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The Role of Peer Irrigators on the Choice and Intensity of Use of Irrigation Techniques

Noah Hayward
University of Arkansas, Fayetteville, hayward504@gmail.com

Kent Kovacs
University of Arkansas, Fayetteville, kkovacs@uark.edu

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Cover Page Footnote

Noah Hayward is a May 2021 honors program graduate in Agribusiness Management and Marketing. Kent Kovacs, the faculty mentor, is an Associate Professor in the Department of Agricultural Economics and Agribusiness.

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Meet the Student-Author

Noah Hayward

At a young age, I knew I always wanted to be a Razorback, and in 2017 I made this dream come true by continuing my education at the University of Arkansas. Prior to this, I grew up in Springdale, Arkansas, where I attended Har-Ber High school from 2015 to 2017. After high school graduation, I began to think about what I wanted to do in life and what kind of career path I wanted to pursue. After careful consideration, I decided to pursue an agricultural business degree to take advantage of the great business opportunities around us. It was truly the best decision I ever made. Looking back now, I see the wonderful and open community this represents. I was more than just another student or number but a voice to be heard with endless educational potential. As a freshman, I decided to take my academics to a higher level by joining the Dale Bumpers Honors College. My mentor Dr. Kent Kovacs helped me to achieve higher levels of success by guiding me through the process. I also thank Dr. Lanier Nalley for keeping me on the right track and leading me through my academic success. Lastly, I want to give great thanks to my committee, Dr. Michael Popp and Dr. Qiuqiong Huang, for helping improve my study. After graduation, I will work as a production supervisor for Simmons Foods, a top 20 poultry company in the United States.

Noah at his May 2021 graduation ceremony, where he received Magna Cum Laude High Honors.

Research at a Glance

- Evaluated the relationship between the irrigation practices in use by farmers' peers and the use and intensity of five common irrigation practices.
- Peer irrigation practice variables interact with the location and farm practices of the agricultural operation to examine heterogeneity in the peer relationship.
- A peer's use of a particular practice has a significant impact on the farmer's use of that same practice, but the impact can differ substantially by location within Arkansas and the type of practices on the farm.

The Role of Peer Irrigators on the Choice and Intensity of Use of Irrigation Techniques

Noah Hayward and Kent Kovacs†*

Abstract

The use and the proportion of farmland that uses prominent irrigation practices in Arkansas were evaluated. A bivariate sample selection model evaluated the determinants of the share of irrigated land in a farm that uses each practice. In addition, the relationship between the irrigation practices a peer uses and the use and intensity of five common irrigation practices was evaluated. If a peer of an Arkansas farmer used center pivot irrigation, this increased the probability that the farmer used center pivot irrigation by 66 percentage points. A peer that used pivot irrigation decreased the proportion of irrigated land that used flowmeter by 0.05. However, a peer using computerized hole selection increased the proportion of irrigated land on a farm using irrigation scheduling by 2.20. The peer effect variables were modeled with interactions for location and farm practices of a farm to examine heterogeneity in the peer relationship. A peer using computerized hole selection increased the likelihood a farmer used computerized hole selection by 55 percentage points, but if the farmer is in the south Arkansas Delta, the likelihood of using the practice increased an additional 60 percentage points. The irrigation practices in use by Arkansas farmers' families and friends affect the decision to use and the proportion of irrigated land that uses center pivot, scientific scheduling, and computerized hole selection.

* Noah Hayward is a May 2021 honors program graduate in Agribusiness Management and Marketing.
† Kent Kovacs, the faculty mentor, is an Associate Professor in the Department of Agricultural Economics and Agribusiness.

Introduction

Agriculture is responsible for roughly 80% of ground and surface water consumption in the United States (USDA, 2019). The adoption and diffusion of modern irrigation technologies can result in many beneficial factors such as reducing costs for farmers and preserving our natural resources. More efficient irrigation practices can reduce consumptive water use and may lower aquifer overdraft. Through modern irrigation technologies, farmers improve consumptive efficiency, which allows more of the water applied to reach the crop. Social learning influences irrigation technology use and how prevalent peer influence is within farming communities in Arkansas. By examining how peers influence farmers' decisions to use a certain irrigation practice, policymakers may better understand what irrigation practices promote irrigation efficiency.

