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Do climate factors matter for producers' irrigation practices decisions?

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ABSTRACT

The study examines whether climatic factors play a role in producers' irrigation decisions. Empirical analysis uses a set of repeated cross-sectional farm level data collected in three American states: Arkansas, Mississippi, and Louisiana. Empirical findings provide evidence that climatic conditions are factored into irrigation decisions. For example, higher mean temperature reduces the likelihood of using sprinkler irrigation in the study area. More importantly, findings of this study point to the importance of studying both long-term and short-term climate patterns. Long-term climate patterns weigh more in producers' decisions regarding the use of sprinklers. Both long-term and short-term climate patterns seem to affect producers' decisions on the use of WMPs. Producers may respond differently to similar changes in long-term and short-term climate patterns. For example, a higher occurrence of drought in the previous year predicts a higher rate of sprinklers, while an increasing trend of drought occurrence during the previous 30 years predicts the opposite. Our findings also highlight the importance of considering various aspects of the climate patterns. Average climate conditions, such as mean temperature and annual precipitation, and the occurrences of extreme weather events, such as droughts and intensive precipitation, have stronger predictive powers of producers' irrigation decisions than the coefficients of variation. In the study area, the occurrence of intensive precipitation seems to have the strongest impact on producers' irrigation decisions.

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1. Introduction

Water shortage is a problem faced by agricultural producers throughout the world. To provide context, agricultural irrigation is responsible for nearly 80% of the total water use in the United States (Aillery and Schaible, 2016). The adoption of more efficient irrigation technology is a frequently proposed solution. Existing studies have identified a wide range of factors that may influence the adoption of more efficient technology. These factors include economic and institutional factors, farm and producer characteristics, and technology traits (Carey and Zilberman, 2002; Caswell and Zilberman, 1986; Koundouri et al., 2006; Moreno and Sunding, 2005).

Despite the wide variety of potential impacts of climate change on agricultural production, limited attention has been directed toward climatic factors and their effects on producers' irrigation decisions. Temperature and precipitation changes may impact the quantity of irrigation water applied and the timing of irrigations, in addition to the supply of water available for irrigation (Elliott et al., 2014; Frieler et al., 2014; Schlenker et al., 2007). Climate change will likely result in more variations in rainfall and temperature as well as more droughts and floods (Hall et al., 2008; Rosegrant et al., 2014). Irrigation is one of the main strategies that can reduce the exposure of producers to growing climate risks. Thus, it is important to consider the impact of climatic conditions on producers' irrigation decisions (Joyce et al., 2011).

The main focus of this research is to examine whether climatic factors play a role in producers' irrigation decisions. This study adds to a relatively small literature that links irrigation decisions and climatic factors (e.g., Frisvold and Deva, 2013; Huang et al., 2017; Negri et al., 2005; Olen et al., 2015). Specifically, this study makes two significant contributions. First, this study is among the very few that examines how climate information factors into producers' irrigation decisions. Multiple aspects of climate conditions are considered in the study including average temperature and precipitation, variations in these factors and the occurrence of extreme weather events. More importantly, climate variables are constructed using different lengths of previous periods to see which period is more likely to be factored into producers' decision making. When studying producers' irrigation behavior, one of the most relevant questions may be the time frame they use to consider changes in climatic conditions. Longer time periods may

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better capture long-term climate trends by smoothing out short term fluctuations. More recent weather events may exert larger impacts on producers who may only look to the recent past when making decisions. Despite the large body of literature on climate change, there is no uniform length of time used to measure climate variations. The length of 30 years is used in many previous studies that examine the impact of or adaptations to climate change. For example, Burke and Emerick (2006) measure long-run trends in climate over the period 1980–2000 and examine adaptation to climate change in U.S. agriculture. However, longer or shorter periods have also been employed. For example, to gauge producers' perceptions of climate change, Di Falco et al. (2011) use a survey question that asks whether producers have noticed changes in mean temperature and rainfall over the last two decades. To our knowledge, very few studies have examined which length of time producers have used in making their irrigation decisions.

Second, this study includes a larger set of irrigation decisions that may be influenced by climatic factors. Except for Huang et al. (2017), most studies to date have focused exclusively on the choices of irrigation technologies (e.g., sprinkler or drip irrigation versus flood irrigation). The exclusive attention to more efficient technologies neglects other actions farmers may undertake in response to a shrinking and more volatile water supply. This study analyzes the joint choices of more efficient irrigation technologies as well as Water Management Practices (WMPs). A wide variety of WMPs can reduce on-farm water use by improving the performance of existing irrigation systems (Negri and Hanchar, 1989; Waskom, 1994; Aillery and Schaible, 2016). Some WMPs may be better at addressing irrigation challenges brought on by more volatile weather patterns. For example, in the United States, tailwater recovery pits, often in conjunction with on-farm reservoirs, capture rainfall and irrigation runoff and store it to meet future irrigation needs (Negri and Brooks, 1990). The large initial capital requirement of sprinkler or drip irrigations makes those technologies unaffordable to poor producers. Therefore, the inclusion of WMPs is more relevant in less developed countries where producers are more vulnerable to climate risks (Brouwer, 2007) and are more likely to resort to WMPs.

