Effects of the California Drought on Fresh Fruit and Vegetable Prices over Time and across Space

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California produces over one third of all vegetables and over two thirds of all fruits and nuts in the United States. The state is the largest producer of over fifty types of fruits and vegetables, including broccoli, grapes, lemons, lettuce, peppers, and strawberries. For some crops – such as artichokes, figs, garlic, and olives – California is the sole producer (California Department of Food and Agriculture, 2017). Because of California's importance in the national market, extreme weather events that impact growing conditions of fruits and vegetables in California may have significant economic consequences nationwide.

Between 2011-2016, the state experienced a prolonged statewide drought that had substantial economic costs. In 2015 alone, estimates suggest $2.7 billion and 21,000 jobs were lost due to the drought (Howitt et al. 2015). According to ERS-USDA, the drought may have long lasting effects on farming systems and production (Wallender et al. 2013). California has historically experienced severe droughts. While understanding the effect of the most severe drought in recent memory is important, there are mounting concerns that climate change likely to result in more widespread and more severe droughts.

This research is closely related to the broad body of literature on the economic impacts of climate change. Global surface temperatures have been steadily increasing and the trend is projected to continue (Karl et al. 2015). Studies focusing on the effects of increasing temperatures generally find that there is a non-linear, concave relationship between temperature and economic outcomes such as overall economic production, agricultural productivity, and labor productivity (Burke, Hsiang and Miguel 2015; Graff-Zivin Neidell 2014; Schlenker and Roberts 2009). Furthermore, extreme weather events such as heat waves, hurricanes, droughts and floods are closely tied to the changing climatic conditions. It is projected that increasing global surface temperatures will lead to greater frequency and intensity of extreme weather events (Meehl et al. 2007). These projections are especially concerning for regional economies, such as California's, that are already experiencing extreme weather events on a relatively more frequent basis. Corroborating with these concerns, in a recent study Cvijanovic et al., (2017) investigate the link between California drought and Arctic sea-ice changes and project that in the next 20 years, California's rainfall will decrease by 10 to 15 percent.

In this paper, we estimate the effect of the recent California drought on the retail prices of fresh fruits and vegetables (FFV) over time and across the United States. Understanding the impact of the recent drought on FFV prices is important for several reasons. From a policy perspective, if FFV prices increase due to the drought it would be important to formulate strategies with potential to mitigate the economic impacts of future droughts. In addition, to the degree that it exists, the heterogeneous price impact of the drought by fruit and vegetable varieties would provide valuable information when making production and marketing decisions. The estimated magnitudes of price changes will be important for understanding the extent to which adaptation occurs (or doesn't occur) across the supply chain. If the drought has no impact on FFV prices it would be important to understand the behavioral mechanisms through which the drought impacts are mitigated. These behavioral responses might occur at any stage of the supply chain such as farmers' adoption of new technologies or techniques, retailers' adjustment of markups, or consumers' substitution between fruits and vegetables and between other foods.

We estimate the impact of the California drought on FFV prices using data on quarterly FFV retail price indices across 26 Metropolitan Statistical Areas (MSAs) and percentage of California land in drought between 2009 and 2014. We find that the drought has an economically small effect on FFV prices. The effect is precisely estimated. This suggests that there might be important behavioral responses along the FFV supply chain that mitigate the impact of the drought. The results also show that *severe drought* and *exceptional drought* have positive marginal effects while *moderate drought* has negative marginal effect on FFV prices. We argue that the latter result could be due to the effective responses by farmers and marketers to the drought risk.

The remainder of the paper is organized as follows. In the next section, we introduce the data used in estimation. The subsequent section presents data analysis and results. The last section concludes.

Data

In order to answer our research question, we use a panel price index for fresh fruits and vegetables published in Çakır et al (2018), which is a quarterly price index at the MSA level. The index is constructed using retail scanner data that comprise weekly sales information at the UPC level from over 40000 stores across United States between 2009 and 2014. The methods used in construction of the price index are detailed in Çakır et al (2018).

To this we add weekly, county-level historical drought data for California from the United States drought monitor. The data provide weekly information on the percentage of California land in five different drought categories: abnormally dry, moderate drought, severe drought, extreme drought and exceptional drought.[1] Table 1 summarizes the data.