Five of the irrigation practices in use by agricultural producers in the Lower Mississippi River Basin of Arkansas are scientific irrigation scheduling, flowmeters, center pivot, computerized hole, and surge (short definitions of these irrigation practices are in Table 1). Social learning affects the use of each irrigation practice and the proportion of land on the farm that utilizes that irrigation practice. Our measure of social learning refers to whether a farmer has a friend or family member that used one or more of twelve different irrigation practices in the last ten years.

Social learning is one way to receive information about irrigation practices (Genius et al., 2014; Conley and Urdy, 2010; Sampson and Perry, 2019). Genius et al. (2014) find that social learning and extension services synergistically increase farmers' knowledge and reduce the time to adoption of drip irrigation (Genius et al., 2014). Conley and Urdy (2010) find that pineapple producers in Ghana make decisions on input use levels based on whether the input use of a peer in a previous year was a success or failure. Other factors that determine irrigation practice use include farm characteristics and farmer demographics (Dridi and Khanna 2005). Economic factors (Schoengold and Sunding, 2014) (e.g., water price, cost of agriculture technology, farmers income, etc.) and farm characteristics (Genius et al., 2014) (e.g., farm size, soil type, location) and farmer demographics (Genius et al., 2014) (e.g., age, education) also play a part in the diffusion of modern irrigation.

The agricultural economy in Arkansas depends on irrigated crops such as cotton, soybeans, and rice. Arkansas contributes 49% of all rice production in the United States (USDA-ERS, 2019). The yield maximization of these crops depends on proper irrigation at all stages of plant growth. Currently, only about 60% of applied water reaches the intended crop, and policymakers recommend more efficient irrigation practices to reduce run-off and evaporation (ANRC, 2014).

Materials and Methods

Mississippi State University Social Science Research Center administered the survey via phone interviews. Prospective survey respondents were from the water user database being managed by the Arkansas Natural Resource Commission and all commercial crop growers identified by Dun & Bradstreet records for the state of Arkansas. More than 600 farmers reached by phone for the survey were eligible. However, two-fifths of eligible farmers declined to participate, and one-third discontinued the survey in progress. The response rate was ultimately 32%, with 199 fully completed surveys by producers (Rosene, 2019). The questionnaire had about 150 questions and took respon-

Table 1. Dependent variables for the model of the use of an irrigation practice.

Variable	Definition	Percentage
Scheduling	=1 if use scientific scheduling through soil moisture sensors, atmometers, or woodruff charts	0.123
Flowmeters	=1 if use flow meters to measure irrigation water applied to a field	0.352
CHS	=1 if uses computer hole selection with a computer software program to determine the diameter of the hole cut into a poly-pipe	0.347
Pivot	=1 if use center pivot to draw water from the ground at a central "pivot" and a sprinkler system rotates circularly, spraying water over the crops	0.376
Surge	=1 if use surge pulses water down furrows by diverting water to the left and right via valve movement	0.188

dents on average 30 to 40 minutes to complete through telephone. The definitions and summary statistics of the dependent variables for the use of each of the irrigation practices modeled are in Table 1, and the definitions and summary statistics of dependent variables for the share of land in each irrigation practice modeled are in Table 2. The definitions and summary statistics for the explanatory variables to predict the use and share of land in the irrigation practices are shown in Table 3.

A bivariate sample selection model was used to find the factors that correlated with the use of an irrigation practice and the proportion of land on a farm that used the practice (Cameron and Trivedi, 2005). A sample selection model is used because we want to understand what explanatory factors influence the proportion of land using an irrigation practice for all farmers rather than only the farmers already using the practice. The bivariate component refers to a dependent variable for a use equation and a dependent variable for the proportion of land equation. The use equation's dependent variable was binary to specify the use of an irrigation practice, and the proportion of land in an irrigation practice was the continuous dependent variable for the other equation.

