DRIVERS OF LAND USE CHANGE IN THE SOUTHERN HIGH PLAINS OF TEXAS

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Abstract

The Southern High Plains of Texas is the most important cotton producing region in the US in terms of both acreage and total production. Cotton acres planted under irrigation have exceeded one million acres each year for the last decade in the region. However, historic data indicates considerable fluctuation in irrigated cotton acreage ranging from 760,000 to 1,500,000 acres planted. Other irrigated crops in the region include corn and grain sorghum. This study investigated potential factors influencing changes in acres planted to cotton, corn, and grain sorghum using historical acreage and price data of these crops from 1974 to 2014. Multiple linear regressions were developed for each crop with planted acreage as the dependent variable. The lag acreage and lag price of the crop and the lag prices of the competing crops served as explanatory variables. Since these crop acreages are related, iterative Seemingly Unrelated Regression was used to simultaneously estimate the parameters. Results indicated that the lag acreage significantly and positively influenced the planted acreage of all crops. Planted acreage of cotton increased with an increase in the lag price of cotton. Grain sorghum acreage was positively affected by its lag price and negatively impacted by the lag price of cotton. It was puzzling to note that corn acreage was negatively related to its lag price and positively related to the lag price of grain sorghum. However, the close relationship between corn and grain sorghum, and a relatively larger coefficient estimate for the lag price of grain sorghum indicates an acreage increase for corn with an increase in the lag price for grains in general.

Introduction

The Southern High Plains (SHP) of Texas is comprised of 16 counties in the lower west side of the Texas Panhandle (USDA NASS, 2015b). The SHP is the most important cotton producing region in the US in terms of acreage and total production. Cotton acres planted under irrigation have exceeded one million acres each year in the region for the last decade. However, historic data indicates considerable fluctuation in irrigated cotton acreage. Other irrigated crops in the region include corn and grain sorghum. Even though corn and grain sorghum occupy relatively small shares of total acreage, they also show considerable year-to-year acreage variation. The average irrigated acreage planted to corn and grain sorghum over the past decade were around 80,000 and 200,000 acres, respectively (USDA NASS 2015a). The SHP is a low rainfall region that depends solely on the Ogallala Aquifer for irrigation water (Lascano et al., 2000). Since the aquifer recharge is negligible, the receding saturated thickness is prompting producers to shift towards crops with lower irrigation requirements (McGuire et al., 2003). Therefore, it is valuable to analyze the irrigated crop choices in this region and the factors that influence these acreage decisions.

Agricultural land use patterns vary geographically and temporally as they express the interaction between natural and cultural forces in the environment (Antrop, 2005). Land use models try to capture the impact of human environment, physical environment, land owner's decision making process, and ecological processes on land use (Reibsame et al., 1994). Soil productivity and its suitability for certain crops greatly influences agricultural land use (Iverson, 1988). Most economic approaches assume that any parcel of land with specific attributes and location is allocated to the use that earns the highest rent.

Since cotton, corn, and grain sorghum are planted during the same cropping season, they compete with each other for irrigated acreage. Consequently, crop choice is dependent on the relative profitability of the crops, resource availability, availability of fixed factors of production, and agronomic considerations such as crop rotation. Among these factors, profitability is assumed to be the most important factor to producers. Since crop productivity can be relatively stable in irrigated production, the expected commodity prices of the competing crops can be a major driver of irrigated land use. Since, agricultural producers have rational expectations about prices, the lag price can be considered an indicator of expected price (Muth, 1961).

Since considerable changes in historic crop acreage has occurred in the SHP and this variability may increase in the future due to a reduced water supply or pumping restrictions, it is important to analyze acreage trends of the crops and to quantify the influence of these possible driving factors on crop choices. The planted acreage of crops has important implications on commodity supply and prices. A predictive model for planted acreage in the region will provide important information for policy makers. The objectives of this study were to 1) assess the changes in irrigated acreage of cotton, corn, and grain sorghum in the SHP of Texas and 2) identify the possible drivers of land use change in the region and quantify their influence on irrigated acreage of cotton, corn, and grain sorghum.

Materials and Methods

The Data

Data on planted acreage and prices received for cotton, corn, and grain sorghum in the SHP from 1975 to 2014 were collected (USDA-NASS, 2015b). Corn and grain sorghum prices were reported in \$/bu. and \$/CWT, respectively. The grain sorghum price was converted to from \$/CWT to \$/bu. to enable meaningful comparison of the marginal impact of grain prices on acreage choices. The acreage data for cotton and corn were not reported for 2011. Hence, yield data for 39 years (1975 to 2014 except 2011) was used to analyze the yield trends using simple linear regression (OLS) with time as the explanatory variable. Lag acreage was an explanatory variable in our empirical model to analyze land use change. Data from 2012 was also excluded from the dataset used for empirical estimation, because lag acreage and prices for 2012 are data from 2011.