Data Analysis and Results

Our key research question is whether the California drought led to higher FFV prices for retail consumers. Figure 1 shows the percentage of California land in drought and the change in the US average prices of FFV for the period between 2009 and 2014. The data show that drought has been persistent over the period. In 2009, the state saw moderate to severe drought in over 75 percent of the land. The drought conditions in 2010 and 2011 were relatively mild. However, since 2011 drought conditions have become both more common across the state and more severe. In particular, in 2014 the whole state was in drought with over 83 percent of the land in extreme or exceptional drought. The figure also shows that FFV prices have been trending upward with an overall increase of

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[1] Downloaded from http://droughtmonitor.unl.edu/Data/DataDownload/ComprehensiveStatistics.aspx

approximately 8.5 percent during the same period. Thus, it appears that there might be a positive correlation between the drought and FFV prices.

A related concern is whether a drought in California led to heterogeneous price effects across the country. This could happen if there are differences in the structural characteristics of local markets that result in differences between retailer mark-up adjustments and, consequently, farm-to-retail pass-through rates. To consider heterogeneous price effects, figure 2 presents drought levels in California over time together with the FFV price trends at the MSA level. The figure shows that FFV prices vary substantially across MSAs with a range (i.e., the vertical distance between the highest price MSA and the lowest price MSA) over 20 percentage points in any quarter. All prices display highly similar temporal variations and seasonal patterns. A priori, figure 2 suggests that there is not any discernable evidence that the drought had a heterogeneous impact on cyclical variations of MSA level prices.

The story might be different for the impacts on long-term trends of prices. It appears from figure 2 that, on average, the price range during 2011 and 2012 is larger than the average range during 2013 and 2014 when the state saw extreme and exceptional drought. This could indicate that regional prices converge in extreme drought seasons. To illustrate this, figure 3 plots a measure of the convergence of prices over time together with the percentage of the California land in drought. The price convergence is measured by the standard deviation of the logarithm of price levels using the formula provided in Çakır et al. (2018, p. 699). The figure shows that between 2009 and 2013 the regional prices diverged, then converged during 2013 and 2014.

Figures 1 and 2 provide two insights into the relationship between the California drought and FFV prices: 1) FFV prices may have increased, slightly, due to the drought, and 2) retail prices converged across MSAs when there was extreme and exceptional drought. We now turn to our econometric analysis to formally test the first hypothesis. Let *i* index MSAs and *t* index quarters. We estimate the following equation:

$$\mathrm{P_{it}} = \alpha_0 + \boldsymbol{A D_t} + t + \lambda_i + \lambda_t + \epsilon_{jt}, \quad (1)$$

where P is FFV prices, $\boldsymbol{D}$ is a vector of drought levels, t is annual time trend, and λ denote fixed effects. The coefficients of interest are the marginal effects of drought levels and are captured by **A.**

Table 2 reports the estimates of equation 1. The first column presents the estimates without the fixed effects and the time trend. The R^2 of this model is less than 1 percent. In model 2, we include quarter fixed effects but the model fit does not improve. In model 3, we control for MSA fixed effects and the R^2 increases to 57 percent. In model 4, we add an annual trend variable, which increases the R^2 to 74 percent. In this model, the marginal effects of drought levels are identified off of the trend variable. As such, they should be interpreted as the deviations from the annual trend.

In model 4, the estimated marginal effects of three drought types are statistically significant, whereas the effects of *abnormally dry* and *extreme drought* are estimated imprecisely. Among the significant effects both *severe drought* and *exceptional drought* have positive and significant effects on FFV prices. However, the estimated magnitudes are small at 0.01. To put the estimates in context, note that the percentage of California land in exceptional drought increased from 0 percent in 2013 to an average of 45 percent in 2014. This increase in the severity of drought increased FFV prices by approximately 0.45 percentage points.

The results also indicate that the marginal effect of *moderate drought* is negative and significant. The estimate implies that a one-percentage point increase in *moderate drought* decreases FFV prices by 0.04 percentage points. This finding may not be counter-intuitive. It is possible that economic responses of farmers or marketers are highly effective at low levels of the drought. For example, farmers' groundwater replacement largely offsets surface water shortages in the state (Howitt et al., 2015). Research also shows that farmers account for drought-risk when making production decisions and undertake investments to improve resilience (Wallender et al. 2013). Similarly, marketers may make decisions to adjust trade flows in response to the drought that may impact relative prices of fruits and vegetables. This hypothesis could be tested via an analysis of the impact of drought at the crop level.

