The Use of Irrigation Practices by Arkansas Producers:

The Impacts and Influencing Factors

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Selected Paper (or Poster) prepared for presentation at the Southern Agricultural Economics Association SAEA) Annual Meeting, Jacksonville, Florida, 2-6 February 2018.

Abstract

Diminishing groundwater resources is threatening the security of nearly half of the world's drinking water supply and 43% of the world's irrigation water supply. As the states ranks the third largest irrigated acreages in the nation, Arkansas is estimated to have an annual gap in groundwater as large as 7 million acre-feet by 2050. One main solution to reduce groundwater use is to improve irrigation efficiency. Using the data from Arkansas Irrigation Survey in 2016, this study first investigates which factors may influence producers' use of water management practices (WMPs). One major finding is that government programs have significant influences on Arkansas producers' usage of WMPs. It provides producers both financial incentives and social incentives to use WMPs. In addition, the study finds that the usage of WMPs tends to have positive impacts on producers' irrigated acres of major crops.

Keywords: Irrigation, Water Management Practices (WMPs), Irrigation Efficiency

1. Introduction

Agriculture is the major user of water in the United States . In 2012, the water usage for agricultural sector is accounted for 80% -90% of human water consumption at the United States, ranked the first among all the sectors (U.S. Department of Agricultural, 2012). Switching to more efficient irrigation technologies could be a solution to declining water supplies. For instance, Sprinkler irrigation saves from 10%-35% of the applied water by distributing water more evenly, compared with traditional gravity irrigation systems (Caswell and Zilnerman, 1986; Negri and Brooks, 1990). Most of existing studies have focused on producers' decisions on switching from traditional gravity irrigation system to more efficient irrigation technologies, such as center pivot irrigation. They have identified a set of procures' socioeconomic characteristics, technology-related characteristic, and institution factors play substantial roles in the switches (e.g. Caswell and Zilnerman, 1986; Green and Sunding, 1997; Negri and Brooks, 1990). Producers' socioeconomic characteristics, such as education and age are often associated with irrigation technology adoptions (Olen, Wu, and Langap, 2016). The technology-related factors, such as the initial investment of technology and expected returns of the technology, are also found to be correlated with the adoption (Moreno and Sunding, 2005). Institutional factors, such as land tenure, could positive influence producers' decisions on switching to more efficient irrigation technologies (Moreno and Sunding, 2005).

However, the focus on switching to more efficient irrigation technologies in response to water shortage issue may miss important aspects of producers' behaviors. Many producers choose to use water management practices (WMPs) to conserve water. Studies have identify that WMPs could significantly reduce water use for the existing irrigation systems. Sophisticated

WMPs applied to gravity-irrigated fields can achieve efficiencies comparable to sprinkler systems (Negri and Hanchar, 1989).

Despite the wide adoption of WMPs, few studies have focused on WMPs. This study investigate which factors have predictive powers of producers' use of WMPs and how it impacts on producers' irrigation decisions. Two contributions are made by this study. Firstly, we model the producers' choices on different WMPs. It significantly expands the existing literature, which focuses mostly on more efficient irrigation technologies. Such knowledge is helpful for policy makers to have a better understanding producers' water conservation behaviors in irrigation. Secondly, this article investigate the impacts of adoption of WMPs on irrigation acreage on farms. Although more efficient irrigation has the potential of reducing water use on farm (e.g. Peterson and Ding, 2005), it may also bring unintended consequences. The water savings from efficient irrigation may provide producers additional irrigation capacity. Profit-maximizing producers my respond this by expanding irrigated acreage, and thus efficient irrigation practices may cause more water to be used for irrigation. Using a seemingly unrelated regression model and three stage least square regression model, this article provides some findings of the impacts of the use of WMPs on irrigated acreages among farms.

The rest of the article is organized as follows. Section 2 describes the study site and data set used. Section 3 introduces the use of irrigation practices in Arkansas. Section 4 discusses the empirical models are used for analysis. Section 5 reports estimation results, and Section 5 concludes with policy implications from our findings.

2. Study Site and Data Description

The study focuses on the state of Arkansas. Agriculture is a key sector in Arkansas's economy. In 2014, the aggregated agriculture sector's share of the state economy for Arkansas is 2 times greater than that for the average of the United States and 1.6 times greater than that for the average contiguous states. In total, it provides almost $11.5 billion in labor income or 17% of the state's total labor income (English, Popp and Miller, 2015). The main crops include rice, soybean, corn and cotton. Arkansas now ranks first in the nation in rice production, accounting for 49.96% of total US production (USDA ERS, 2016).

Arkansas's crop production relies heavily on irrigation. Almost all rice is irrigated. The spikes of precipitation in Arkansas are usually from March to May and from October to December, while the growing season of the major crops is from April to September/October (ANRC, 2015). In addition, in eastern Arkansas, where most of row crops are grown, most precipitation falls as scattered thunderstorms (Watkins, 2012). As a result, nearly 90% of soybean, corn and cotton are irrigated by producers in Arkansas (NASS, 2014). In 2007, Arkansas accounted for 7.9% of all cropland under irrigation in the US, making the state the fourth largest user of irrigation water in the country (Schaible and Aillery, 2012)

More than 80% of irrigation water in Arkansas is groundwater pumped from Mississippi River Alluvial Aquifer (MRVVA, NASS, 2014; Schrader 2008). The continuous and unsustainable pumping has put the MRVAA in danger by withdrawing at rates greater than those of natural recharges. Many counties in eastern Arkansas have been designated as critical groundwater areas due to continued decline in groundwater levels (Arkansas Soil and Water Conservation Commission, 2003). An annual gap in groundwater as large as 7 million acre-feet is projected for 2050 and most of the expected shortfall is attributed to agriculture (ANRC, 2015). To combat growing projected scarcity, the state of Arkansas and the ANRC have identified two critical initiatives in the 2014 Arkansas Water Plan Update, which highlight adopting conservation measures that can improve on-farm irrigation efficiency and infrastructure-based solutions that convert more irrigated acres currently supplied by groundwater to surface water in Arkansas (ANRC, 2015). Therefore, the study of the uses of water management practices (WMPs) and their effects on agriculture producers' irrigation decisions are of particular importance to the region.

The main data set used in the empirical analysis is the 2016 Arkansas Irrigation Use Survey conducted by authors with collaborators from Mississippi State University. The sample in the survey is randomly drawn from the water user database managed by the Arkansas Natural Resources Commission (ANRC) and all commercial crop growers identified by Dun & Bradstreet records for the state of Arkansas. Of 3,712 producers that enumerators have attempted to contact through phone calls, a total of 224 valid responses are received for a 6.03% response rate. Of these responses, 199 are from the main survey and 25 are from the pilot survey. Descriptive statistics of the main survey and the pilot survey respondents are similar in nature, so the data sets are combined. In the survey, a series of detailed information on irrigation practices employed by Arkansas producers are collected, containing information on the usage of irrigation technologies and WMPs at farm level. County level climate data are also obtained from NOAA, National Climatic Data Center (2016) to calculate county level mean daily temperature and average annual precipitation in the previous 30 years. The same data set is also used to construct the aridity index, defined as the ratio of annual mean daily temperature to annual precipitation.

3. The Use of Irrigation Practices in Arkansas

Table 2 reports the type of irrigation technologies used on farms. More than 87% of Arkansas producers in the sample use gravity irrigation, which include flood irrigation, border irrigation and/or furrow irrigation (Table 1). More than 71% of producers use more than one type of irrigation technologies on their farms. Nearly 65% of the producers use both flood and furrow irrigation on their farm. Only 4.91% of producers exclusively use center pivot. Since the unit of analysis of the study is at the farm level and the dominant choice of irrigation technology is gravity irrigation, this study focuses on the choices of WMPs conditional on the types of irrigation technologies used on farm.

The survey collected information on 15 WMPs that may be used in Arkansas. Figure 1 shows that only 6.3% of producers do not use any WMPs. The majority of the producers (80.8%) use between 1 and 6 WMPs. Table 2 shows that some of the most commonly used practices include multiple inlet irrigation (38.39%), tailwater recovery (45.54%) and precision grade (57.14%). Several other practices such as computerized pipe-hole section (31.7%), storage reservoir (34.82%) and end blocking (30.80%) are also used by many producers.

Based on which aspects of irrigation a WMP is used for, WMPs are put into four groups (Figure 1 and Table 3). Water flow control practices include computerized pipe-hole selection, multiple inlet irrigation, surge irrigation, and cutback irrigation. The second group includes water recovery and storage reservoir. The third group is field management practices that include zero grade, precision grade, end blocking wrapped surface, and deep tillage. The last group, advanced irrigation scheduling practices, includes soil moisture sensor, ET or Atmomter, computerized scheduling, and woodruff chart. The most prevalent group of WMPs used by producers is field management practices, nearly 85% of producers use one or more of WMPs in this group. The least prevalent group of WMPs is advanced irrigation scheduling practices, 85% of producers do not use any of WMPs belonging to this group.

More than 75% of producers uses WMPs from more than one group (Table 2). Most producers that only use WMPs from one group use field management practices. Among the producers that use two groups of WMPs, the most commonly observed pattern of WMP uses is the combination of and field management practices. About 23% of producers follow the pattern. Among the producers that use three groups of WMPs, the most commonly observed pattern of WMP uses is the combination of water flow control, water recovery/storage, and field management practices. Nearly 28% of producers follow the pattern.

The survey also collected information on the usage history of some WMPs. Figure 2 shows that although some WMPs were used as early as 1950s, only after 1980s did the usage rate of WMPs start to grow rapidly. In the group of water flow control practices, the multiple inlet irrigation practice is the practice that has the longest usage history. Given that Arkansas ranks first in terms of rice production nationwide and multiple inlet irrigation practice is usually applied for rice production, so it should be used earlier than any other WMPs in this group. The WMP that has highest average usage growth rate in this group is computerized pipe-hole selection, which grows rapidly after 2010. In the group of water recovery/storage practices, the usage rate of tailwater recovery system and the usage rate of water storage reservoir are similar during last 65 years because in practice, these two practices are usually used as complimentary WMPs at farms. For the group of field management practices, the usage rate of zero grade practice increases much faster than that of precision grade practice over years. This is consistent with the usage history of multiple inlet irrigation practice. Zero grade practice is one of the most common WMPs for rice production and rice is the major crop production in the state of

Arkansas; thus, the usage rate of zero grade practice increases rapidly than other WMPs in this group in last 30 years. At last, the usage of advanced irrigation scheduling practices begins in 1990s, which is relatively later compared to other groups of WMPs. This might be correlated to the fact that the advanced irrigation scheduling practices are relatively new WMPs in the market. Producers just started to use this group of WMPs during recent years.

4. Empirical Models

4.1.1. The choice of WMPs

We first examine the likelihood for a producer to use different groups of WMPs. Producers in Arkansas often use different WMPs simultaneously to improve irrigation efficiency. The use of multiple WMPs can result in complementarities and trade-offs, meaning that some combinations make more sense for producers than others. The model could take into account the complex decision-making in multiple choice of WMPs is the multivariate probit model (MVP). In the model, a set of binary choices (*yes/no*) are used for each group of WMPs and the choices are modeled jointly using correlations among disturbances.

The advantage of this model is that it allows for simultaneous choices of different groups of WMPs for producers, which may be true in this study. In addition, it does not require us to formulate a prior assumption regarding choice patterns, which is helpful because producers might simultaneously choose more than one mode of WMPs.