Empirical Model

The econometric model used in this study can be conceptualized as a two-step process. The first step was to develop multiple regression equations to explain planted acreage of each crop using its lag acreage and lag price, and the lag prices of the two competing crops as explanatory variables. This resulted in the following three regression equations.

$$Cotton\ Acreage = \beta_0 + \beta_1 LA_{cotton} + \beta_2 LP_{cotton} + \beta_3 LP_{corn} + \beta_4 LP_{sorghum} + \varepsilon \quad (1)$$

$$Corn\ Acreage = \beta_0 + \beta_1 LA_{corn} + \beta_2 LP_{cotton} + \beta_3 LP_{corn} + \beta_4 LP_{sorghum} + \varepsilon \quad (2)$$

$$Sorghum\ Acreage = \beta_0 + \beta_1 LA_{sorghum} + \beta_2 LP_{cotton} + \beta_3 LP_{corn} + \beta_4 LP_{sorghum} + \varepsilon \quad (3)$$

where LA is lag acreage, LP is lag price, $\beta^i s$ are the coefficient estimates, and ε is the error term.

Even though these are three separate equations, the error terms in these equations are correlated because change in acreage of one crop will influence the acreage of the other crops. Hence, these three equations were simultaneously estimated using iterative Seemingly Unrelated Regression (SUR) procedure (Zellner, 1962) in STATA® (StataCorp, 2013) to quantify the influence of the factors driving irrigated land use in the region. Our SUR model was estimated using the Feasible Generalized Least Square (FGLS) algorithm (Cameron and Trivedi, 2009). SUR is more efficient than OLS when the errors are correlated (Greene, 2008), which is a realistic assumption in this case.

Results and Discussion

The descriptive statistics of the price and acreage data for cotton, corn, and grain sorghum in the NHP are provided in Table 1. The descriptive statistics clearly indicate the dominance of cotton in the region. The average irrigated area planted to cotton was 1,154,282 acres, while that of corn and grain sorghum were only 86,941 and 141,762 acres, respectively. However, cotton acreage had much higher year-to-year variability compared to corn and grain sorghum. The variability in irrigated acreage was the lowest for corn indicating that corn producers may be less likely to shift to other crops. Grain prices showed far higher variability than cotton prices.

Table 1. Descriptive Statistics of acreage and price data for the three crops from 1975 to 2014 (2011 not included)

Statistic	Planted acreage (acres)			Price (\$/lbs. for cotton & \$/bu. for grains)		
	Cotton	Corn	Sorghum	Cotton	Corn	Sorghum
Mean	1,154,282	86,941	141,762	\$0.55	\$3.06	\$2.67
Minimum	760,000	38,500	32,200	\$0.28	\$1.87	\$1.60
Maximum	1,500,000	200,000	512,000	\$0.82	\$7.12	\$6.27
Standard Deviation	170,284	38,441	123,274	\$0.11	\$1.14	\$1.01

The historical trends in irrigated acreage and price data for cotton, corn, and grain sorghum are illustrated in Figure 1. There is considerable year-to-year variability in cotton and grain sorghum planted acreages, while acreage variability was lower for corn. However, planted acreages of all three crops showed a negative trend over time. This may be indicative of the fact that producers are moving away from irrigated crop production as water availability decreases. On average, corn and grain sorghum acreages decreased by about 1,700 and 2,400 acres per year, respectively, while cotton acreage decreased by only 230 acres per year.

