IMPACT OF VARIABLE RATE TECHNOLOGY ADOPTION ON COTTON YIELD IN TEAXS

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Abstract

Uniform input application in the farm may not be the optimal strategy in fields with considerable within-field variability in soil characteristics and crop conditions. Variable Rate Technology (VRT) takes the within-field variability into consideration and aims to match resource application to field conditions and crop requirements. However, since VRT technology is a response to the extent and distribution of within-field variability, the yield advantage from adopting this technology differs from field to field. Even though Texas is the most important cotton producing state in the US, the rate of VRT adoption is very low here. Providing a regional estimate of the impact of VRT adoption on cotton yield is very important to boost adoption rates in Texas. This study used the 2013 Southern Cotton Precision Farming Survey to empirically estimate the impact of VRT adoption on cotton yield in Texas. A two-stage least square procedure was used to estimate the yield improvement from VRT adoption in Texas. Separate analyses were performed to evaluate the yield improvements from VRT adoption in irrigated and dryland cotton. The results revealed that VRT adoption did not significantly increase the yield of dryland cotton in Texas. However, the impact of VRT adoption on irrigated cotton yield was significant at 10% alpha level (p value: 0.07). The lint yield increase from VRT adoption for irrigated cotton in Texas is estimated to be 119 lbs. /acre.

Introduction

Precision agriculture (PA) is defined as a "holistic and environmentally friendly strategy in which farmers can vary input use and cultivation methods – including application of seeds, fertilizers, pesticides and water, variety selection, planting, tillage, harvesting – to match varying soil and crop conditions across a field" (Srinivasan, 2006). In this information era, PA is considered as a management system with several components such as geo-spatial referencing, auto steering tractors, yield monitors, automatic section control, and variable rate technology (McBratney et al., 2005; Pierce and Nowak, 1999). PA has multiple advantages such as increased the profitability by increasing the efficiency of input use, and reduction in the negative environmental impact by applying only the required amount on input according to local needs that vary with time and space within a field (Pierce and Nowark, 1990).

The main components of PA technology are collection and processing of field variability data, and variable rate application of inputs (Blackmore et al., 2003). Because of this variability in field condition, the input requirements in some parts of the field may be different from that of other parts (Basso et al., 2013). Hence, adjusting the resource application and agronomic practices with the within-field variability in field conditions and crop requirement leads to increased input use efficiency (Whelan and McBratney, 2000). The application of input matching the field variability is done using Variable Rate Technology (VRT). VRT is a computer based system capable of applying inputs in differential preset rates at various parts of the field (Khanna et al., 1999). Since, the fertility of the filed can vary from location to location, VRT ensures optimal resource availability at all parts of the field and leads to yield enhancement.

Texas is the most important cotton producing state in the US. Texas accounts for a major portion of cotton acreage and production in the US. In 2014, Texas accounted for 6 million bales of cotton production out of 16 million produced nationally (USDA NASS, 2014). Since cotton producers need to take several input management decisions, VRT can be a helpful tool for cotton producers in Texas.

Even with potential advantages of VRT, its adoption level is very low in the US, especially among cotton farmers. The adoption level is particularly low in Texas. The 2013 Sothern Precision Farming Survey revealed that only 6.87% of cotton producers in Texas adopted VRT for input application (Nair et al., 2014). There are several factors influencing the low adoption of VRT. The lack of awareness about the existence and potential advantages of PA technology among the farmers (Daberkow and McBride, 2000), high cost of technology, and difficulty in proper understanding of the technologies employed for both collection and interpretation of field variability data (Reichardt and Jurgens, 2009) are some factors that leads to lower adoption of the VRT technology.

VRT can increase the cotton yield in several ways. More fertile parts of the field can support a higher plant population and hence variable rate seeding can enhance the yield. VRT matches input application to field variability and hence ensures optimal availability of inputs in all parts of the field. Hence VRT can lead to higher yield compared to blanket input application. Even though VRT adoption can lead to yield enhancement, lack of demonstrated evidence of yield or economic advantage is regarded as the most important factor influencing the low adoption of VRT (Khanna et al., 1999). This occurs because the yield improvement due to VRT adoption varies from field to field.

Since VRT is a response to the extent and distribution of within-field variability, the yield increase from VRT adoption depends on the farm field in which the practice is adopted. Hence the estimates of yield improvement due to VRT adoption are generally not consistent across locations. For example, while some researchers reported yield increase from variable rate nitrogen application (Bronson et al., 2006), some others reported that variable rate nitrogen application has no significant impact on crop yield (Koch et al., 2004).