Let U represents the utility associated with the use of *k*th practices and U_0 otherwise. A producer decides to use *k*th practice if $Y_{ik}^{*} = U_{ik} - U_0 > 0$. The net utility Y_{ik}^{*} that the producer derives from using *k*th group of WMPs is a latent variable determined by the observed factors and the multivariate normally distributed term ε_i,

$$Y_{ik}^{*} = \mathbf{X_{1i}}\boldsymbol{\beta}_{\mathbf{k}} + \varepsilon_i \qquad (1)$$

In the equation, $\mathbf{X_{1i}}$ is a vector of explanatory variables that affect a producer's decision to WMPs. $\mathbf{B_k}$ is a vector of regression of coefficients to be estimated.

As stated above, the producer is expected to use a given practice if the expected net utility gain is greater than zero. The system of equations describing the overserved dichotomous choices of the producer is given as follow

$$Y_{ik} = \begin{cases} 1 & if\ Y_{ik}^{*} > 0 \\ 0 & otherwise \end{cases} \qquad (2)$$

where Y_{ik} is a binary observable variable indicating the *i*th producer's decision on using the *k*th WMP. In the MVP, the error term ε_i is assumed to jointly follow a multivariate normal distribution is given as follow:

$$\Omega = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \cdots & \rho_{1k} \\ \rho_{21} & 1 & \rho_{23} & \cdots & \rho_{2k} \\ \rho_{31} & \rho_{12} & 1 & \cdots & \rho_{3k} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho_{k1} & \rho_{k2} & \rho_{k3} & \cdots & 1 \end{bmatrix}$$

After normalizing the diagonal elements of the variance-covariance matrix to one, the off-diagonal elements, *p(rho)* is the pairwise correlation coefficient between the error terms of any two equations to be estimated in the model. If the off-diagonal elements are 0, the model becomes a univariate probit model, which means the choices among different groups of WMPs are not correlated with each other. Otherwise, the model is a multivariate probit model, indicating the choices among different groups of WMPs are correlated.

In the specifications, the following variables are included in $\mathbf{X_{1i}}$ vector: (1) a dummy variable that equals 1 if the producer is land owner, (2) A dummy variable that equals 1 if the producer has a bachelor degree or above, (3) A dummy variable equals 1 if the producer has agriculture-related education background, (4) years of farming experience, (5) gross income in

1,000 dollars, (6) the percentage of gross income from farming activities, (7) the percentage of acres that is irrigated by groundwater, (8) a dummy variable equals 1 if the producer concerns about water shortage issue may occur in the state, (9) a dummy variable equals 1 if the producer owns a flow meter, (10) mean daily temperature in previous 30 years in county, (11) average total annual precipitation (inch) in previous 30 years at county, (12) the participation rate of government programs such as conservation reserve program (CRP) at county level, (13) a dummy variable equals 1 if the producer's family members, friends or neighbors used practice in the same group, and (14) two dummy variables indicating whether the producer comes from White River region or Delta region.

Since the MVP model only consider the probability of use of a particular group of WMPs with no distinction made between, for example, producers who use on group of WMPs and those who use more than one group of WMPs. However, in practice, combination of different groups of WMPs could improve irrigation efficiency. Therefore, the second part of analysis consists using an ordered probit model to analyze the factors that influence the number of group of WMPs used by producers in 2015. There are five possible choices for producer *i*: $N_i = 0$ (none of group of WMPs implemented), $N_i = 1$ (only one group of WMPs implemented), $N_i = 2$ (two groups of WMPs implemented), $N_i = 3$ (three groups of WMPs implemented), $N_i = 4$ (four groups of WMPs implemented). Then the ordered probit model could be represented by following functions with latent variable N_{ik}^*:

$$N_i^* = \mathbf{X_{1i}}\, \boldsymbol{\lambda_i} + e_i;\ e_i \sim NID(0, \sigma^2) \tag{3}$$

and

$$N_{ik} = \begin{cases} 0 & if\ N_{ik}^* \le \pi_1 \\ 1 & if\ \pi_1 \le N_{ik}^* \le \pi_2 \\ 2 & if\ \pi_2 \le N_{ik}^* \le \pi_3 \\ 3 & if\ \pi_3 \le N_{ik}^* \le \pi_4 \\ 4 & if\ \pi_4 \le N_{ik}^* \end{cases} \tag{4}$$

where N_{ik}^* is utility gained for using k group of WMPs, π are threshold parameters to be estimated simultaneously with the other coefficient $\boldsymbol{\lambda_k}$, $\mathbf{X_{1i}}$ is a vector of variables that influence producer's decisions on how many groups of WMPs should be used on farm, which is the same as the explanatory variables in the multivariate probit model. e_i is assumed to be normally distributed across observations.

4.1.2. The number of WMPs

In addition to assessing producers' choices of different groups of WMPs, this part of analysis investigates each group of WMPs separately. Specifically, we examines which factors influence producers' decisions on how many WMPs in each group should be used on farm. The dependent variables in this set of analysis are (1) The number of overall WMPs used by producers, (2) The number of water flow control practices used by producers, (3) The number of water recovery/storage practices used by producers, (4) The number of field management practices used by producers, and (5) The number of advanced irrigation practices used by producers. Since we are interested in explaining the likelihood that a producer will use more WMPs, the Poisson is the fundamental probability distribution to be used (Greene, 2012). A Poisson random variable, Y, has the following probability density function (PDF):

$$Pr(Y_i = j) = \frac{\theta_i^j}{j!} \exp(-\theta_i),\ j = 0,1,2,3 \ldots \tag{5}$$

where j is the number of WMPs used by the producer i, θ_i is the expected number of WMPs used by producer i, which is defined as $\theta_i = E(Y_i|\mathbf{X_{1i}}) = \exp(\mathbf{X_{1i}}'\boldsymbol{\beta})$. $\mathbf{X_{1i}}$ is a vector of explanatory variables that may affect producers' choices of WMPs, which is the same as variables influencing producers' decisions on which group of WMPs should be used. A characteristic of the Poisson distribution is that the mean of dependent variable (expected number of WMPs used by producer) equals its variance.

When we examine the number of individual WMPs used, test results reject the null hypothesis of equi-dispersion in some specifications, which indicates mean and variance are different and thus sample data do not fit a Poisson distribution well. In this case, estimation using the standard Poisson model can still generate consistent estimates of parameters, but standard errors tend to be biased upward (Wang, 1997). To address this issue, a generalized Poisson model is applied to by introducing a dispersion factor δ into the PDF (Winkelmann and Zimmermann, 1994):

$$Pr(Y_i = j) = \frac{\theta_i(\theta_i+\delta j)^{j-1}}{j\,!}\exp(-\theta_i - \delta j)\,, \quad j = 0,1,2,3\ldots \qquad (6)$$

where the dispersion factor is defined as $\max(-1, \theta/_4) < \delta < 1$. In the generalized Poisson model, θ_i still is defined as exp($\mathbf{X_{1i}}'\boldsymbol{\beta}$), where $\mathbf{X_{1i}}$ is a vector of explanatory variables that may affect producers' choices of WMPs. The vector $\boldsymbol{\beta}$ is a vector of regression of coefficients to be estimated. The mean of the Y_i becomes $\theta_i/(1 - \delta)$, The variance of the dependent variable is $\theta_i/(1-\delta)^3$.

As is shown above, the generalized Poisson model is a natural extension of Poisson model. When $\delta = 0$, it reduces to the standard Poisson model where equi-dispersion applies. When $\delta < 0$, the mean of dependent variable is greater than the variance, the generalized Poisson model displays under dispersion. When $\delta > 0$, over dispersion occurs.

The parameters ($\boldsymbol{\beta}$, δ) in the generalized Poisson model can be estimated using maximum likelihood estimation (MLE) with the following log-likelihood function:

$$L(\boldsymbol{\beta}, \delta) = \sum_{j=1}^{n} \{\ln \theta_i + (j-1)\ln(\theta_i + \delta j) - (\theta_i + \delta j) - \ln j\} \quad (7)$$

4.1.3. Time to adopt WMPs

The third part of this section investigates which factors influence how long it takes for a producer to adopt a WMP after it became available in market using duration analysis. Duration analysis is originally used in biomedical research to study survival rate. More recently, Burton (2003), Carletto et al. (1999), and Dadi (2004) have used it to study agricultural technology adoption issue. Rather than focusing explicitly on the length of a duration, duration analysis estimates the probability that an individual will transit to a new state in the instant following time *t* given that the individual has stayed in the old state up to time *t*.

Suppose *T* is a continuous variable representing the duration that a producer waits before adopting a WMP, the probability of a producer waits until or after time *t* to adopt is represented by the survival function:

$$S(t) = \Pr(T \geq t) = 1 - F(t) \quad (8)$$

The hazard function, $h(t)$, is the probability that the producer uses the WMP shortly after time *t* given the he or she has not used it before *t*.

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr(t \leq T \leq t + \Delta t | T \geq t)}{\Delta t}$$

$$= \lim_{\Delta t \to 0} \frac{F(t+\Delta t) - F(t)}{\Delta t \times S(t)} = \frac{f(t)}{S(t)} \quad (9)$$

where $F(t)$ and $f(t) = dF(t)/dt$ are the corresponding cumulative density function and PDF.

The most commonly used parametric model for duration analysis is the Weibull model. It assumes a producer's hazard to start using a WMP at time *t* consists of two hazards: the baseline hazard, which is independent of producers' characteristics and represents the hazard every producer faces at time *t*, and individual's hazard, which varies with a producer's characteristics. Then the hazard of starting to use a WMP for a producer *i* at time *t* is:

$$h_i(t) = h_0(t)g(\mathbf{X}'_{2i}\mathbf{Z}) \qquad (10)$$

where $h_i(t)$ is the hazard that the producer i faces for adopting a WMP at time *t*, $h_0(t)$ is assumed to be $h_0(t) = pt^{p-1}$ with a shape parameter *p*, denoting the hazard every producer faces at time t. If the shape parameter $p < 1$, the function exhibits a decreasing hazard over time. If the shape parameter $p > 1$, the function exhibits an increasing baseline hazard over time. If the shape parameter $p = 1$, the baseline hazard is constant over time. The function $g(\mathbf{X}'_{2i}\mathbf{Z})$ is defined as $\exp(\mathbf{X}'_{2i}\mathbf{Z})$, representing how the characteristics of producer i influence the hazard he or she faces for starting to use the WMP shortly after time *t*. Besides explanatory variables in the vector $\mathbf{X}_{1i}$, an aridity index in the year before adopting the technology or WMP, which is calculated as the annual average temperature divided by annual precipitation, is used is put in the vector $\mathbf{X}_{2i}$.

Parameters **Z** is estimated by maximizing the log-likelihood function:

$$\ln L(\mathbf{Z}) = \sum_{i=1}^{n} \ln h_i(t, \mathbf{Z}) \qquad (11)$$

In the sample data used in empirical analysis, by the time the survey is conducted, some sample producers still have not used any WMPs. We do not observe *T* for those producers. One solution is to use a right censored model. Although we do not know how long these producers will take to adopt a WMP, we know that *T* for those producers is a duration that is longer than the duration between when the WMP was first available and the time of the survey. Thus, we could estimate β by maximizing the modified log-likelihood function:

$$ln\,L(\boldsymbol{Z}) = \sum_{i=1}^{n} d_j\, ln\, h_i(t, \boldsymbol{Z}) + \sum_{j=1}^{n} (1 - d_i)\, ln\, S(t, \boldsymbol{Z}) \quad (12)$$

where $d_j = 0$ if producer j has not adopted a WMP at time t, $d_j = 1$ otherwise. $S(t, \boldsymbol{Z})$ is the survival function representing the probability of a producer has not adopt the WMP until time t.

