areas due to severe drought (USDA, 2014). Drought directly affects agricultural production and prices of agricultural products. Even the wet winter of 2016 in Central California will not compensate for California's extended drought. The growing likelihood of La Niña event may cause below-average precipitation in California the next winter (NOAA, 2017). Understanding water use by sector and by source in California even when drought was moderate in most California counties is crucial to the State's water management and policies.

3. Data

The dependent variable used for this analysis is employment growth between 2010 and 2016. The annual full-time and part-time employment (number of jobs) for these two periods were obtained from U.S. Bureau of Economic Analysis (BEA). The main dataset on water use by sector in California for the starting year 2010 is acquired from USGS. Water use measured in Mgal/d (million of gallons of water used per day) and is categorized by source: surface and ground water. We aggregate irrigation, livestock, and aquaculture as one category representing agricultural water use. Water for industrial use is defined for purposes such as fabricating, processing, washing, diluting, cooling, or transporting a manufactured product, etc. To differentiate agricultural counties from others, we acquire total number of establishments by the North American Industry Classification System (NAICS) code from U.S. Census County Business Patterns (CBP) and extract establishment data for agricultural related industries[3] for the year 2010. We then calculate the share of number of establishments in agricultural related industries out of total number of establishments. We expect that agricultural counties have higher share of establishments in agricultural related industries.

Other control variables for the starting year 2010 are requested from various sources. Population, race, and age data by county are obtained from U.S. Census. We calculate the percentage of seniors over 65 years old. Social capital variables such as number of professional organizations, business associations, labor organizations, religious organizations, civic and social organizations, political organizations, bowling centers, fitness centers, and golf courses were acquired from the study by Rupasingha, Goetz, and Freshwater (2006)[4]. To control for region-specific unobservable attributes, we create six region dummy variables that vary by factors such as job opportunities, composition of population by educational attainment, housing prices, industrial compositions, etc.[5] Summary statistics of these variables are presented in Table 1.

4. Empirical Model

We use employment growth model to estimate the effects of water by source and sector. Key variables in our analysis include surface water and groundwater, respectively, for agricultural and industrial uses, along with their interaction terms with the share of establishments in agricultural related industries. The empirical model for this analysis is shown in equation (1), which is based on the employment growth model by Ciccone and Papaioannou (2009).

$$\Delta lny_{j,2010-2016} = \alpha_0 + \beta lny_{j,2010} + \sum_m^n \gamma_{m,n} WATER_{j,2010}^{m,n} + \sum_m^n \rho_{m,n} \left(WATER_{j,2010}^{m,n} \times AG\_ESTAB_{j,2010} \right) + \sum_k \theta_k X_{j,2010}^k + r_k + \varepsilon_{j,2010-2016}$$

where the dependent variable represents employment growth rate in county *j* during the year period 2010-2016; $lny_{j,2010}$ is the natural logarithm of the employment in county *j* in the initial year 2010; $WATER_{j,2010}^{m,n}$ is water use by sector *m* (*m* represents either industrial or agricultural water uses) and source *n* (*n* represents either surface or ground water) in county *j* in the initial year 2010; $AG\_ESTAB_{j,2010}$ is the portion of establishments in agricultural sectors in county *j* in the year 2010; $X_{j,2010}^k$ represents vectors of control variables (e.g. county-level demographic information, social capital variables, and population); r_k is region fixed effects capturing unobservable characteristics that vary by region; and $\varepsilon_{j,2010-2016}$ represents residual growth.

The key variables of interest are the standalone components of water uses and their interaction terms with the share of number of establishments in agricultural sectors. The standalone variables measure the relationship between water use and economic growth considering water sources and sectoral uses, while the interaction components examine the effects on agricultural counties.

5. Results

The regression results are presented in Table 2. The coefficients of groundwater uses are not statistically significant, and the impacts of groundwater use on employment growth are undetermined. Groundwater extraction benefits local and regional economies on one hand especially considering its high demand for agricultural sector in dry season, but its long-term costs if not properly managed involve increased energy costs for pumping groundwater and potential damages to the ecosystem. Turning to the coefficient of industrial surface water use, it is positive and statistically significant, suggesting that more surface water use in industrial sector promotes employment growth. Perhaps before substituting surface water for groundwater withdrawal, freshwater utilization does not constrain economic growth. This is consistent with previous finding that water utilization increases economic growth for most regional economies unless water scarcity conditions have worsened (Barbier, 2004).

Turning to the interaction term of industrial surface water use and the share of number of establishments in agricultural sectors, the coefficient of this interaction term is negative and statistically significant. Agricultural counties are expected to have larger share of establishments in agricultural sectors. Industrial surface water use lowers employment growth in agricultural counties. This is not surprising because more industrial surface water uses in water-constrained regions could potentially lower agricultural surface water use thus affecting agricultural productivity and economic growth in the agricultural counties.

For other control variables, coefficient of percent of population over 65 years old is negative and statistically significant, suggesting that economic growth is likely to be slower for counties that have larger share of retirees.

6. Conclusion

In this paper, we use an employment growth model to estimate the effects of water use by sector on economic growth in California. We focus on California for this current study because this state is one of the most important agricultural regions in the nation, and has experienced water scarcity and groundwater overdraft issues. We find that utilization in additional units of surface water does not constrain economic growth. Instead, more surface water use in industrial sector promotes employment growth. In addition, we find that industrial surface water use lowers employment growth in counties that have higher share of establishments in agricultural sectors. This result is consistent with previous finding that water scarcity could pose a barrier for economic growth in water-stressed regions, especially for key sectors such as agriculture (Barbier, 2004). Given the regional comparative advantage in California's Central Valley, agricultural water use accounts for higher portion of total water withdrawal. Thus, challenges for agricultural sectors caused by surface water shortage or by greater competing demands for surface water from other sectors could constrain regional economic growth.