The dependent variable in the use equation, y_1, was an incompletely observed value of a latent dependent variable y_1^*, where the observation rule was,

$$y_1 = \begin{cases} 1 \; if \; y_1^* > 0, \\ 0 \; if \; y_1^* \leq 0 \end{cases}$$

and the proportion of land equation was such that

$$y_2 = \begin{cases} y_2^* \; if \; y_1^* > 0, \\ - \; if \; y_1^* \leq 0. \end{cases}$$

This model indicated that y_2 was observed when $y_1^* > 0$, and y_2 did not take on a value when $y_1^* \leq 0$. The latent variables y_1^* and y_2^* specify that the use and proportion of land in each practice were not observed for the population as a whole. This then specified a linear model with additive errors for the latent variables, so

$$y_1^* = x_1'\beta_1 + \varepsilon_1,$$

$$y_2^* = x_2'\beta_2 + \varepsilon_2.$$

Bias in the estimation of β_2 would arise if ε_1 and ε_2 were correlated.

Maximum likelihood was used for this estimation, which is asymptotically efficient, and used the additional assumption that the correlated errors were joint normally distributed and homoscedastic with

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} \sim \aleph \left[\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix} \right].$$

The bivariate sample selection model used the likelihood function

$$L = \prod_{i=1}^{n} \{\Pr [y_{1i}^* \leq 0]\}^{1-y_{1i}} \{f(y_{2i} \mid y_{1i}^* > 0) \times Pr[y_{1i}^* > 0]\}^{y_{1i}}$$

where the first term came from the use equation when $y_{1i}^* \leq 0$, and the second term corresponded to the proportion of land equation when $y_{1i}^* > 0$. A likelihood ratio (LR) test with a Chi-squared statistic was used to determine whether the bivariate sample selection model was necessary for unbiased estimation of the coefficients for the explanatory variables on the proportion of irrigated land using an irrigation practice.

Results and Discussion

The marginal effects for the explanatory variables that relate to the irrigation practices of a farmer's peers on the use of flowmeters, pivots, computerized hole selection, and surge are in Table 4. If a peer used a flowmeter for irrigation, the likelihood of using a flowmeter by the farmer increased by 64 percentage points. However, if a peer used flowmeters in the ridge area, the likelihood of using flowmeters increased by only 19 percentage points (0.64 – 0.45 = 0.19). Likewise, if a peer used flowmeters and the producer is in the north Arkansas delta, the likelihood of using flowmeters increased by only 27 percentage points (0.64 – 0.37 = 0.27). These results show that the influence of peers on an agricultural producer's irrigation practices differs across the Arkansas region. If a peer used pivots for irrigation, the likelihood of a farmer

Table 2. Dependent variables for the model of the share of land in an irrigation practice.

Variable	Definition	Mean	Std. Dev	10th Percentile	90th Percentile
Share_Sched	Share of land that uses scientific scheduling	0.044	0.17	0	0.05
Share_FM	Share of land that uses flowmeters	0.089	0.20	0	0.31
Share_CHS	Share of land that uses computerized hole selection	0.107	0.22	0	0.45
Share_Pivot	Share of land that uses center pivot	0.085	0.21	0	0.30
Share_Surge	Share of land that uses surge irrigation	0.021	0.097	0	0.04

Table 3. Explanatory variables for predicting the use and share of land in irrigation practices.

Variable	Definition	Percentage
PeerPivot	=1 if peers[a] used center pivot	0.65
PeerSurge	=1 if peers used surge irrigation	0.36
PeerCHS	=1 peers used computerized hole selection	0.56
PeerFlowMeter	=1 if peers used flowmeters on the wells	0.65
PeerTWR	=1 if peers used tailwater recovery system	0.71
PeerZeroGrade	=1 if peers used zero grade leveling	0.75
PeerEndBlock	=1 if peers used alternate used end blocking, cutback irrigation, or furrow diking in irrigation	0.55
PeerAltWetDry	=1 if peers used alternate wetting and drying for rice irrigation	0.35
PeerCHS*Fin	=1 if peers used computerized hole selection and primary reason for adoption of tailwater recovery and reservoirs was financial assistance	0.05
PeerFM*Ridge	=1 If peers used flow meter and located in ridge	0.20
PeerFM*ND	=1 if peers used flow meter and located in North Delta	0.04
PeerCHS*SD	=1 if peers used computerized hole selection in the South Delta	0.03
PeerTWR*GP	=1 if peers used tailwater recovery systems in the Grand Prairie region	0.19
PeerTWR*Fin	=1 if peers used tailwater recovery system and primary reason for adoption of tailwater recovery and reservoirs was financial assistance	0.06
PeerTWR*RegCons	=1 if peers used tailwater recovery system and participated in regional conservation partnership program	0.11
Crop types		**Percentage**
IrrSorghum	=1 if grows irrigated sorghum	0.07
IrrCotton	=1 if grows irrigated cotton	0.14
Socioeconomic characteristics		**Percentage**
AgEdu	=1 if formal education related to agriculture	0.59
IncMid	=1 if household income between $75K and $200K	0.42
IncHigh	=1 if household income greater than $200K	0.13