4.2. Impact of irrigation practices on irrigated acres

The last part of analysis investigates the impact of WMPs on four outcome variables: total irrigated acres on farm, irrigated acres of major crops (rice, soybean, corn). Therefore, four equations are estimated. The system of equations can be represented as:

$$A_{im} = X_{3i}\eta + \boldsymbol{N_{im}}\boldsymbol{\Gamma} + \varepsilon_{im} \quad (13)$$

where the dependent variable, A_{jm}, denotes the irrigated acres in the four equations. The key variables of interest are in the vector $\boldsymbol{N_{im}}$, which captures information of WMPs used by a producer. Firstly, a set of regressions that using the weighted number of WMPs in different groups to measure the WMPs employed by the producer is run to see the effects of current usage of different WMPs on irrigation decisions among producers. The weighted number of WMPs is computed as the irrigated acres under WMP divided by the total irrigated acres. Then another set of regressions that using variables that indicate whether the producer used WMPs in 2010 as the measurement of usage of WMPs is conducted because we concern that the irrigation decisions might also influence the usage of WMPs during the same year. In addition, a set of regressions that using a set of dummy variables to indicate the number of groups of WMPs used by producers is run to check the robustness of the results. The X_{3i} include all variables in the vector $\mathbf{X_{1i}}$ except (1) a dummy variable indicating whether the producer is aware of state tax credits program and (2) a dummy variable indicating whether the producer's family members, friends or neighbors used WMPs in the same group. Seemingly unrelated regressions are used to estimate the system of equations represented by equation (13).

Because producers may decide their irrigation practices and irrigated acres simultaneously, a potential endogenous issue may appear in WMPs usage variables in vector N and the variable that indicates the percentage of gravity irrigated acres at farm**.** To address potential endogenous issues, instrumental variables (IVs) are used to estimate Equation (13). We instrument for WMPs usage variables and the percentage of gravity irrigated acres using the following IVs: a set of dummy variables indicating whether the producer's family members, friends or neighbors use the same group of WMPs, a dummy variable indicating whether the producer is aware of state tax credits program, which allows producers claim up to $9,000 tax credit for conversions to surface water or land leveling, and a continuous variable indicating the average percentage of gravity irrigated acres at farm in county level. All of these variables are correlated to producers' choices of WMPs, but they are not likely to be directly correlated with the dependent variables (irrigated acres for different crops). Therefore, they could potentially serve as IVs. The method of three-stage least squares is used to conduct the IV estimation.

5. Results

5.1.1. The choice of WMPs

We first analyze producers' behaviors of using different WMPs by sorting WMPs into four groups (Table 5 and Table 6). The estimation results of choices of different groups of WMPs in 2015 using a multivariate probit model are reported in Table 4 and Table 5. Table 4 shows several pairwise correlations between the error terms in the MVP model are statistically significant, suggesting that the use of these groups of WMPs are interdependent. Specifically, the positive and significant sign between water flow control practice and field management practices indicate that producers normally use these two groups as complementary practices.

The estimates coefficients of explanatory variables are shown in Table 5. Each column is a specification of a binary choice regrading whether producers use one group of WMPs or not. Although the estimated coefficient of an independent variable does not directly measure the marginal effect of that variable on the choice of using one group of WMPs, the sign of the estimated coefficient does indicate the direction of the effect. We found a significant positive correlations of gross income with field management practices and advanced irrigation practices. This is consistent with the common understanding that field management practices and advanced irrigation practices require high initial investments, so producers who have more gross income are more likely to use field management practices and advanced irrigation practices.

Of the variables indicating producers' irrigation practices, the coefficient of total irrigated acres is significantly positive in the equations of water flow control practices and field management practices. This may imply that water flow control practices are more likely to be used by large size farms because large size farms are more likely to allow producers to have more flexibility in their decision-making, opportunity to use new practices on a trial basis, and ability to deal with risk (Amsalu and Graaff, 2006). The percentage of gravity irrigated acres have a positive impact on the likelihood for a producer to use field management practices. This is in line with the fact that field management practices are designed for gravity irrigation systems. The percentage irrigation water from groundwater is negatively correlated to water recovery or storage practices, suggesting that producers who rely more heavily on groundwater for irrigation have a smaller possibility to use these WMPs. Concerning water shortage issues may occur in the state increases the likelihood that producers use field management practices, while owning a flow meter increases the likelihood that producers use water recovery or storage practices.

Of the remaining variables, two climate variables do not show consistent signs among different equations. This may suggest that climate does not appear to have an impact on producers' decisions to use one group of WMPs. Awareness of state tax credits program increases the likelihood for producers to use advanced irrigation scheduling practices. Family members, friends or neighbors who used practices in the same group consistently show significant signs in different equations, implying that producers whose family members, friends or neighbors have used WMPs are more likely to have opportunities to learn functions and benefits of WMPs, and thus are more likely to use WMPs in the same group.

However, the MVP model does not allow one to understand the factors that drive producers' choices towards the joint use of serval of groups of WMPs. An ordered probit model is used to investigate factors influencing the number of groups of WMPs used by producers in 2015 (Table 6). The first column reports the estimated coefficients of explanatory variables, while the rest of columns report the marginal effects of the explanatory variables on each outcome of the dependent variable.

The coefficient of years of farming experience is negative; suggesting that younger producers are more likely to use more groups of WMPs. Similar findings are presented in the previous research (Huang, 2017). For variables indicating characteristics of producers' current irrigation practices, the total irrigated acres increases the likelihood of producers to use more groups of WMPs. One possible explanation might be that farms that have large irrigated acres are likely to be large size farms. Given the requirement of large initial capital investment on water flow control practices and field management practices, large size farms are more likely to have access to credit for capital investment and enjoy economies of scale, and thus they tend to use more groups of WMPs. The coefficient of the percentage of gravity irrigated acres is positive, indicating that producers who rely more heavily on gravity irrigation system tend to use more groups of WMPs. The higher reliance on groundwater for irrigation decreases the probability for producers to use more groups of WMPs. This is consistent with the results obtained by Huang et al. (2017). Groundwater is generally a more reliable source of water than surface water, the quantity of groundwater varies much less seasonally than surface water. Thus, greater reliance on groundwater encourages producers to use more advance irrigation systems, such as drip irrigation, but discourages producers to use more WMPs. Owning a flow meter and concerns about future water shortages in the state both increase the likelihood for producers to use more groups of WMPs. This may imply that producers who are concerned about water shortage issues are more likely to improve water use efficiency on farm by using more WMPs. Another coefficient that is significant is the variable indicating whether producers are aware of the state tax credits program. This suggesting that awareness of state tax credits program increases the possibility for producers to use more groups of WMPs.

The marginal effects are reported in column 2 to column 6 of table 6. For $N \leq 2$ (Column 2—Column 4), the marginal effects are inconsistent with the coefficients, particularly with regards to their signs. However, for $N \geq 3$ (Column 5 and 6), the marginal effects are in agreement with coefficients with regards either to their signs or significances. This may suggest that characteristics of the producers who use very few groups of WMPs, are different from those who use many groups of WMPs. The former may comprise of producers who operate small size farms, while the later may include producers who operate large size farms. The other interesting insight form these findings is that estimated coefficients of the ordered probit models better fit the characteristics of producers who use more than two groups of WMPs. For the producers who operate small size farms and use very few groups of WMPs, specific measures are required to up-scale the adoption rate of WMPs

5.1.2. The number of WMPs

Then Table 7 analyzes each group of WMPs separately. It examines the number of WMPs in each group used by producers in 2015 using the generalized Poisson model. Tests reject the null hypothesis of equi-dispersion and suggests an under-dispersion issue in our sample. That is, the mean of dependent variable is statistically smaller than the variance (Cameron and Trivedi, 2005). Therefore, the generalize Poisson model is used for this part of analysis instead of an original Poisson model. A range of variables is found to have influence on producers' use of different groups of WMPs. Results are very similar to the Table 5.

A somewhat interesting finding in this set of analysis is a strong influence of government programs offered at the local level on the number of WMPs in different groups used by producers. Policy makers in Arkansas have been promoting WMPs as a way to increase surface water use (e.g., ANRC, 2015b; Arkansas Soil and Water Conservation Commission, 1990). For example, Arkansas offers a state tax credits program that allows producers to claim up to $9,000 in tax credits for conversions to surface water or land leveling. The awareness of these state tax credits programs increases the likelihood of producers to use more WMPs in different groups although it may not influence the producers' decisions on whether to use this group of WMPs as shown in Table 4. Also, the higher percentage of participation rate of government program increases the likelihood for producers to use more WMPs. Previous studies have shown that producers who participate in conservation programs, such as the CRP, have better access to conservation information and make production decisions based on this information (Lubbell et al., 2013). Thus, producers who come from a county where the government program participation rate is high tend to use more WMPs.

5.1.3. Time to adopt WMPs

Table 8 presents estimate results on which factors may influence producers' decisions on when to start using a WMP. The estimate value of the shape parameter of the baseline hazard function, ln p, for all WMPs are greater than 0 (column 2- column 9), suggesting the existence of epidemic effects (Karshenas and Stoneman, 1993). It implies that endogenous learning is a process of self-propagation of information about a new technology that grows with the spread of that technology, and thus the probability to use a new WMP for every producer increases with the passing time. The WMP that has the biggest epidemic effects is advanced irrigation scheduling practices, while the smallest one is water storage reservoir. This is consistent with the figures showing the usage history of WMPs (Figure 2). Producers adopt irrigation scheduling practices more rapidly than water storage reservoir. One possible explanation is that the cost of using advanced irrigation scheduling practices is relatively lower than water storage, and thus it is likely to take a shorter time for producers to adopt advanced irrigation scheduling practices on a trial basis.

The results also suggest that producers' demographic characteristics do not appear to play a consistent role in producers' decisions on when to start using WMPs. Having agriculture-related education background increases conditional probabilities for producers to start using computerized pipe-hole selection practice and precision grade practice shortly, but having a bachelor or above degree tend to have no impact. A number of possible explanations may be provided for these. For instance, computerized pipe-hole selection practice and precision grade practice are relatively simple WMPs, so it does not require a higher education background for its use. However, higher education background may become more important as more complex WMPs are introduced.

For variables that capture information of producers' current irrigation practices, the results suggest that every 1,000 acres increase in total irrigated acres, holding all other variables constant, increases conditional probabilities for producers to adopt center pivot system and multiple inlet irrigation practice by 10.4% and 8.25% respectively on average. As we expect, increasing the percentage of gravity irrigated acres reduces the estimate hazard of using center pivot system but increases the estimate hazard of using WMPs, such as multiple inlet irrigation practice and zero grade practice. WMPs are normally chosen to pair with gravity irrigation technologies to increase irrigation efficiency. Furthermore, higher reliance on groundwater decreases conditional probabilities for producers to adopt different WMPs, such as multiple inlet irrigation practice, tail water recovery system, and water storage reservoir. This result is supported by the previous regression result of the number of WMPs used by producers (Table 6) and also is consistent with the results obtained by Huang et al. (2017). Groundwater is more likely to be supplied with sufficiently high pressure for modern irrigation technologies, such as center pivot irrigation system, so producers who rely more heavily on groundwater are more likely to use center pivot irrigation system instead of WMPs. The coefficient of concern about water shortage issues in the state is significant at 10% level in the specification of precision grade practice, implying that producers who are concerned about water shortage issues in the state have a higher conditional probability of using precision grade practice in the next short period than producers who do not by 44.7% on average. Owning a flow meter also increases producers' conditional probabilities of using water storage reservoir in the next short period by 47.9% on average.