The research done in this paper is limited to the scope of California. Future research can be done at the county level covering the whole U.S by including water uses for more industrial sectors. Some of the sectors that are not captured in this analysis such as thermoelectric and mining could play a larger role in the economic growth in other regions[6]. Another future timely research undertaking could be to address climate change and drought in a dynamic setting while estimating the relationship between water use and economic growth. We would like to note that this paper does not take in consideration of irrigation adaptations under changes in climate. Addressing different irrigation technology that targets at improving irrigation efficiency could be another worthy avenue of future research.

Endnotes

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1. In the paper, we use water withdrawal in million of gallons of water used per day (Mgal/d) as our measurement for fresh water utilization. The data is obtained from U.S. Geographical Survey (USGS) at https://water.usgs.gov/watuse/data/

2 . This data is obtained from U.S. Census. https://www.census.gov/quickfacts/fact/table/CA,fresnocountycalifornia,santaclaracountycalifornia/PST045216

3. Agricultural related industries are taken from CBP data that is classified as NAICS code 11 “forestry, fishing, hunting, and agriculture support”.

4 . Data is available at http://aese.psu.edu/nercrd/community/social-capital-resources/social-capital-variables-for-1997-2005-and-2009. Data for the closet year 2005 is used to represent 2010-year data in our analysis.

5. According to a proposed initiated in 2013, 58 counties of California could be divided into 6 regions: Jefferson, North California, Silicon Valley, Central California, West California, and South California. Information available at: https://en.wikipedia.org/wiki/Six_Californias

6 These sectors were not added in this analysis because most counties recorded zeros.

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Table 1. Summary statistics for variables at the county level

Variables	Description	Mean	Std. Dev.	Min	Max
Dependent variable					
Employment_2010	Total full-time and part-time employment (number of jobs) in 2010 (BEA)	338,869	781101	969	5366445
Employment_2016	Total full-time and part-time employment (number of jobs) in 2016 (BEA)	401,126	929374	1156	6384920
Water related variables					
Ag Ground	Agricultural, groundwater withdrawals in 2010 (irrigation, livestock, and aquaculture), fresh, in Mgal/d	154.17	228.95	0	1208.13
Ag Surface	Agricultural, surface-water withdrawals in 2010 (irrigation, livestock, and aquaculture), fresh, in Mgal/d	263.38	409.80	0.21	1805.2
Industry Ground	Industrial, groundwater withdrawals in 2010, fresh, in Mgal/d	6.88	14.07	0	103.27
Industry Surface	Industrial, surface-water withdrawals in 2010, fresh, in Mgal/d	0.019	0.11	0	0.85
Agricultural employment					
Ag establishment	Percent of establishments in agricultural sector out of total number of establishments, 2010 (%)	1.04	1.10	0.00	4.59
Social capital					
Bus05	Number of business associations, 2005	26.00	48.68	0	320
Labor05	Number of labor organizations, 2005	21.37	47.29	0	322
Prof05	Number of professional organizations, 2005	13.17	28.29	0	183
Golf05	Number of public golf courses, 2005	12.48	20.10	0	110
Relig05	Number of religious organizations, 2005	190.24	427.03	0	3030
Civic05	Number of civic and social associations, 2005	43.93	90.02	0	625
Bowl05	Number of bowling centers, 2005	3.76	6.99	0	48
Fitness05	Number of physical fitness facilities, 2005	61.09	115.72	0	743
Pol05	Number of political organizations, 2005	4.64	12.33	0	82
Demographic characteristics					
Population	Total population in 2010	643,667	1418696	1160	9825473
Age65_above	Percent of population over 65 years old in 2010	0.39	0.14	0.09	0.63

Table 2. Results from the Employment Growth Model

Variables	Coefficients
Ag Ground	-0.00015
	(.0001)
Ag Surface	.000063
	(.000035)
Industry Ground	0.0012
	(.0021)
Industry Surface	1.88***
	(.30)
Ag establishment	-0.011
	(0.034)
Ag Surface*Ag establishment	-0.000025
	(0.000029)
Ag Ground*Ag establishment	.000053
	(.000036)
Industry Ground*Ag establishment	-.0013
	(0.0016)
Industry Surface*Ag establishment	-2.99***
	(0.49)
Employment_2010	1.71e-07
	(2.72e-07)
Population	-2.42e-07
	(1.50e-07)
Prof05	-.000060
	(.0014)
Bus05	-.0011
	(0.0013)
Labor05	-.000039
	(0.0018)
Golf05	.0039
	(0.0023)
Relig05	-0.000045
	(0.00054)
Civic05	0.0012
	(0.00062)
Polp05	0.0017
	(0.0051)
Bowl05	0.014*
	(0.0066)
Fitness05	-0.000043
	(0.00068)
Age65_Above	-.25*
	(0.10)

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Table 2 (Continued). Results from the Employment Growth Model

Variables	Coefficients
Constant	0.222**
	(2.86)
Observations	58
Region fixed effects (6 regions)	Yes
R-squared	0.4371

Clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1