The yield response to VRT is field and location specific. Since the evidence of yield enhancement is critical for increased adoption of VRT, it is important to estimate the yield increase from VRT adoption in Texas, which is a major cotton producing state in the US. The objective of this study is to estimate the impact of VRT adoption on cotton yield in Texas

Materials and Methods

The materials and methods used for this study are described below in three sections. The first section is on the data used for the study, the second section is on the econometric model, and the third section is on the empirical model.

The data

The data adoption of precision agriculture practices, irrigation practices, and demographic data for this study was extracted from the 2013 Southern Precision Farming Survey (see Boyer et al., 2014 for details of the survey). The survey received 1811 responses from cotton farmers of 12 southern US states with a response rate of 13.76%. The survey provided information on adoption of different variability data gathering technologies, adoption of various variability rate technologies, type of irrigation technology used, different farming practices adopted in the farm, acreage and production of cotton during 2007 and 2008, and characteristics of the farm and the farmer. Since the objective of this study was to estimate the impact of VRT adoption on cotton yield in Texas, only the data for Texas was used in this study. The survey was sent out to 4563 cotton producers in Texas and we received 597 usable responses with a response rate of 13.1%.

In a large state like Texas, there is considerable variability in the soil and climatic conditions experienced in various counties. To account for the possible differences in soil and climatic conditions on a particular farm, county-wise average cotton productivity data (average for the last 5 years) was used (USDA NASS, 2014). The water availability is also highly var4iable among the counties in Texas. To account for this difference, we used data on average pumping lift for wells in each county (Texas Tech University, 2014).

Econometric Model

The lint yield of cotton is influenced by several soil and climatic factors and farm and farmer characteristics that affects management decisions. The agronomic management practices adopted in a particular farm including VRT will be influenced by several socio-economic characteristics of the producer. However, VRT adoption also be influenced by the socio-economic characteristics of the producer (Larson et al., 2008; Sevier and Lee, 2004; Walton et al., 2010). This leads to the problem of endogeneity. Two stage least square estimation with instrumental variable was used to account for the endogeneity problem (Cameron and Trivedi, 2005).

In the two stage least squares procedure, the endogenous variable is regressed on all the explanatory variables including the instrumental variable in stage 1. The independent variable is regressed on the predicted value of the endogenous variable and the explanatory variables other than the instrumental variables in the second stage. Since the consistency of the parameter estimates of the second stage is not dependent on specifying the correct functional form in the first stage (Kelejian, 1971), linear probability model was used in the first stage and multiple linear regression model was used in the second stage. The regression equations estimated in stage 1 and 2 are provided below and Eq. 1 and Eq. 2.

$$Pr\ (y=1/X) = X\beta + v \tag{1}$$

$$Y=\hat{y}\beta_1+ X_1\beta_2+u \tag{2}$$

where y is the endogenous variable X is the matrix of explanatory variables (including the instrumental variable), β is the vector of coefficients to be estimated, v is the error term for equation 1, Y is the independent variable, $\hat{y}$ is the predicted value of the endogenous variable, X_1 is the matrix of explanatory variables excluding the instrumental variable, u is the error term for equation 2, and β_1 and β_2 are the coefficient estimates of $\hat{y}$ and X_1, respectively.

Empirical Model

The definition of all the variables used in the empirical model is provided below as Table 1. Among the variables listed in Table 1, *yield* is the independent variable and *adopt* is the endogenous variable. The variable *dist* is the instrumental variables (excluded exogenous variables), and the remaining variables are the explanatory variables (included exogenous variables). The survey defined precision farming as “collecting information about within field variability in yield and crop needs, and using that information to manage inputs” before asking the question on precision farming adoption. Since the VRT adoption levels and yield of the irrigated cotton production is significantly different from those of dryland cotton production, separate models were estimated for irrigated and dryland cotton.

Table 1. Definition of variables used in the empirical model.