The climate variables, including mean daily temperature in previous 30 years and average annual precipitation in previous 30 years have mixed impacts on producers' decisions regarding the time to start using different WMPs. Interpretation of these results is difficult, especially for average annual precipitation, which carries an unexpected sign. However, the previous one year aridity index before using WMPs, which is computed by average annual temperature divided by annual precipitation for the previous one year before producers start to use the WMP, consistently shows positive and significant signs, suggesting that the aridity has a strong positive impact on conditional probabilities for producers to start using WMPs shortly.

Of the remaining variables, the participation rate of government programs plays a salient role in increasing producers' conditional probabilities of using WMPs in a short time, specifically, it increases producers' conditional probabilities of using multiply inlet and zero grade practice in the next short time period. Furthermore, producers who know others using the same group of WMPs have higher conditional probabilities to start using WMPs shortly than producers who do not for most of WMPs. This implies that knowing other family members, friends or neighbors who used WMPs could provide producers a greater chance to learn the benefits of WMPs, and thus increases their conditional probabilities to start using WMPs shortly.

5.2. Impact of irrigation practices on irrigated acres

Table 9-Table 10 present the estimation results of how current and historical usage of WMPs influences producers' irrigation decisions on how many acres should be irrigated for different crops. The seemingly unrelated regressions reveal that the usage of different groups of

WMPs has mixed effects on producers' decisions on how many acres should be irrigated for each crop. The weighted numbers of all groups of WMPs currently used by producers have no effect on producers' decisions on total irrigated acres, while the weighted number of water recovery or storage practices currently used by producers has a negative impact on irrigated rice acres. For historical usage of WMPs, the usage of water flow control practices in 2010 have consistently positive effects on the total irrigated acres, irrigated rice acres and soybean acres. Additionally, the usage of field management practices in 2010 has a significant and positive impact on irrigated rice acres. Table 11 shows how the number of groups of WMPs used by producers influences producers' irrigation decisions. The coefficient of the number of groups of WMPs equaling three consistently shows a positive sign for all specifications, suggesting that the increase usage of WMPs is likely to increase producers' irrigated acres for all of major crops.

For control variables in regressions, the estimates are the same as our expectations. Years of farming experience negatively influence the irrigated acres for producers. The higher reliance on farming activities, which is captured by the percentage of gross income from farming activities, increases irrigated acres for producers. This may be explained by irrigated crops tending to have higher yields, and thus producers who have higher reliance on farming activities try to generate more yields and income by irrigating more crops. The percentage of gravity irrigated acres is positively correlated with irrigated rice acres because gravity irrigation system is the irrigation system generally used by rice producers. The climate variables tend to have no impact on irrigation decisions in terms of irrigated acres among producers.

6. Conclusion

Depth-to-groundwater in the MRVAA has consistently increased since early 20th century. Long-term projections indicate that only 40% of groundwater demand may be met by 2050 (ANRC, 2015). Critical initiatives to slow and reverse groundwater decline in the Delta include the adoption of more efficient irrigation technology and the construction of infrastructure to increase the use of surface water resources that are relatively abundant in the state. This study find that Arkansas producers are more likely to use WMPs instead of modern irrigation technologies, such as center pivot system, to adapt to the drought occurrences. Therefore, it is important to expand the existing literature that focuses mostly on more efficient irrigation technologies. In places where WMPs are more prevalent, such as Arkansas, a framework that only models the choice of different irrigation technologies may lead to wrong policy implications.

Of the findings regarding which factors influence producers' choices on different WMPs, we find that climate variables does not seem to play an important role in producers' decisions on whether to use a specific WMP, although previous research indicates climate could influence producers' decisions to start using WMPs in general (Huang et al, 2017). In contrast, the government programs are appearing to have strong influence on producers' decisions to use different WMPs. The awareness of tax credits program and the participation of government conservation programs both increase likelihoods for producers to use different WMPs.

There is some evidence that the use of WMPs has a positive impact on producers' decisions on how many acres should be irrigated for major crops. This conclusion should have important policy implications. While large water saving could be achieved by increasing the usage of WMPs on farm, such practices may also increase irrigation acres for major crops. If the positive impacts on irrigation acres is to the extent that producers irrigate crops without thinking about water usage, then the water use efficiency could be hampered. Policymakers and extension agents need to take such unintended consequence into account when prompting WMPs. For example, other programs that could reduce producers' irrigation water usages should be implemented along with WMPs to increase irrigation efficiency in Arkansas.

References

Amsalu, A., and J. De Graaff "Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed." *Ecological Economics* 61 (2007):294-302.

Arkansas Natural Resources Commission (ANRC) *2014 Arkansas Water Plan (AWP) Update*. Little Rock, AR: ANRC, 2015

Arkansas Soil and Water Conservation Commission *The 1990 Arkansas Water Plan Update*. Little Rock, AR: Arkansas Soil and Water Conservation Commission, 1990.

Ben-Akiva, M.E., and S.R. Lerman *Discrete choice analysis: theory and application to travel demand* MIT press, 1985.

Bradley Watkins, K. "The 2010 and 2011 Arkansas Drought Experience." *Choices* 27 (2012):1-7.

Burton, M., D. Rigby, and T. Young "Modelling the adoption of organic horticultural technology in the UK using duration analysis." *Australian Journal of Agricultural and Resource Economics* 47 (2003):29-54.

Cameron, A.C., and P.K. Trivedi *Microeconometrics: methods and applications*. New York, NY: Cambridge University Press, 2005.

Carletto, C., A. de Janvry, and E. Sadoulet "Sustainability in the diffusion of innovations: Smallholder nontraditional agro-exports in Guatemala." *Economic Development and Cultural Change* 47 (1999):345-69.

Caswell, M.F., and D. Zilberman "The effects of well depth and land quality on the choice of irrigation technology." *American Journal of Agricultural Economics* 68 (1986):798-811.

Dadi, L., M. Burton, and A. Ozanne "Duration analysis of technological adoption in Ethiopian agriculture." *Journal of Agricultural Economics* 55 (2004):613-31.

English, L.A., J. Popp, and W. Miller *Economic Contribution of Arkansas Agriculture. No. 992*. Arkansas Agricultural Experiment Station, The University of Arkansas System Division of Agriculture, 2013. Available at https://www.uaex.edu/division/docs/Economic_Contribution_2013.pdf:

ERS. *Rice Yearbook*. : 2016. Available at http://www.ers.usda.gov/data-products/rice-yearbook/

Feather, P.M., and G.S. Amacher "Role of information in the adoption of best management practices for water quality improvement." *Agricultural Economics* 11 (1994):159-70.

Freudenhammer, D., B. Peterson, C. Ding, B. Boehm, and S. Grundmann "The influence of cylinder head geometry variations on the volumetric intake flow captured by magnetic resonance velocimetry." *SAE International Journal of Engines* 8 (2015):1826-36.

Genius, M., P. Koundouri, C. Nauges, and V. Tzouvelekas "Information transmission in irrigation technology adoption and diffusion: social learning, extension services, and spatial effects." *American Journal of Agricultural Economics* 96 (2013):328-44.

Green, G.P., and D.L. Sunding "Land allocation, soil quality, and the demand for irrigation technology." *Journal of Agricultural and Resource Economics* (1997):367-75.

Huang, Q., Y. Xu, K. Kovacs, and G. West "Analysis of Factors that Influence the Use of Irrigation Technologies and Water Management Practices in Arkansas." *Journal of Agricultural and Applied Economics* 49 (2017):159-85.

Isgin, T., A. Bilgic, D.L. Forster, and M.T. Batte "Using count data models to determine the factors affecting farmers' quantity decisions of precision farming technology adoption." *Computers and Electronics in Agriculture* 62 (2008):231-42.

Karshenas, M., and P.L. Stoneman "Rank, stock, order, and epidemic effects in the diffusion of new process technologies: An empirical model." *The Rand journal of economics* (1993):503-28

Lohr, L., and T.A. Park "Choice of insect management portfolios by organic farmers: lessons and comparative analysis." *Ecological Economics* 43 (2002):87-99.

Lubell, M., B. Cutts, L. Roche, M. Hamilton, J. Derner, E. Kachergis, and K. Tate "Conservation program participation and adaptive rangeland decision-making." *Rangeland Ecology & Management* 66 (2013):609-20.

Mariano, M.J., R. Villano, and E. Fleming "Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines." *Agricultural Systems* 110 (2012):41-53.

Moreno, G., and D.L. Sunding "Joint estimation of technology adoption and land allocation with implications for the design of conservation policy." *American Journal of Agricultural Economics* 87 (2005):1009-19.

NASS. *2012 Census of Agriculture: Farm and Ranch Irrigation Survey (2013). No. AC-12-SS 1*. USDA NASS, 2014. Available at http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Farm_and_Ranch_Irrigation_Survey/.

Negri, D.H., and J.J. Hanchar "Water conservation through irrigation technology." (1989):

Negri, D.H., and D.H. Brooks "Determinants of irrigation technology choice." *Western Journal of Agricultural Economics* (1990):213-23.

Schaible, G., and M. Aillery "Water conservation in irrigated agriculture: Trends and challenges in the face of emerging demands." (2012).

U.S. Departent of Agriculture, Economic Research Service. *Irrigation and Water Use (2012)*. Available at http:// www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use.aspx

Watkins K.B. "The 2010 and 2011 Arkansas Drought Experience." *Choices* (2012):1–7