The rest of the paper is organized as follows. The second section presents the empirical method. The third section describes the study area and the data sets used. The fourth section regression results. The fifth section concludes. It should be noted that although the study site is in a developed country, the approach used is not specific to the study area and can be readily applied to other areas as long as data are available.

2. Empirical method

Producers' decisions regarding irrigation technologies and/or WMPs can be modeled either as a set of binary variables (whether a technology and/or a WMP is used), or a set of continuous variables (share of a producer's crop land allocated to a technology and/or a WMP). The information available in the data will dictate whether binary or continuous variables are modeled. In the continuous case, the relationship between a producer's irrigation practice decisions and potential influencing factors can be expressed as:

$$y_{icjkt} = \boldsymbol{\alpha}_{cjk} + \mathbf{W}_{ict}\boldsymbol{\gamma}_{jk} + \mathrm{X}_{ict}\boldsymbol{\beta}_{jk} + \varepsilon_{icjkt} \quad (1)$$

In Eq. (1), the dependent variable y_{icjkt} is the share of producer i's farm land irrigated with technology j and/or WMP k in period t. Producer i is located in county c. The vectors $\boldsymbol{\beta}_{jk}$, and $\boldsymbol{\gamma}_{jk}$ are the parameters to be estimated and ε_{icjkt} is the error term in regressions. For each combination of technology j and WMP k, there will be an estimating equation. So multiple equations are estimated since there is usually more than one combination of technology j and WMP k. Eq. (1) is the general representation of all the estimating equations. It can be applied to any study area and any combination of different irrigation technologies and WMPs.

On the right-hand side, the key variables of interest are contained in the vector $\mathbf{W}_{ict}$, which measures historical climatic conditions that producers may use to form their irrigation decisions. Three sets of climate variables are included. First, the first set of variables measure the average climate conditions such as mean daily temperature (MDT) and total precipitation during the growing season. The second set of variables use variance to measure the volatility in temperature and precipitation. Coefficient of variation, instead of variance, is used so that the measure is unit free. Coefficient of variation (CV) is the ratio of the standard deviation to the mean. CV is not calculated for measures from the previous year since only one observation is used to construct such measures. The third set of variables gauge the occurrence of specific extreme events. The first even considered is drought. Computation of the drought variable is based on the Palmer Drought Severity Index, where a month of severe drought receives an index score of -3 or less (Palmer, 1965; NIDIS, 2016). Months during the growing season when severe drought occurs are used to construct the variable as the share of months experiencing severe drought. The second event considered is intensive rainfall. Negri et al. (2005) and Groisman et al. (2012) argue that daily precipitation more than 25.4 mm (one inch) is detrimental to crop growth. Therefore, we use the share of days in the growing season when precipitation exceeds 25.4 mm to measure the frequency of excessive precipitation events (Bell et al., 2004). Because large farms have larger exposure to climate risks than smaller farms, all climate variables are interacted with farm size.

To determine whether more recent or long-term temperature and precipitation patterns are better predictors of producers' irrigation decisions, the climate variables can be constructed using various lengths of previous periods. From the producers' point of view, it is reasonable to treat 30 years as a long-run time horizon. It is also possible that some producers may only look at what just happened in the previous year. Other lengths of time periods (e.g., previous 5 years, previous 10 years) can also be used. Variables that measure weather condition of the current year are not included because producers most likely have made decisions regarding irrigation technologies/WMPs prior to the irrigation season and before such information is observed.

When estimating Eq. (1), it is important to control for non-climate factors that may influence producers' decisions regarding irrigation technologies and/or WMPs. Those factors are included in the vector $\mathbf{X}_{ict}$. Findings from previous studies provide guidance on which variables to include in $\mathbf{X}_{ict}$. Economic factors, like input, crop, and water prices, impact technology choice, while institutional factors, such as land tenure, may also play a role (Soule et al., 2000; Moreno and Sunding, 2005). Installation costs and technological traits will also impact a producer's choice between available technologies (Moreno and Sunding, 2005; Koundouri et al., 2006; Olen et al., 2015). Farm size and land quality have also been shown to impact adoption (Caswell and Zilberman, 1986; Negri and Brooks, 1990; Shrestha and Gopalakrishnan, 1993). Similarly, producer characteristics, such as age and education, are often linked with irrigation decisions (Koundouri et al., 2006; Olen et al., 2015).

Since the dependent variable in Eq. (1) is continuous, county-level fixed effects can be used to control for any unobserved time-invariant county characteristics in estimating Eq. (1). Some important county-level factors include the characteristics of irrigation supply (e.g., water yields in the aquifer in groundwater using areas) and status of irrigation technology and WMPs development. In equation (1), the use of county-level fixed effects is denoted by the term, $\boldsymbol{\alpha}_{cjk}$. It captures any time-invariant county-level