Variable	Definition
yield	The average cotton lint yield (lbs. / acre) reported by the producer
adopt	Dummy variable that assumes the value 1 if the producer adopted VRT and 0 otherwise
others	Dummy variable that assumes the value 1 if the county with the majority of the producer’s field does not overlies the Ogallala Aquifer and 0 otherwise
shallow	Dummy variable that assumes the value 1 if the average saturated thickness of the Ogallala Aquifer in the county with the majority of the producer’s field is < 17 meters
medium	Dummy variable that assumes the value 1 if the average saturated thickness of the Ogallala Aquifer in the county with the majority of the producer’s field is between 17 and 23 meters
deep	Dummy variable that assumes the value 1 if the average saturated thickness of the Ogallala Aquifer in the county with the majority of the producer’s field is > 23 meters
perCP	The percentage of the total cotton acreage of the producer under center pivot irrigation system
perSDI	The percentage of the total cotton acreage of the producer under sub-surface drip irrigation system
countyprod	Average cotton yield for the county with the majority of the producer’s field for the last 5 years
age	Age of the primary decision maker (years)
exp	Number of years of farming experience of the primary decision maker of the farm
edu	Dummy variable that assumes the value 1 if the primary decision maker of the farm has less than high school education and 0 otherwise.
comp	Dummy variable that assumes the value 1 if computers are used for farming operations and 0 otherwise
croprot	Dummy variable that assumes the value 1 if crop rotation is followed in the field and 0 otherwise
covercrop	Dummy variable that assumes the value 1 if cover crops are planted in the field and 0 otherwise
acreage	The total cotton acreage planted by the producer
perown	Percentage of the total cotton acreage owned by the producer

Results and Discussion

Since the objective of this study is to estimate the impact of VRT adoption on cotton yield, only the results of the second stage regression is presented and discussed here. The results of the second stage regression for both irrigated and dryland cotton is presented in Table 2.

Table 2. The coefficient estimates and p values for second stage regression.

Variable	Irrigated Cotton		Dryland Cotton	
	Coefficient Estimate	p > |z|	Coefficient Estimate	p > |z|
adopt	119.04	0.0710	11.89	0.8001
shallow	-142.5	0.1702	-	-
medium	-98.86	0.0215	-	-
deep	-8.91	0.8915	-	-
perCP	1.41	0.0169	-	-
perSDI	-0.62	0.4590	-	-
countyprod	0.58	0.0029	1.28	<0.0001
age	5.24	0.0724	0.57	0.7907
exp	-3.35	0.1583	0.95	0.6160
edu	37.35	0.6836	-25.63	0.0035
comp	-29.01	0.5485	42.73	0.2730
croprot	1.33	0.9801	46.09	0.4669
covercrop	-46.0	0.2990	-111.53	0.1450
acreage	-0.02	0.7112	-0.02	0.4669
perown	0.18	0.7209	-0.01	0.9767

The results show that the adoption of PA practices in general by Texas cotton farmers can result in an increase of cotton yield by 119.04 lbs. / acre for irrigated cotton production in Texas. This estimate of yield increase was statistically significant at 10% alpha level. However the estimate for dryland cotton production was statistically significant even at 10% alpha level. This result showing statistically significant yield increase due to VRT adoption contradicts the findings from 2009 Southern Precision Farming Survey (Nair et al., 2012a; 2012b). Irrigation is an input that interacts with the efficiency of other inputs like Nitrogen. Moreover, irrigated agriculture is more resource intensive compared to dryland farming. Hence, the yield enhancing effect of VRT can be more pronounced in irrigated cotton production. This may be the reason for observing significant yield increase due to VRT adoption in irrigated cotton and no yield improvement in dryland cotton.

It is also interesting to note that the counties overlying Ogallala showed lower yields compared to those not overlying it. The counties with medium saturated thickness showed significantly lower yield compared to counties not overlying Ogallala while the counties with shallow and deep were on par with non-Ogallala counties. This result shows the need to use the modeled well yield in place of the saturated thickness data for further analysis.

The irrigation method also significantly influenced irrigated cotton yields. The irrigated cotton yields increased by 1.41 lbs. / acre for a one percentage increase in percentage of the total cotton acreage under center pivot irrigation system. However, the percentage of total acreage under sub-surface drip did not significantly influenced cotton yield.

Among other factors, the average cotton productivity of the county for last five years significantly influenced both the irrigated and dryland cotton yield. The results also showed that older farmers are likely to get higher irrigated cotton yield. It is also interesting to note that more educated farmers were found to have lower productivity of dryland cotton.

Summary

Even though precision farming practices have multiple advantages including yield increase, its adoption level is very low; especially in Texas. Since variable rate technology is a response to the extend and distribution of within-field variability, the yield and economic advantages of its adoption deferrers from field to field. Hence, lack of demonstrated evidence of yield enhancement due to VRT adoption is regarded as a deterrent for its adoption. The objective of this study is to estimate the impact of VRT on the lint yield of cotton in Texas. The study used the 2013 Southern Precision Farming Survey along with the county wise hydrologic data yield data. The two-stage least squares approach using instrumental variable was used for the estimation. The results revealed that the adoption of VRT is estimated to result in 119.04 lbs. / acre yield increase in irrigated cotton. However, the adoption of VRT did not significantly influence the yield of dryland cotton.

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