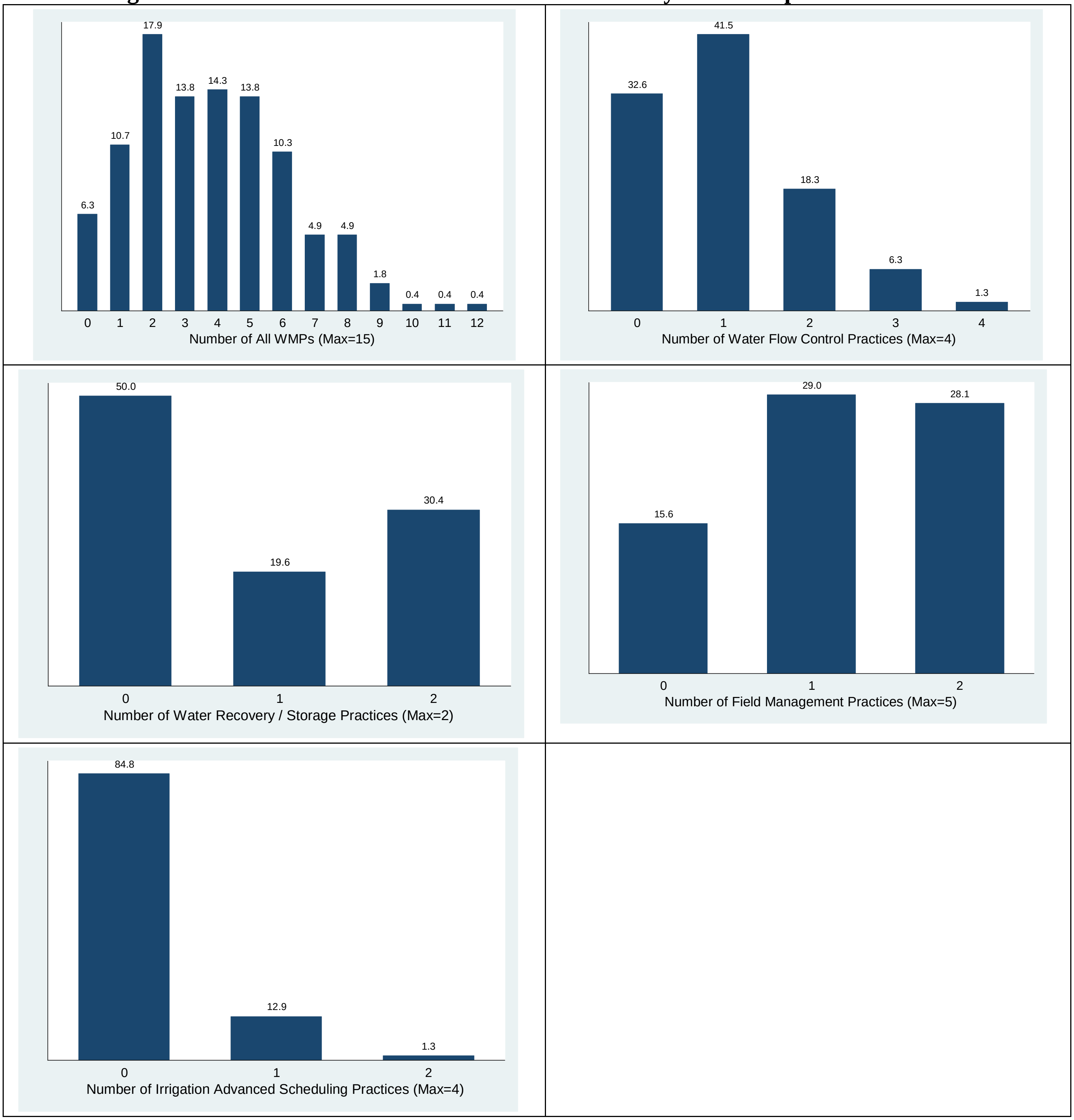
Wang, W., and F. Famoye "Modeling household fertility decisions with generalized Poisson regression." *Journal of Population Economics* 10 (1997):273-83.

William, H. *Econometric Analysis Solutions Manual 5th ed* Prentice Hall, 2012.

Winkelmann, R., and K.F. Zimmermann "Count data models for demographic data∗." *Mathematical Population Studies* 4 (1994):205-21.

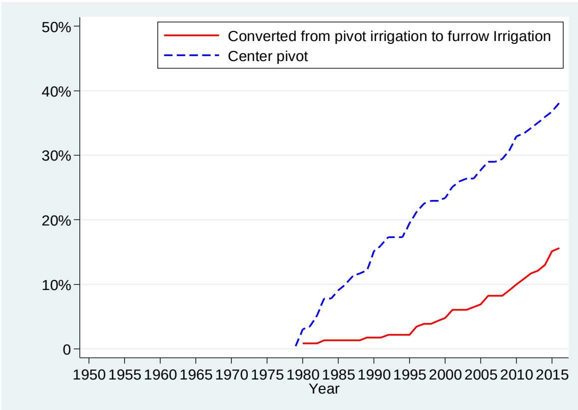
Olen, B., J. Wu, and C. Langpap "Irrigation decisions for major west coast crops: Water scarcity and climatic determinants." *American Journal of Agricultural Economics* 98 (2015):254-75.

Figure 1. Distributions of the number of WMPs used by Arkansas producers in 2015

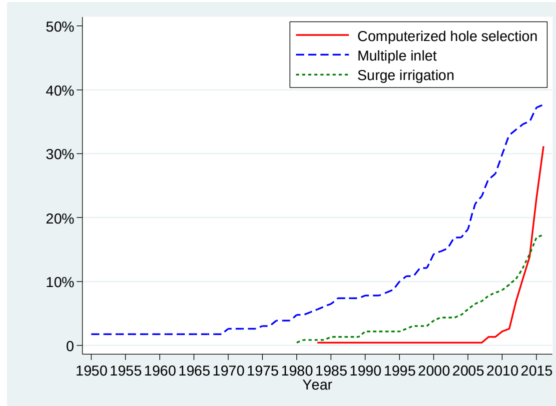


Source: Arkansas Irrigation Survey

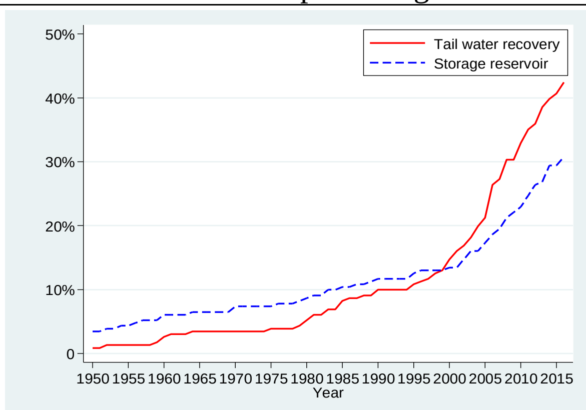
Figure 2. Use of WMPs over time in Arkansas, 1950-2015



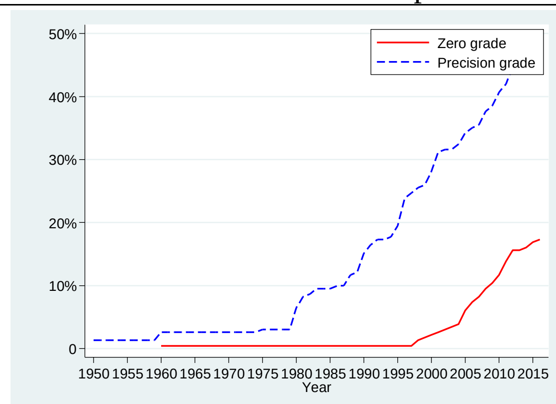
Panel a. Center pivot irrigation



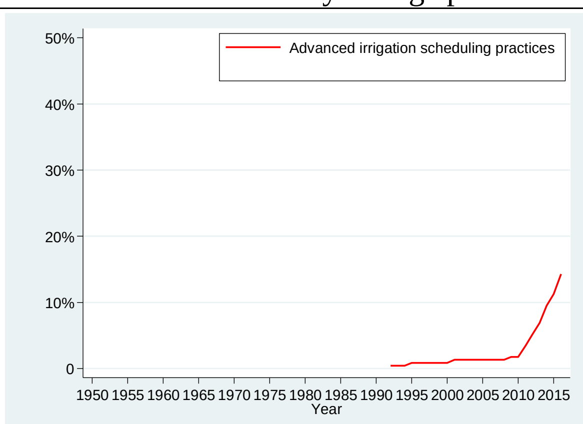
Panel b. Water flow control practices



Panel c. Water recovery/storage practices



Panel d. Field management practices



Panel e. Advanced irrigation scheduling practices

Source: Arkansas Irrigation Survey

Table 1. The portfolio of irrigation systems used by Arkansas producers in 2015

N irrigation systems	Flood irrigation	Border irrigation	Furrow irrigation	Center pivot irrigation	N Producers	% Producers
4	Yes	Yes	Yes	Yes	17	7.59
3	Yes	Yes	Yes	No	26	11.61
3	Yes	No	Yes	Yes	23	10.27
3	No	Yes	Yes	Yes	1	0.45
2	Yes	Yes	No	No	1	0.45
2	Yes	No	Yes	No	79	35.27
2	Yes	No	No	Yes	2	0.89
2	No	Yes	Yes	No	1	0.45
2	No	Yes	No	Yes	1	0.45
2	No	No	Yes	Yes	12	5.36
1	Yes	No	No	No	15	6.70
1	No	Yes	No	No	11	4.91
1	No	No	Yes	No	22	9.82
1	No	No	No	Yes	13	5.80
				Total	**224**	**100**

Table 2. The portfolio of WMPs used by Arkansas producers in 2015

N groups	Water flow control	Water recovery/storage	Field management	Advanced irrigation scheduling	N Producers	% Producers
4	Yes	Yes	Yes	Yes	16	7.14
3	Yes	Yes	Yes	No	62	27.68
3	Yes	No	Yes	Yes	9	4.02
3	No	Yes	Yes	Yes	4	1.79
2	Yes	Yes	No	No	5	2.23
2	Yes	No	Yes	No	52	23.21
2	Yes	No	No	Yes	2	0.89
2	No	Yes	Yes	No	19	8.48
2	No	No	Yes	Yes	1	0.45
1	Yes	No	No	No	5	2.23
1	No	Yes	No	No	6	2.68
1	No	No	Yes	No	26	11.61
1	No	No	No	Yes	3	1.34
0	No	No	No	No	14	6.25
				Total	**224**	**100**

Table 3. Groups of WMPs used by Arkansas producers in 2015

Type	WMPs	% producers
Water flow control practices (67.41%)	Computerized pipe-hole selection	31.70
	Multiple inlet irrigation (Rice)	38.39
	Surge irrigation	18.30
	Cutback irrigation	13.84
Water recovery/ storage practices (50%)	Tail-water recovery system	45.54
	Storage reservoir	34.82
Field management practices (84.38%)	Zero grade	18.30
	Precision grade	57.14
	End blocking	30.80
	Wrapped surface	25.89
	Deep tillage	47.32
Advanced irrigation scheduling practices (15.63%)	Soil moisture sensor	9.38
	ET or Atmometer	3.13
	computerized scheduling	5.80
	woodruff chart	1.34

Table 4 Correlation matrix of the error terms from Multivariate Probit model

	Rho 1	Rho 2	Rho 3	Rho 4
Rho 1	1	0.00961	0.438***	0.0202
		(0.163)	(0.157)	(0.194)
Rho 2		1	0.267	0.294
			(0.188)	(0.204)
Rho 3			1	-0.0872
				(0.210)
Rho 4				1

Note: Standard errors reported in parentheses; *significant at 10%; **significant at 5%, ***significant at 1%.