[a] Peers include family members, friends, or neighbors using technology within the past 10 years.

using pivot irrigation increased by 66 percentage points. If a peer used computerized hole selection (CHS) for irrigation, the likelihood of a farmer using computerized hole selection increased by 55 percentage points. Having a peer that used computerized hole selection in the south Arkansas delta increased the likelihood of a farmer using computerized hole selection to 115 percentage points (0.55 + 0.6 = 1.15). This result is further evidence that peers' influence on the choice of irrigation practice can differ by geographic region.

Having a peer that used surge irrigation increases the likelihood that a farmer used surge by 9 percentage points. However, if the farmer lived in the Grand Prairie, then having a peer that used surge irrigation increased the likelihood the farmer used surge by an additional 47 percentage points. If the farmer lived near Crowley's Ridge, having a peer that used surge irrigation increased the chance the farmer used surge by 24 percentage points. The location of the farmer's residence had a significant influence on whether having a peer using surge would lead to the farmer using surge themselves. The investigation of the reasons for the dramatic variation across locations is a direction for future research. If a farmer used zero grade leveling, having a peer that used surge irrigation decreased the likelihood the farmer used surge by 15 percentage points. This suggested there is a substitution between field management practices, like zero grading in use for rice, and water flow control practices such as surge for row crops. Table 4 also shows the marginal effects for the type of crops grown on the farm to explain the use of an irrigation practice. A producer that cultivated sorghum was 45 percentage points more likely to use pivot, and a producer that cultivated cotton was 24 percentage points less likely to use flowmeters and 80 percentage points more likely to use pivot.

Marginal effects for explaining the proportion of irrigated land that used an irrigation practice appear in Table 5. The significant Chi-squared statistic indicated that the bivariate sample selection model was necessary for unbiased estimates of the coefficients on the explanatory variables predicting the share of irrigated land that uses scientific scheduling, flowmeters, and CHS. Having a peer that used CHS increased the proportion of irrigated land a farmer used for scientific scheduling by 2.2. Having a peer that used a flowmeter increased the proportion of irrigated land a farmer used for flowmeters by 0.33. Having a peer that used center pivot increased the proportion of land a farmer used for pivot by 0.18. Having a peer that used alternate wetting and drying or end blocking decreased the proportion of irrigated land in center pivot by 0.23 and 0.22, respectively. Having a peer that used computerized hole selection increased the proportion of irrigated land a farmer used for computerized hole selection by 0.17.

Table 4. Marginal effects for the peer and crop type variables to explain the use of an irrigation practice.

Variable	Flowmeters	Pivot	CHS	Surge
PeerPivot		0.66 (0.0) a		
PeerCHS			0.55 (0.00) a	
PeerFlowmeter	0.64 (0.00) a			
PeerCHS*SD			0.6 (0.05) c	
PeerCHS*Fin			0.82 (0.02) b	
PeerSurge				0.09 (0.46)
PeerSurge*GP				0.47 (0.01) a
PeerSurge*Ridge				0.24 (0.06) c
PeerZeroGrade				-0.15 (0.037) b
PeerFM*Ridge	-0.45 (0.048) b			
PeerFM*ND	-0.37 (0.063) c			
IrrSorghum		0.45 (0.009) a		
IrrCotton	-0.24 (0.087) c	0.8 (0.0) a		
Pseudo R^2	0.28	0.42	0.42	0.53

a – 1%, b – 5%, c – 10% significance. *P*-values from the probit model estimates in parentheses. There are 222 observations for each model of irrigation practice use.

A producer that had formal education related to agriculture had a 1.15 higher proportion of irrigated land that uses scheduling. A producer that had a household income between $75,000 and $200,000 had a 0.95 higher proportion of irrigated land that used scheduling than a producer with a household income of less than $75,000. A producer that had a household income greater than $200,000 had a further 0.86 higher proportion of land that uses scheduling. A producer that grew irrigated sorghum had a 0.12 higher proportion of land that used pivot. A producer that grew irrigated cotton had a 0.23 higher proportion of land that used pivot.