Conclusion

In this paper, we investigated the effect of the recent California drought on FFV prices. We summarized the relationship between the percentage of California land in drought and the quarterly FFV prices for the period between 2009 and 2014. These trends show that FFV prices might have slightly increased during the drought and that regional price differences might have decreased when the state was in severe and extreme drought. We also conducted an econometric analysis and find that the drought had a significant but economically small effect on FFV prices. Specifically, high intensity drought such as severe or exceptional drought has a positive impact, while low intensity drought such as moderate drought has a negative impact on FFV prices. The economically small impact of the drought on FFV prices indicates that effective adaptation along the supply chain might have occurred. More work is needed to identify and examine the behavioral responses that mitigate the impact of drought along the supply chain. Also, future research should be directed to investigate any heterogeneous effects by examining the impact of the drought at the crop level.

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Table 1: Summary of Data

	Description	Unit	Mean
D0	Percentage of California land in abnormally dry	%	12.67 (11.93)
D1	Percentage of California land in moderate drought	%	19.25 (20.75)
D2	Percentage of California land in severe drought	%	18.77 (24.50)
D3	Percentage of California land in extreme drought	%	8.60 (17.75)
D4	Percentage of California land in exceptional drought	%	7.57 (19.65)
Price	Quarterly fresh fruit and vegetable prices at the Metropolitan Statistical Area level	Index	98.81 (3.59)
Observations	624		

Notes: Standard deviations in parentheses.

Table 2: Estimates of the California Drought on Fresh Fruit and Vegetable Prices

Dependent Variable: Quarterly regional prices of fruits and vegetables				
	Model 1	Model 2	Model 3	Model 4
D4 - Exceptional	0.03 (0.02)	0.06*** (0.01)	0.06*** (0.01)	0.01** (0.00)
D3 - Extreme	0.11*** (0.02)	0.05* (0.02)	0.05*** (0.01)	-0.01 (0.01)
D2 - Severe	-0.00 (0.01)	0.02 (0.01)	0.02*** (0.00)	0.01* (0.00)
D1 - Moderate	-0.05*** (0.02)	-0.06** (0.01)	-0.06*** (0.00)	-0.04*** (0.00)
D0 - Dry	0.11*** (0.04)	0.07 (0.03)	0.07*** (0.01)	0.01 (0.01)
Trend				1.33*** (0.16)
Constant	97.37*** (0.64)	97.83*** (0.62)	100.65*** (0.42)	97.60*** (0.74)
Quarter fixed effects	No	Yes	Yes	Yes
MSA fixed effects	No	No	Yes	Yes
R^2	0.091	0.092	0.568	0.740
N	624			

Notes: Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$).

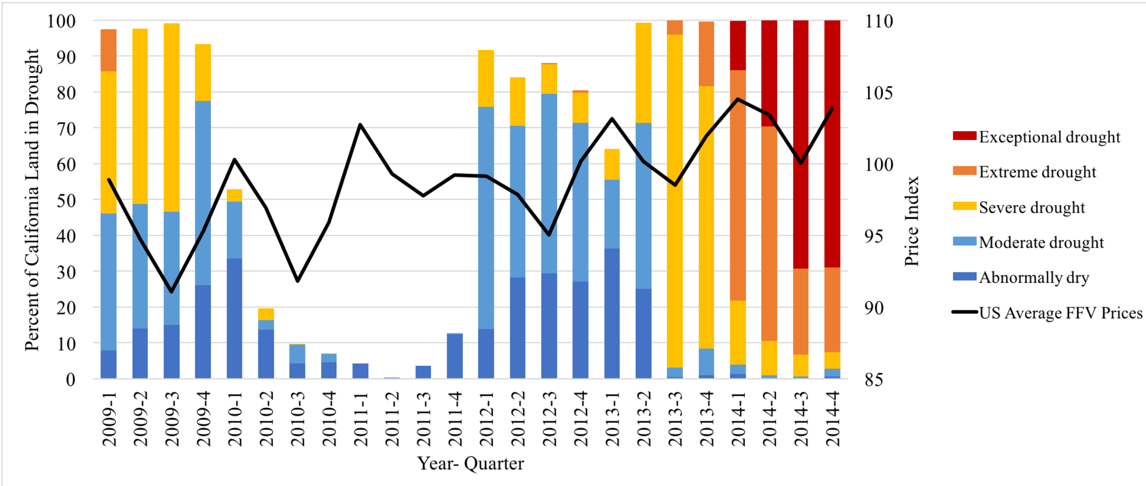

Figure 1. California drought and the change in US average prices of fresh fruits and vegetables (FFV) during 2009-2014, quarterly