Table 5. The choice of different groups of WMPs used Multivariate Probit model

	Water flow control	Water recovery /storage	Field management	Advanced irrigation scheduling
Land owner	-0.364	0.00689	0.00403	0.192
	(0.302)	(0.310)	(0.341)	(0.338)
Highest degree is Bachelor or above	0.207	-0.198	0.158	0.196
	(0.224)	(0.255)	(0.274)	(0.275)
Education agriculture-related	0.296	-0.158	-0.106	0.296
	(0.209)	(0.239)	(0.252)	(0.262)
Years of farming experience	-0.0104	-0.00466	-0.000767	-0.0223**
	(0.00713)	(0.00836)	(0.00827)	(0.00908)
Gross income (1000 dollars)	0.000565	-0.000352	0.00250*	0.00316**
	(0.00110)	(0.00121)	(0.00141)	(0.00126)
% gross income from farming	0.537	-0.102	0.318	0.0421
	(0.424)	(0.473)	(0.481)	(0.476)
Total irrigated acres (1000 acres)	0.181***	0.0391	0.254***	0.0143
	(0.0670)	(0.0399)	(0.0927)	(0.0411)
% gravity irrigated acres	0.629	0.831	0.757*	-0.446
	(0.407)	(0.664)	(0.455)	(0.507)
% irrigation water from groundwater	0.0325	-1.629***	0.327	0.239
	(0.324)	(0.355)	(0.366)	(0.452)
Concerned water shortage may occur in state	0.181	0.0646	0.659**	-0.0839
	(0.222)	(0.244)	(0.260)	(0.285)
Own a flow meter	0.305	0.555**	0.145	0.244
	(0.248)	(0.253)	(0.279)	(0.271)
Mean daily temperature in previous 30 years (°F)	-0.127	0.168	-0.268*	-0.0450
	(0.128)	(0.145)	(0.157)	(0.164)
Average annual precipitation in previous 30 years (Inch)	-0.0382	-0.0320	0.133	0.139*
	(0.0674)	(0.0780)	(0.0872)	(0.0843)
Aware of state tax credits program	0.279	-0.0320	0.196	0.751***
	(0.204)	(0.222)	(0.242)	(0.256)
% participated in government program (County level)	-0.0773	0.297	1.024	-0.0460
	(0.548)	(0.590)	(0.689)	(0.680)
Family members, friends or neighbors used practices in the same group	0.521*	1.694***	0.378	0.709***
	(0.293)	(0.295)	(0.376)	(0.255)
White River	-0.211	-0.300	-0.389	-0.273
	(0.277)	(0.299)	(0.341)	(0.344)
Delta	-0.427	-0.800**	-0.411	-0.180
	(0.324)	(0.354)	(0.399)	(0.388)
Constant	9.077	-12.11	14.82	-1.547
	(8.756)	(9.924)	(10.48)	(11.11)
Observations	224			

Note: Standard errors reported in parentheses; *significant at 10%; **significant at 5%, ***significant at 1%.

Table 6. The number of groups of WMPs used Ordered Probit model, Average marginal effects (AME)

	(1)	(2)	(3)	(4)	(5)	(6)
	Coefficient	Number of categories of WMPs=0	Number of categories of WMPs=1	Number of categories of WMPs=2	Number of categories of WMPs=3	Number of categories of WMPs=4
Land owner	-0.0750	0.00738	0.0115	0.00436	-0.0150	-0.00827
	(0.207)	(0.0205)	(0.0318)	(0.0121)	(0.0414)	(0.0229)
Highest degree is Bachelor or above	0.166	-0.0164	-0.0256	-0.00969	0.0333	0.0184
	(0.167)	(0.0168)	(0.0257)	(0.0103)	(0.0335)	(0.0186)
Education agriculture-related	0.151	-0.0148	-0.0232	-0.00878	0.0302	0.0166
	(0.159)	(0.0159)	(0.0244)	(0.00959)	(0.0317)	(0.0177)
Years of farming experience	-0.0106**	0.00104*	0.00162**	0.000615*	-0.00211**	-0.00117*
	(0.00529)	(0.000555)	(0.000822)	(0.000367)	(0.00106)	(0.000613)
Gross income (1000 dollars)	0.00170**	-0.000168*	-0.000262**	-0.0000992*	0.000341**	0.000188**
	(0.000815)	(0.0000861)	(0.000127)	(0.0000568)	(0.000163)	(0.0000952)
% gross income from farming	0.504	-0.0497	-0.0775	-0.0294	0.101	0.0556
	(0.310)	(0.0319)	(0.0480)	(0.0203)	(0.0619)	(0.0356)
Total irrigated acres (1000 acres)	0.0927***	-0.00913***	-0.0143***	-0.00540**	0.0186***	0.0102***
	(0.0313)	(0.00352)	(0.00504)	(0.00234)	(0.00633)	(0.00370)
% gravity irrigated acres	0.738**	-0.0727**	-0.113**	-0.0430*	0.148**	0.0814**
	(0.335)	(0.0346)	(0.0518)	(0.0256)	(0.0674)	(0.0396)
% irrigation water from groundwater	-0.590**	0.0582**	0.0908**	0.0344**	-0.118**	-0.0652**
	(0.247)	(0.0268)	(0.0388)	(0.0173)	(0.0491)	(0.0292)
Concerned water shortage may occur in state	0.387**	-0.0381**	-0.0594**	-0.0225*	0.0774**	0.0427**
	(0.169)	(0.0181)	(0.0265)	(0.0117)	(0.0333)	(0.0200)
Own a flow meter	0.352**	-0.0347*	-0.0541*	-0.0205*	0.0705**	0.0389*
	(0.178)	(0.0188)	(0.0279)	(0.0112)	(0.0349)	(0.0206)
Mean daily temperature in previous 30 years (°F)	-0.0592	0.00583	0.00910	0.00344	-0.0118	-0.00653
	(0.0989)	(0.00978)	(0.0153)	(0.00583)	(0.0198)	(0.0110)
Average annual precipitation in previous 30 years (Inch)	5.514	-0.00543	-0.00848	-0.00321	0.0110	0.00608
	(5.165)	(0.00519)	(0.00797)	(0.00316)	(0.0103)	(0.00579)
Aware of state tax credits program	0.423***	-0.0417**	-0.0651***	-0.0247**	0.0848***	0.0467**
	(0.153)	(0.0170)	(0.0241)	(0.0112)	(0.0304)	(0.0182)
% participated in government program (County level)	0.512	-0.0504	-0.0787	-0.0298	0.102	0.0565
	(0.419)	(0.0422)	(0.0649)	(0.0263)	(0.0840)	(0.0472)
Family members, friends or neighbors used WMPs	0.382	-0.0376	-0.0587	-0.0222	0.0764	0.0421
	(0.450)	(0.0446)	(0.0694)	(0.0275)	(0.0902)	(0.0502)
White River	-0.381*	0.0375*	0.0586*	0.0222*	-0.0763*	-0.0421*
	(0.203)	(0.0212)	(0.0319)	(0.0131)	(0.0407)	(0.0231)
Delta	-0.637***	0.0628**	0.0980***	0.0371**	-0.128***	-0.0703**
	(0.240)	(0.0268)	(0.0375)	(0.0174)	(0.0481)	(0.0281)
Observations	224	224				

Note: Standard errors reported in parentheses; *significant at 10%; **significant at 5%, ***significant at 1%.

Table 7. The number of WMPs used Generalized Poisson regression, Average marginal effects (AME)

	(1)	(2)	(3)	(4)	(5)
	WMPs	Water flow control	Water recovery /storage	Field management	Advanced irrigation scheduling
Land owner	-0.0913	-0.129	-0.0273	0.0724	-0.315
	(0.366)	(0.147)	(0.450)	(0.115)	(0.444)
Highest degree is Bachelor or above	0.185	0.217*	-0.221	-0.0968	0.306
	(0.303)	(0.124)	(0.381)	(0.0926)	(0.406)
Education agriculture-related	0.552*	0.180	-0.0463	0.162*	0.471
	(0.297)	(0.123)	(0.350)	(0.0915)	(0.400)
Years of farming experience	-0.0106	-0.00512	0.00512	-0.00180	-0.0238*
	(0.00955)	(0.00391)	(0.0119)	(0.00294)	(0.0128)
Gross income (1000 dollars)	0.00201	0.000380	-0.00158	0.000462	0.00414**
	(0.00151)	(0.000646)	(0.00175)	(0.000470)	(0.00175)
% gross income from farming	0.430	0.212	0.287	0.0486	-0.361
	(0.579)	(0.232)	(0.701)	(0.179)	(0.739)
Total irrigated acres (1000 acres)	0.146***	0.0326	0.0556	0.0442***	-0.0212
	(0.0481)	(0.0202)	(0.0659)	(0.0150)	(0.0645)
% gravity irrigated acres	1.636**	-0.00378	1.523	0.253	-0.377
	(0.764)	(0.271)	(1.069)	(0.218)	(0.790)
% irrigation water from groundwater	-1.487***	-0.0865	-3.260***	-0.244*	0.299
	(0.437)	(0.187)	(0.576)	(0.140)	(0.637)
Concerned water shortage may occur in state	0.826**	0.174	0.318	0.122	-0.247
	(0.321)	(0.131)	(0.370)	(0.0948)	(0.422)
Own a flow meter	0.723**	0.00942	0.884**	0.199**	0.389
	(0.315)	(0.131)	(0.372)	(0.0974)	(0.388)
Mean daily temperature in previous 30 years (°F)	-0.326*	-0.0742	0.489**	-0.167***	-0.0583
	(0.193)	(0.0801)	(0.225)	(0.0568)	(0.229)
Average annual precipitation in previous 30 years (Inch)	0.0436	0.000556	-0.153	0.0140	0.0850
	(0.0946)	(0.0393)	(0.116)	(0.0287)	(0.132)
Aware of state tax credits program	1.118***	0.405***	0.255	0.231***	1.115***
	(0.279)	(0.113)	(0.336)	(0.0830)	(0.387)
% participated in government program (County level)	2.029***	0.416	0.0902	0.648***	0.811
	(0.774)	(0.299)	(0.886)	(0.230)	(0.973)
Family members, friends or neighbors used practices in the same group		0.809***	2.827***	0.360**	0.982**
		(0.264)	(0.535)	(0.179)	(0.416)
White River	-0.401	-0.00354	-0.401	-0.0560	-0.535
	(0.358)	(0.150)	(0.441)	(0.112)	(0.542)
Delta	-0.532	-0.200	-1.468***	0.0954	-0.118
	(0.431)	(0.169)	(0.547)	(0.127)	(0.536)
Equi-dispersion statistics	-0.72	-5.51		-5.27	-0.32
P-value	0.471	0.000***		0.000***	0.747
Observations	224	224	224	224	224

Note: Standard errors reported in parentheses; *significant at 10%; **significant at 5%, ***significant at 1%.