A peer using tail-water recovery (TWR) increased the proportion of irrigated land using surge by 0.05. A peer using TWR resulted in the farmer located in the Grand Prairie using a lower proportion of irrigated land with surge (-0.24). A farmer that received financial assistance for TWR or reservoirs and had a peer who used TWR also had a lower proportion of irrigated land with surge (-0.17). However, a farmer that participated in a regional conservation program and had a peer using TWR increased the proportion of land under surge by 0.13. The results for the proportion of irrigated land that used surge illustrated the heterogeneous effect of having a peer that used TWR.

There appeared to be complementarities and substitutions among irrigation practices witnessed through the peer effects. For example, a farmer with a peer that uses CHS increased the proportion of land in scheduling by 2.20. A farmer with a peer using pivot or end blocking resulted in a farmer increasing the proportion of their land using scheduling by 1.09 and 0.62, respectively. These results indicate how CHS, pivot, or end-blocking can be used together with scheduling to increase greater irrigation efficiency and suggests the irrigation practices farmers view as complements for their fields. If a farmer had a peer using surge or precision leveling, this lowered the proportion of land being irrigated with flowmeters. There can also be substitution among the irrigation practices as well that farmers use to achieve irrigation efficiency.

There appeared to be a relationship between pivot irrigation and the crops being produced. A producer cultivating sorghum increased the proportion of land using pivot by 0.12. A producer cultivating cotton increased the

Table 5. Marginal effects for the peer, crop type, and socioeconomic variables to explain the share of land that uses an irrigation practice.

Variable	Share_ Sched	Share_FM	Share_Pivot	Share_CHS	Share_Surge
PeerPLevel		-0.18 (0.06) c			
PeerSurge		-0.130 (0.02) b			
PeerCHS	2.2 (0.015) b			0.17 (0.06) c	
PeerFlowMeter		0.33 (0.00) a			
PeerPivot	1.09 (0.00) a		0.18 (0.05) b		
PeerAltWetDry			-0.23 (0.06) c		
PeerEndBlock	0.62 (0.084) c		-0.22 (0.014) b		
PeerTWR					0.05 (0.70)
PeerTWR*GP					-0.24 (0.09) c
PeerTWR*Fin					-0.17 (0.05) b
PeerTWR*RegCons					0.13 (0.04) b
IrrSorghum			0.12 (0.085) c	-1.46 (0.025) b	
IrrCotton	-1.4 (0.00) a	-0.19 (0.04) b	0.23 (0.065) c		
AgEdu	1.15 (0.01) b		0.18 (0.005) a		
IncMid	0.95 (0.002) a				
IncHigh	0.86 (0.00) a				
Pseudo R^2	0.76	0.10	0.14	0.09	0.09
LR test- Chi-squared statistic	16.12 a	63.49 a	1.15	9.49 a	1.85
Number of observations	59	81	30	40	52

a – 1%, b – 5%, c – 10% Significance. The *P*-values from the bivariate sample selection model estimates in parentheses. The significance of the Chi-squared statistic for the LR test for scheduling, flow meters, and CHS indicates the bivariate sample selection model is necessary for unbiased estimation of the coefficients on the explanatory variables.

proportion of land using pivot by 0.23. Producers with a formal agriculture education irrigated a higher proportion of their land with scientific scheduling and center pivot. Pivot and scheduling both involved the use of sophisticated equipment, and a formal education may allow them to better utilize newer and advanced practices. Farm income only influenced the proportion of irrigated land that uses scientific scheduling, perhaps because only farms with high income were willing to take a risk on new irrigation technologies.

Conclusions

Social learning through the knowledge of the irrigation practices in use by friends and family influenced Arkansan farmers' use of five common irrigation practices. In addition to examining if a farmer's social learning led to the use of an irrigation practice, the proportion of land irrigated with the irrigation practice is considered as well. A peer's use of center pivot had the greatest impact on a farmer using center pivot themselves. A peer's use of an irrigation practice differed substantially by location within Arkansas and the type of practices an agricultural producer already has on their farm.

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