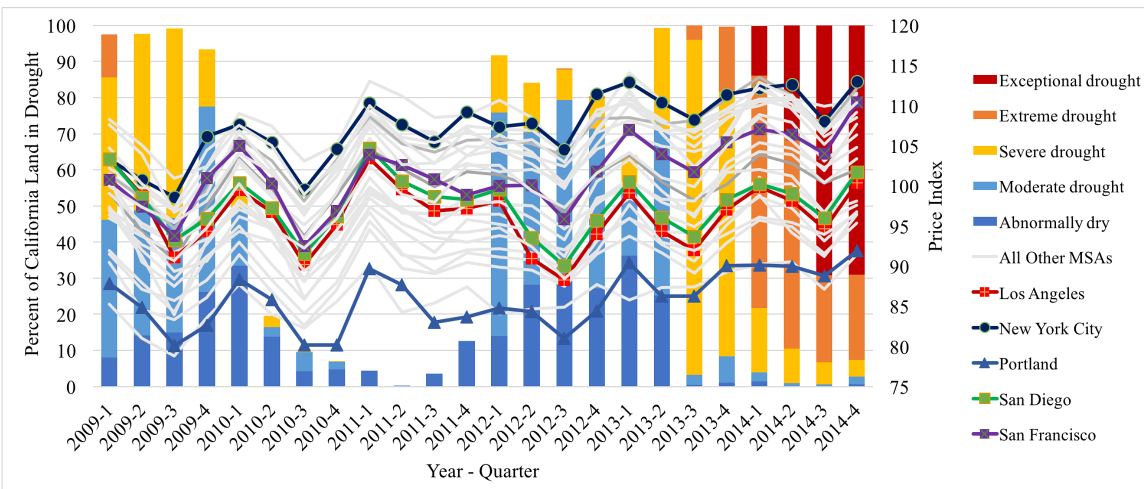

Figure 2. California drought and the change in prices of fresh fruits and vegetables (FFV) across Metropolitan Statistical Areas (MSAs) during 2009-2014, quarterly

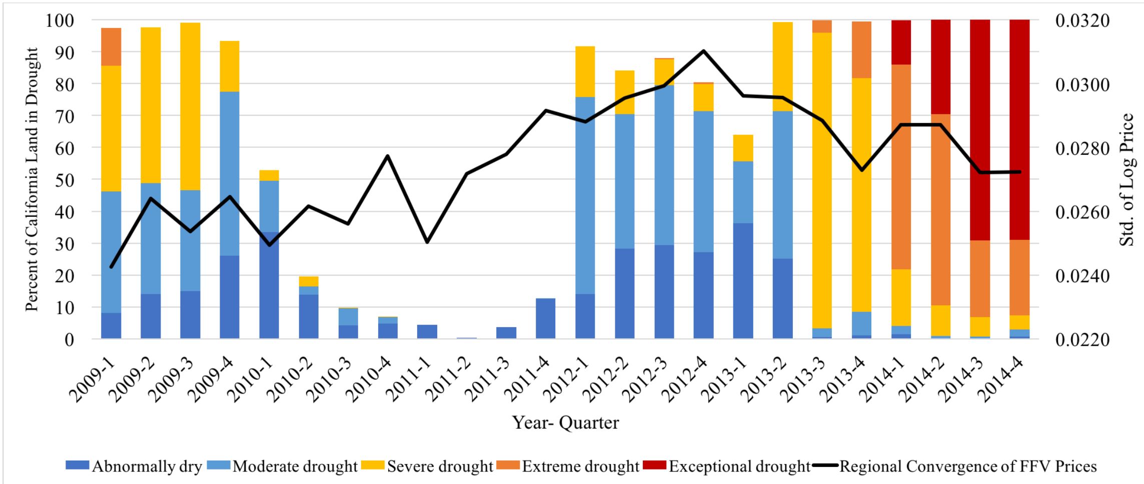

Figure 3. California drought and the convergence of fresh fruit and vegetable (FFV) prices across contiguous Metropolitan Statistical Areas during 2009-2014, quarterly