Table 8. The starting time to use WMPs used Weibull model, Average marginal effects (AME)

	(1) Center pivot	(2) Computerized pipe-hole selection	(3) Multiple inlet	(4) Surge irrigation	(5) Tail water recovery	(6) Water storage	(7) Zero grade	(8) Precision grade	(9) Advanced irrigation scheduling
Land owner	-0.348	-0.356	-0.0939	-0.202	0.0907	0.496	0.216	0.226	-0.00356
	(0.324)	(0.315)	(0.294)	(0.527)	(0.303)	(0.349)	(0.524)	(0.274)	(0.189)
Highest degree is Bachelor or above	0.0912	-0.0219	0.266	0.354	-0.0164	-0.337	-0.680*	0.129	0.0244
	(0.290)	(0.286)	(0.262)	(0.389)	(0.238)	(0.275)	(0.408)	(0.230)	(0.152)
Education agriculture-related	0.0463	0.484*	0.221	-0.239	-0.165	-0.163	0.761	0.375*	0.0766
	(0.269)	(0.283)	(0.270)	(0.382)	(0.233)	(0.262)	(0.464)	(0.220)	(0.146)
Years of farming experience	0.0154*	-0.0119	0.00319	-0.00980	0.00288	-0.00378	-0.0161	-0.00393	-0.00339
	(0.00922)	(0.00902)	(0.00862)	(0.0122)	(0.00747)	(0.00839)	(0.0129)	(0.00758)	(0.00494)
Gross income (1000 dollars)	-0.00150	0.00128	-0.00145	0.000362	-0.000764	-0.000976	0.000421	0.000440	0.000880
	(0.00139)	(0.00137)	(0.00149)	(0.00186)	(0.00121)	(0.00154)	(0.00216)	(0.00113)	(0.000775)
% gross income from farming	0.438	0.0743	0.783	0.172	-0.0297	0.107	0.590	0.655	-0.0441
	(0.621)	(0.537)	(0.550)	(0.717)	(0.445)	(0.529)	(0.809)	(0.451)	(0.294)
Total irrigated acres (1000 acres)	0.124***	0.0475	0.0820**	-0.0821	0.0587	-0.00661	0.0780	0.0488	-0.00776
	(0.0386)	(0.0425)	(0.0365)	(0.0803)	(0.0404)	(0.0533)	(0.0692)	(0.0375)	(0.0304)
% gravity irrigated acres	-3.246***	-0.0485	2.096**	0.354	1.926	0.208	4.311*	0.648	-0.0985
	(0.459)	(0.600)	(1.045)	(0.908)	(1.209)	(0.966)	(2.302)	(0.596)	(0.315)
% irrigation water from groundwater	0.496	0.492	-0.650*	0.267	-1.274***	-1.668***	-0.791	-0.482	0.0717
	(0.486)	(0.520)	(0.342)	(0.569)	(0.324)	(0.374)	(0.613)	(0.321)	(0.227)
Concerned water shortage may occur in state	0.465	0.453	0.138	0.00496	0.237	0.297	0.557	0.439*	-0.0304
	(0.306)	(0.352)	(0.263)	(0.411)	(0.274)	(0.329)	(0.463)	(0.254)	(0.158)
Own a flow meter	0.290	0.336	-0.0113	0.133	0.221	0.477*	0.181	0.316	0.0601
	(0.273)	(0.294)	(0.267)	(0.424)	(0.266)	(0.289)	(0.446)	(0.228)	(0.165)
Mean daily temperature in previous 30 years (°F)	0.130	-0.0300	-0.242	0.0696	0.238	0.455**	-0.938***	-0.237*	-0.0434
	(0.160)	(0.199)	(0.177)	(0.271)	(0.179)	(0.216)	(0.260)	(0.139)	(0.0907)
Average annual precipitation in previous 30 years (Inch)	0.0756	0.0598	0.151*	0.236*	0.0468	-0.0721	0.460***	0.199***	0.0715
	(0.0916)	(0.152)	(0.0886)	(0.129)	(0.0753)	(0.0959)	(0.129)	(0.0748)	(0.0750)

	(1) Center pivot	(2) Computerized pipe-hole selection	(3) Multiple inlet	(4) Surge irrigation	(5) Tail water recovery	(6) Water storage	(7) Zero grade	(8) Precision grade	(9) Advanced irrigation scheduling
Aridity in the year before the technology /practice is used	0.551***	0.290	0.680***	1.361***	0.247**	0.187	1.290***	0.576***	0.333
	(0.163)	(0.549)	(0.157)	(0.246)	(0.110)	(0.153)	(0.240)	(0.134)	(0.320)
Aware of state tax credit program	-0.0980	0.470*	0.0842	0.484	0.0879	0.218	0.797**	0.202	0.131
	(0.257)	(0.266)	(0.235)	(0.400)	(0.215)	(0.264)	(0.375)	(0.215)	(0.141)
% participated in government program (County level)	0.236	0.0111	1.410**	-0.475	0.121	0.569	2.654***	0.573	0.240
	(0.736)	(0.818)	(0.633)	(1.080)	(0.586)	(0.719)	(0.962)	(0.568)	(0.400)
Family members, friends or neighbors used this technology/WMP	2.091***	2.542***	1.558***	2.203***	1.678***	2.123***	2.312**	0.433	0.0695
	(0.493)	(0.475)	(0.393)	(0.414)	(0.414)	(0.613)	(1.028)	(0.387)	(0.142)
White River	0.0826	0.275	-0.447	-1.585***	-0.351	-0.649**	-1.103*	0.340	-0.330
	(0.420)	(0.540)	(0.290)	(0.501)	(0.279)	(0.318)	(0.575)	(0.259)	(0.288)
Delta	0.324	0.615	-0.417	-1.833***	-1.094**	-1.314***	0.182	0.0979	-0.107
	(0.451)	(0.472)	(0.381)	(0.645)	(0.438)	(0.509)	(0.576)	(0.327)	(0.248)
Constant	-19.63*	-45.06***	-4.342	-25.95	-34.93***	-40.04***	25.72	-3.476	-81.21***
	(11.24)	(13.75)	(12.19)	(19.04)	(12.65)	(15.12)	(18.14)	(9.820)	(8.532)
Ln p Constant	0.375***	2.449***	1.033***	0.992***	1.105***	0.263**	1.583***	1.027***	3.238***
	(0.0947)	(0.111)	(0.102)	(0.155)	(0.0956)	(0.112)	(0.155)	(0.0887)	(0.0655)
Observations	224	224	224	224	224	224	224	224	224

Note: Standard errors reported in parentheses; *significant at 10%; **significant at 5%, ***significant at 1%.

Table 9. Regressions of irrigated acres (1,000 acres) on the current usage of WMPs

	Seemingly Unrelated Regressions				Three-stage least squares			
	(1) Total	(2) Rice	(3) Soybean	(4) Corn	(5) Total	(6) Rice	(7) Soybean	(8) Corn
Weighted N water flow practices in 2015	0.194	0.276	0.181	-0.100	-3.045	0.349	-4.806	2.833
	(0.504)	(0.186)	(0.280)	(0.199)	(5.456)	(2.026)	(5.139)	(3.737)
Weighted N water recovery/storage practices in 2015	-1.155	-0.575**	-0.482	0.104	-0.650	-1.146	4.180	-3.844
	(0.711)	(0.262)	(0.395)	(0.281)	(7.312)	(2.715)	(6.886)	(5.008)
Weighted N field management practices in 2015	0.0178	0.0837	-0.0592	0.0204	0.414	-0.477	1.398	-1.263
	(0.324)	(0.119)	(0.180)	(0.128)	(2.588)	(0.961)	(2.437)	(1.772)
Weighted N advanced irrigation scheduling practices in 2015	-0.593	-0.148	-0.591	0.00509	5.595	-0.436	6.391	-3.709
	(0.786)	(0.290)	(0.436)	(0.311)	(7.514)	(2.790)	(7.076)	(5.146)
Own a flow meter	1.273***	0.326**	0.668***	0.0307	1.649	0.307	1.320	-0.352
	(0.383)	(0.141)	(0.212)	(0.151)	(1.013)	(0.376)	(0.954)	(0.694)
Land owner	0.293	-0.175	0.103	0.188	0.431	-0.140	0.0289	0.310
	(0.450)	(0.166)	(0.250)	(0.178)	(0.641)	(0.238)	(0.604)	(0.439)
Highest degree is Bachelor or above	0.584	0.269**	0.198	0.0550	0.618	0.286	0.0905	0.163
	(0.362)	(0.133)	(0.201)	(0.143)	(0.501)	(0.186)	(0.472)	(0.343)
Education agriculture-related	-0.440	-0.144	-0.182	-0.0172	-0.466	-0.137	-0.0709	-0.0989
	(0.351)	(0.129)	(0.195)	(0.139)	(0.571)	(0.212)	(0.538)	(0.391)
Years of farming experience	-0.0353***	-0.00370	-0.0179***	-0.00908**	-0.0335**	-0.00621	-0.0144	-0.0121
	(0.0112)	(0.00413)	(0.00622)	(0.00443)	(0.0153)	(0.00569)	(0.0144)	(0.0105)
Gross income	-0.000150	-0.000674	-0.000149	0.000116	-0.00163	-0.000382	-0.00178	0.00109
	(0.00179)	(0.000658)	(0.000992)	(0.000707)	(0.00295)	(0.00110)	(0.00278)	(0.00202)
% gross income from farming	2.778***	0.874***	1.244***	0.445*	3.194***	1.177***	1.039	0.836
	(0.644)	(0.237)	(0.357)	(0.255)	(0.926)	(0.344)	(0.872)	(0.634)
% gravity irrigated acres	0.603	0.757***	-0.318	0.161	3.691	3.030	-2.309	3.523
	(0.729)	(0.269)	(0.405)	(0.289)	(5.358)	(1.990)	(5.046)	(3.669)
% irrigation water from groundwater	0.264	-0.365*	0.298	0.184	0.953	-0.355	2.141	-1.136
	(0.598)	(0.220)	(0.332)	(0.236)	(2.604)	(0.967)	(2.453)	(1.784)
Concerned water shortage may occur in state	-0.108	0.0309	0.205	-0.313**	-0.558	-0.0266	-0.0111	-0.288
	(0.369)	(0.136)	(0.205)	(0.146)	(0.563)	(0.209)	(0.530)	(0.386)

	Seemingly Unrelated Regressions				Three-stage least squares			
	(1) Total	(2) Rice	(3) Soybean	(4) Corn	(5) Total	(6) Rice	(7) Soybean	(8) Corn
Mean daily temperature in previous 30 years (°F)	0.0499	-0.127	0.0712	0.111	-0.285	-0.230	-0.309	0.278
	(0.222)	(0.0817)	(0.123)	(0.0878)	(0.508)	(0.189)	(0.479)	(0.348)
Average annual precipitation in previous 30 years (Inch)	-0.118	-0.0156	-0.0804	0.00172	-0.118	0.0184	-0.0516	-0.0112
	(0.114)	(0.0420)	(0.0633)	(0.0451)	(0.178)	(0.0660)	(0.167)	(0.122)
% participated in government program (County level)	0.112	0.0285	-0.157	0.459	0.876	0.0648	1.626	-0.696
	(0.944)	(0.348)	(0.524)	(0.373)	(2.340)	(0.869)	(2.204)	(1.603)
White River	0.521	0.288*	0.236	-0.169	0.923	0.178	1.275	-0.911
	(0.444)	(0.163)	(0.246)	(0.176)	(1.225)	(0.455)	(1.153)	(0.839)
Delta	0.869*	0.147	0.484*	-0.158	1.397	0.365	1.024	-0.370
	(0.522)	(0.192)	(0.290)	(0.206)	(0.920)	(0.342)	(0.866)	(0.630)
Constant	-1.510	9.029	-3.217	-8.180	22.60	13.86	27.95	-23.90
	(15.09)	(5.558)	(8.378)	(5.968)	(38.19)	(14.18)	(35.96)	(26.15)
Observations	224				224			

Notes: Standard errors reported in parentheses; *significant at 10%; **significant at 5%, ***significant at 1%.