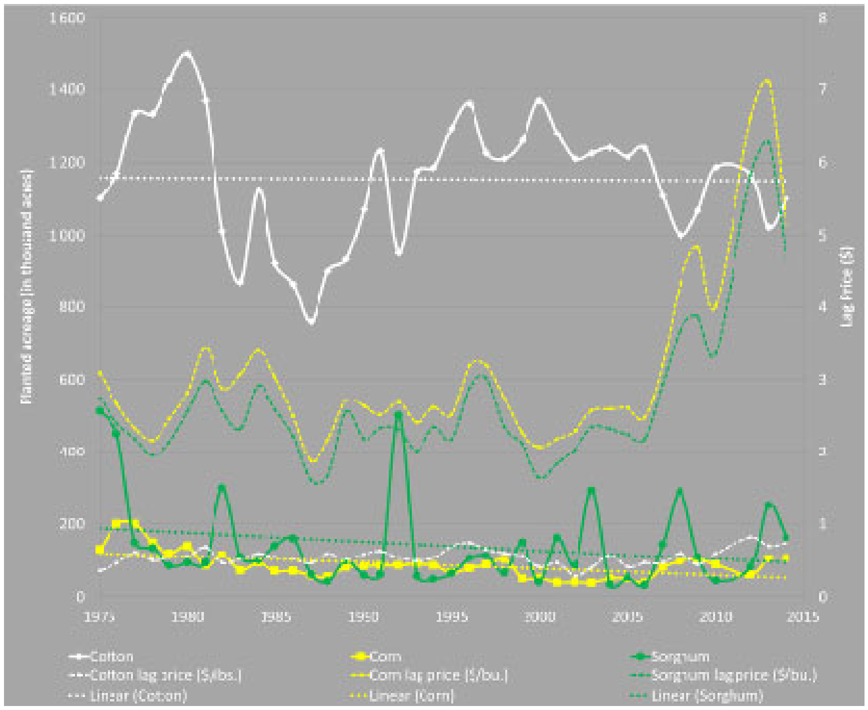

Figure 1. Planted acreage of irrigated cotton, corn, and sorghum and their prices in the Texas NHP.

Overall results of the SUR analysis of the acreage equations for the SHP are presented in Table 2. The irrigated acreages of all three crops were significantly influenced by at least one of the explanatory variable. The explanatory variables accounted for most of the variability in cotton and corn acreage (R^2 of 0.5371 and 0.6903, respectively). However, only 26% of the variability in grain sorghum acreage was explained by its lag acreage and the lag prices of cotton, corn, and grain sorghum.

Table 2. Results of SUR regression analysis for crop acreage equations

Equation	No. of obs.	No. of param.	RMSE	R square	Chi Square	p-value
Cotton acreage	38	4	115,844	0.5371	72.78	<0.001
Corn acreage	38	4	21,242	0.6903	84.97	<0.001
Sorghum acreage	38	4	105,571	0.2617	14.01	<0.007

The coefficient estimates and p-values for explanatory variables in all three equations are provided in Table 3. Irrigated cotton acreage was significantly influenced by lag acreage ($p<0.001$) and the lag price of cotton ($p=0.053$). A one cent per lbs. increase in the lag price of cotton increased planted acreage of cotton by 3,933 acres.

The lag acreage and the lag prices of cotton (at 10% α level), corn, and grain sorghum were significant drivers of irrigated corn acreage. A one cent per lb. increase in the lag cotton price reduced corn acreage by 698 acres, while a 10 cents per bu. increase in the lag sorghum price increased corn acreage by 7,047 acres. However, the results show a negative relationship between corn prices and corn acreage due to the close relationship between corn and sorghum prices (Figure 1), and a relatively larger coefficient for the lag sorghum price.

Planted acreage of grain sorghum was significantly and positively influenced by its lag acreage and lag price and negatively influenced by the lag price of corn. A 10 cent per bu. increase in the lag grain sorghum price increases grain sorghum acreage by 26,655 acres, while a 10 cent per bu. increase in the lag corn price leads to an 18,745 acre decrease in area planted to grain sorghum.

Table 3. Influence of lag acreage and lag prices on planted acreage of irrigated cotton, corn, and grain sorghum

Variable	Cotton Acreage		Corn Acreage		Sorghum Acreage	
	Coef.	p-value	Coef.	p-value	Coef.	p-value
Lag acreage	0.780238	<0.001	0.752012	<0.001	0.208297	0.066
Lag price (cotton)	393,328	0.053	-69,754	0.070	-436,848	0.019
Lag price (corn)	-19,228	0.886	-50,312	0.031	-187,453	0.108
Lag price (sorghum)	-23,992	0.877	70,472	0.009	266,554	0.048
Constant	158,926	0.322	26,996	0.155	213,154	0.028

Conclusions

This study analyzed irrigated acreage trends for cotton, corn, and grain sorghum over time in the Texas SHP and the driving factors that influence crop choices. The irrigated acreages planted to all three crops showed a negative trend through time. On average, corn and grain sorghum acreages decreased by 1,700 and 2,400 acres per year, respectively, while cotton acreage decreased by only 230 acres per year. This may be indicative of the fact that producers are moving away from irrigated crop production as water availability decreases. The lower decline in irrigated cotton acreage may be due to the ability of cotton to perform well under deficit irrigation.

In general, the lag acreage and the lag price of each crop were significant drivers of irrigated planted acreage of that crop. The lag acreage of all crops significantly influenced its own planted acreage, indicating the influence of fixed resources and technical knowledge about the specific crop. The lag prices of cotton and grain sorghum significantly and positively influenced the planted acreage indicating the rational expectation of the producer to consider current prices as indicators of expected prices next season (Muth, 1961). However, corn acreage was negatively influenced by its lag price and positively influenced by sorghum lag price. This may have happened because of the close association between corn and grain sorghum prices. Moreover, the coefficient estimate of sorghum lag price (70,472) was much higher than that of corn lag price (-50,312) in absolute value, leading to a net positive response of corn acreage to lag grain prices.

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