Endogenous variables: Weighted water management practices, % gravity irrigated acres

IV variables: aware of state tax credits program; family members, friends or neighbors used WMPs in the same group; other producers average % gravity irrigated acres

Table 10. Regressions of irrigated acres (1,000 acres) on the previous usage of WMPs

	Seemingly Unrelated Regressions				Three-stage least squares			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Total	Rice	Soybean	Corn	Total	Rice	Soybean	Corn
Used water flow control practices in 2010	0.728**	0.232*	0.361*	0.139	-1.260	-0.293	1.239	-1.273
	(0.369)	(0.135)	(0.206)	(0.147)	(4.418)	(1.258)	(1.879)	(1.721)
Use water storage practices in 2010	0.391	0.180	0.0724	0.117	-2.689	0.599	-1.400	0.0289
	(0.383)	(0.140)	(0.214)	(0.152)	(4.046)	(1.152)	(1.720)	(1.575)
Used field management practices in 2010	0.191	0.306**	0.0833	-0.0922	0.266	0.808	0.00734	-1.127
	(0.355)	(0.130)	(0.198)	(0.141)	(4.314)	(1.228)	(1.834)	(1.680)
Used advanced irrigation scheduling practices in 2010	-1.125	-0.245	-0.462	0.00269	14.51	3.345	2.163	-1.245
	(1.251)	(0.458)	(0.699)	(0.498)	(32.18)	(9.163)	(13.68)	(12.53)
Own flow meter	1.096***	0.267*	0.607***	0.00281	1.503	0.183	0.693*	0.207
	(0.373)	(0.136)	(0.208)	(0.148)	(0.950)	(0.270)	(0.404)	(0.370)
Land owner	0.273	-0.228	0.103	0.212	0.0672	-0.330	0.0931	0.341
	(0.447)	(0.164)	(0.250)	(0.178)	(1.112)	(0.317)	(0.473)	(0.433)
Highest degree is Bachelor or above	0.422	0.182	0.124	0.0426	0.453	0.134	-0.0494	0.425
	(0.363)	(0.133)	(0.203)	(0.144)	(0.947)	(0.270)	(0.403)	(0.369)
Education agriculture-related	-0.519	-0.161	-0.234	-0.0320	-1.005	-0.265	-0.448	0.192
	(0.345)	(0.126)	(0.193)	(0.137)	(1.225)	(0.349)	(0.521)	(0.477)
Years of farming experience	-0.0369***	-0.00467	-0.0181***	-0.00938**	-0.0385**	-0.00540	-0.0185**	-0.0105
	(0.0111)	(0.00406)	(0.00620)	(0.00441)	(0.0179)	(0.00509)	(0.00760)	(0.00696)
Gross income (1000 dollars)	0.000496	-0.000380	0.0000392	0.000190	-0.00456	-0.00154	-0.0000457	-0.000602
	(0.00178)	(0.000652)	(0.000996)	(0.000708)	(0.00990)	(0.00282)	(0.00421)	(0.00385)
% gross income from farming	2.568***	0.757***	1.158***	0.410	4.151*	0.743	1.269	1.325
	(0.646)	(0.237)	(0.361)	(0.257)	(2.303)	(0.656)	(0.980)	(0.897)
% gravity irrigated acres	0.0231	0.556**	-0.522	0.0889	9.754	1.259	1.157	2.945
	(0.752)	(0.275)	(0.420)	(0.299)	(11.36)	(3.234)	(4.830)	(4.423)
% irrigation water from groundwater	0.958*	-0.0193	0.570*	0.188	0.0152	0.0685	0.204	0.234
	(0.550)	(0.201)	(0.308)	(0.219)	(1.825)	(0.520)	(0.776)	(0.711)
Concerned water shortage may occur in state	-0.301	-0.0543	0.0939	-0.328**	-0.507	-0.182	-0.0390	-0.0773
	(0.367)	(0.134)	(0.205)	(0.146)	(1.042)	(0.297)	(0.443)	(0.406)

	Seemingly Unrelated Regressions				Three-stage least squares			
	(1) Total	(2) Rice	(3) Soybean	(4) Corn	(5) Total	(6) Rice	(7) Soybean	(8) Corn
Mean daily temperature in previous 30 years (°F)	-0.0118	-0.167**	0.0486	0.120	-0.0969	-0.152	0.106	-0.109
	(0.215)	(0.0788)	(0.120)	(0.0856)	(0.598)	(0.170)	(0.254)	(0.233)
Average annual precipitation in previous 30 years (Inch)	-0.105	-0.00216	-0.0815	-0.00319	-0.0676	-0.0106	-0.0929	0.0632
	(0.111)	(0.0406)	(0.0620)	(0.0441)	(0.220)	(0.0628)	(0.0937)	(0.0858)
% participated in government program (County level)	0.156	0.132	-0.137	0.395	0.293	-0.0558	-0.0981	0.717
	(0.909)	(0.333)	(0.508)	(0.362)	(1.740)	(0.496)	(0.740)	(0.678)
White River	0.727	0.373**	0.321	-0.138	-0.150	0.385	0.0607	-0.235
	(0.444)	(0.163)	(0.248)	(0.177)	(1.409)	(0.401)	(0.599)	(0.549)
Delta	1.251**	0.324*	0.624**	-0.119	0.861	0.435	0.416	-0.0172
	(0.520)	(0.190)	(0.291)	(0.207)	(1.212)	(0.345)	(0.516)	(0.472)
Constant	2.574	11.72**	-1.512	-8.743	1.810	10.38	-6.130	3.646
	(14.64)	(5.360)	(8.184)	(5.822)	(38.64)	(11.00)	(16.43)	(15.05)
Observations	224				224			

Notes: Standard errors reported in parentheses; *significant at 10%; **significant at 5%, ***significant at 1%.

Endogenous variables: Weighted water management practices, % gravity irrigated acres

IV variables: aware of state tax credits program; family members, friends or neighbors used WMPs in the same group; other producers average % gravity irrigated acres

Table 11. Regressions of irrigated acres (1,000 acres) on the number of groups of WMPs

	Seemingly Unrelated Regressions			
	(1) Total	(2) Rice	(3) Soybean	(4) Corn
Number of categories of WMPs=1	-0.0719	-0.0605	0.180	0.149
	(0.772)	(0.290)	(0.437)	(0.308)
Number of categories of WMPs=2	0.552	0.211	0.412	0.172
	(0.709)	(0.266)	(0.401)	(0.283)
Number of categories of WMPs=3	1.803**	0.567**	0.906**	0.619**
	(0.757)	(0.284)	(0.428)	(0.302)
Number of categories of WMPs=4	0.915	0.473	0.405	0.318
	(0.923)	(0.346)	(0.522)	(0.368)
Own a flow meter	0.894**	0.249*	0.520**	-0.0885
	(0.368)	(0.138)	(0.208)	(0.147)
Land owner	0.247	-0.194	0.0801	0.183
	(0.436)	(0.164)	(0.246)	(0.174)
Highest degree is Bachelor or above	0.356	0.189	0.110	0.00197
	(0.352)	(0.132)	(0.199)	(0.141)
Education agriculture-related	-0.498	-0.142	-0.205	-0.0235
	(0.336)	(0.126)	(0.190)	(0.134)
Years of farming experience	-0.0336***	-0.00300	-0.0170***	-0.00847*
	(0.0110)	(0.00414)	(0.00624)	(0.00441)
Gross income (1000 dollars)	-0.000735	-0.000773	-0.000530	-0.0000792
	(0.00173)	(0.000647)	(0.000975)	(0.000688)
% gross income from farming	2.396***	0.761***	1.064***	0.281
	(0.648)	(0.243)	(0.366)	(0.258)
% gravity irrigated acres	-0.0996	0.558**	-0.602	-0.0439
	(0.718)	(0.269)	(0.406)	(0.286)
% irrigation water from groundwater	0.821	-0.0835	0.536*	0.182
	(0.527)	(0.198)	(0.298)	(0.210)
Concerned water shortage may occur in state	-0.196	0.0198	0.128	-0.335**
	(0.362)	(0.136)	(0.205)	(0.145)
Mean daily temperature in previous 30 years (°F)	-0.00894	-0.182**	0.0596	0.140
	(0.216)	(0.0809)	(0.122)	(0.0861)
Average annual precipitation in previous 30 years (Inch)	-0.0828	0.00943	-0.0768	-0.00538
	(0.111)	(0.0418)	(0.0629)	(0.0444)
% participated in government program (County level)	0.246	0.201	-0.113	0.392
	(0.890)	(0.334)	(0.503)	(0.355)
White River	0.781*	0.414***	0.359	-0.128
	(0.427)	(0.160)	(0.241)	(0.170)
Delta	1.407***	0.370*	0.686**	-0.0751
	(0.504)	(0.189)	(0.285)	(0.201)
Constant	1.808	12.46**	-2.575	-10.16*
	(14.70)	(5.518)	(8.310)	(5.868)
Observations	224			

Notes: Standard errors reported in parentheses; *significant at 10%; **significant at 5%, ***significant at 1%.
Only including the number of groups of WMPs used by producers as the measurement of the usage of WMPs because the distinctive patterns observed at Table 2. Using 4 groups of WMPs might be collinear with using advanced scheduling practices, using 3 groups of WMPs might be collinear with using water recovery/storage practices, and using 2 groups might be collinear with using water flow control practices. Adding those variables together might take statistical significance away for some variables.

Appendix. Summary Statistics

Variables	Mean	Standard Deviation	Min	Max
Total irrigated acres (1,000 acres)	2.62	2.64	0.035	20.05
Irrigated rice acres (1,000 acres)	0.73	0.98	0	6.25
Irrigated soybean acres (1,000 acres)	1.33	1.46	0	12
Irrigated corn acres (1,000 acres)	0.35	0.97	0	10
Weighted N water flow practices in 2015	0.28	0.38	0	2
Weighted N water recovery/storage practices in 2015	0.16	0.27	0	1
Weighted N field management practices in 2015	0.52	0.51	0	2.49
Weighted N advanced irrigation scheduling practices in 2015	0.06	0.23	0	1.61
Used water flow control practices in 2010	0.37	0.48	0	1
Use water storage practices in 2010	0.37	0.48	0	1
Used field management practices in 2010	0.43	0.50	0	1
Used advanced irrigation scheduling practices in 2010	0.02	0.13	0	1
Land owner	0.82	0.39	0	1
Highest degree is Bachelor or above	0.51	0.50	0	1
Education agriculture-related	0.56	0.50	0	1
Years of farming experience	32.82	15.74	1	73
Gross income (1,000 dollars)	127.91	94.84	7.5	325
% gross income from farming	0.82	0.26	0.05	1
Total irrigated acres (1,000 acres)	2.62	2.64	0.035	20.05
% irrigated acres use gravity irrigation system in 2015	0.89	0.24	0	1
% irrigation water from groundwater	0.75	0.33	0	1
Concerned water shortage may occur in state	0.70	0.46	0	1
Own a flow meter	0.34	0.47	0	1
Mean daily temperature in previous 30 years (°F)	73.69	1.13	71.13	76.15
Average annual precipitation in previous 30 years (Inch)	22.27	1.66	20.66	26.36
Average aridity between 1950 and 2015	3.28	0.10	2.85	3.41
Aware of state tax credits program	0.46	0.50	0	1
% participated in government program (County level)	0.43	0.20	0	1
Family members, friends or neighbors used water flow control practices	0.87	0.34	0	1
Family members, friends or neighbors used water recovery/storage practices	0.71	0.46	0	1
Family members, friends or neighbors used field management practices	0.92	0.28	0	1
Family members, friends or neighbors used advanced irrigation scheduling	0.49	0.50	0	1
Family members, friends or neighbors used center pivot	0.67	0.47	0	1
Family members, friends or neighbors used use computerized pipe-hole selection	0.52	0.50	0	1
Family members, friends or neighbors used multiple inlet	0.65	0.48	0	1
Family members, friends or neighbors used surge irrigation	0.33	0.47	0	1
Family members, friends or neighbors used tail water recovery system	0.66	0.48	0	1
Family members, friends or neighbors used water recovery/storage practices	0.71	0.46	0	1
Family members, friends or neighbors used zero grade	0.72	0.45	0	1
Family members, friends or neighbors used precision grade	0.88	0.33	0	1
White River	0.41	0.49	0	1
Delta	0.33	0.47	0	1
Observations	224			