AGRICULTURAL LAND USE CHANGE IN THE US COTTON BELT

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Abstract

Over 20% of the world's cotton is produced in 17 southern states in the US, collectively known as the Cotton Belt. Corn and grain sorghum are two of the major summer row crops competing with cotton for acreage in the region. There are spatial and temporal variations in agricultural land use in this region driven by ecological, and economic factors, and government policies. The objective of this study was to identify and quantify the factors influencing acreage distribution among the major crops in the region. Historic data on irrigated and dryland acreages of cotton, corn, and grain sorghum by county from 1972 to 2015 was used to estimate the model. Regression equations were developed for each crop with its planted acreage as the dependent variable and year, lag acreage of that crop, the lag fiber:grain price ratio, and dummy variables for years each farm bill was in effect as explanatory variables. Iterative Seemingly Unrelated Regression (SUR) was used to simultaneously estimate these equations. The results showed that year, lag acreage of the crop, lag fiber:grain price ratio, and the Farm Bills had significant impact on the acreage planted to cotton, corn, and grain sorghum.

Introduction

Land use changes extensively with time and location as it is influenced by both natural forces and anthropogenic factors (Anthrop, 2005). The spatial variability in agricultural land use is due to variability in soil characteristics, irrigation water availability, and climatic conditions (mainly quantity and distribution of rainfall). There are temporal variations in agricultural land use mainly driven by ecological and socio-economic factors and government policies. Land use decisions are a result of the interaction between human environment, physical environment, land owner's decision making process, and ecological processes making it a complex procedure to model (Reibsame et al., 1994). However, we can consider land use in a region as the aggregate of the choices of individual decision makers as they respond to bio-physical attributes of the land according to the socio-cultural conditions to maximize their economic and socio-cultural wellbeing. Hence, land use change is usually modeled as a function of these driving forces (Verburg et al., 2004).

The US is the third largest cotton producer in the world behind India and China (FAOSTAT, 2017). Over 20% of the world's cotton is produced in 17 southern states in the US, collectively known as the Cotton Belt. This geographic area plays a major role in maintaining the top status of the US in cotton production. Even though considerable productivity gains have occurred for cotton and other crops over time (USDA NASS, 2017), planted acreage plays a major role in total production. For example, total upland cotton acreage planted in the US between 1970 and 2016 ranged from 7.86 million acres in 1983 to 16.72 million acres in 1995 with a standard deviation of 2.05 million acres (USDA NASS, 2017).

Corn and grain sorghum are two of the major summer row crops competing with cotton for acreage in the region. There is considerable year-to-year variability in acres planted to cotton, corn, and grain sorghum in the US and in the Cotton Belt. The high variability has profound impact on production and price volatility. Hence, it is very important to identify the driving forces that influence the land allocated to these crops and to quantify the impact of these driving forces on acreage allocation among these crops. Therefore, the objective of this study was to identify and quantify the factors influencing acreage distribution among the major crops in the region.

Materials and Methods

Data

Data for irrigated acreage planted to upland cotton, corn, and grain sorghum were collected by NASS districts for the 17 states in the US Cotton Belt (Alabama, Arizona, Arkansas, California, Florida, Georgia, Kansas, Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia) from 1972 to 2015 (USDA-NASS, 2017). Prices received by farmers for cotton ($/lb) and corn ($/bu) were also collected from 1972 to 2015 (USDA-NASS, 2017) for each of these states. We also collected data on which farm bill was in effect during this period.

Empirical Model

The Cotton Belt has considerable acreage planted to corn and grain sorghum. Therefore, cotton, corn, and grain sorghum compete for the same surface area during the same growing season. We hypothesized that the lag-acreage of a crop is a predictor of the planted acreage because of suitability of land, technical knowhow of the producer, and resource fixity. We also hypothesized that a potential driver of the acreage choice is the relative price of fiber (cotton) with respect to the grains. Since corn and grain sorghum prices exhibits similar pattern, we calculated the fiber:grain price ratio as the ratio of cotton price ($/lb) to corn price ($/bu). The lag of fiber:grain price ratio was used as a proxy for producer's expectation of the relative prices. Time trend (year) and dummy variables for the years a farm bill was in effect were other explanatory variables. Commodity prices were generally well above the target prices set during 2008 Farm Bill resulting in no government payments. Hence, the 2008 Farm Bill was used as baseline and excluded from the 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 the above-described explanatory variables. This resulted in the following three regression equations.

$$Acr_{Cot} = \beta_0 + \beta_1 Yr + \beta_2 LAcr_{Cot} + \beta_3 LPR + \beta_4 FB73 + \beta_5 FB77 + \beta_6 FB81 + \beta_7 FB85 + \beta_8 FB90 + \beta_8 FB96 + \beta_8 FB02 + \beta_8 FB14 + \varepsilon$$

$$Acr_{Corn} = \beta_0 + \beta_1 Yr + \beta_2 LAcr_{Corn} + \beta_3 LPR + \beta_4 FB73 + \beta_5 FB77 + \beta_6 FB81 + \beta_7 FB85 + \beta_8 FB90 + \beta_8 FB96 + \beta_8 FB02 + \beta_8 FB14 + \varepsilon$$

$$Acr_{Sor} = \beta_0 + \beta_1 Yr + \beta_2 LAcr_{Sor} + \beta_3 LPR + \beta_4 FB73 + \beta_5 FB77 + \beta_6 FB81 + \beta_7 FB85 + \beta_8 FB90 + \beta_8 FB96 + \beta_8 FB02 + \beta_8 FB14 + \varepsilon$$

where Acr_{Cot}, Acr_{Corn}, and Acr_{Sor}, are the irrigated acreage planted to cotton, corn, and grain sorghum, respectively. *Yr* is the year and *LPR* is the lag fiber:grain price ratio. $LAcr_{Cot}$, $LAcr_{Corn}$, and $LAcr_{Sor}$, are the lag irrigated acreage planted to cotton, corn, and grain sorghum, respectively. *FB73, FB77, FB81, FB85, FB90, FB96, FB02,* and *FB14* are the years in which Farm Bills of 1973, 1977, 1981, 1985, 1990, 1996, 2002, and 2014 were in effect, respectively. The βs are the coefficient estimates and ε is the error term.

Since these three crops compete for the same piece of land, change in acreage of one crop will likely influence the acreage of the other crops. This creates correlation between the error terms of the three individual equations. Therefore, these three equations were simultaneously estimated using the 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). Since correlation between errors is a realistic assumption in this model, SUR is more efficient than OLS in this case (Greene, 2008).

Results and Discussion

The trend in irrigated upland cotton acreage in the top five US states and the national total is presented in Figure 1. There is considerable year-to-year variability in planted acreage of cotton in the US and these states. Texas accounts for approximately half of US upland cotton acreage in most years, and appears to drive national acreage (Figure 1).

The results of the SUR regression analysis for the three crop acreage equations is presented in Table 1. High R^2 values indicate that the explanatory variables in the model were good predictors of agricultural land use change in the region.

Table 1. Results of SUR regression analysis for crop acreage equations.

Equation	No. of obs.	No. of par.	RMSE	R square	Chi Square	P value
Cotton acreage	2278	11	56,566	0.9792	111,964	<0.001
Corn acreage	2278	11	34,370	0.9419	37,703	<0.001
Sorghum acreage	2278	11	69,104	0.8255	11,016	<0.001

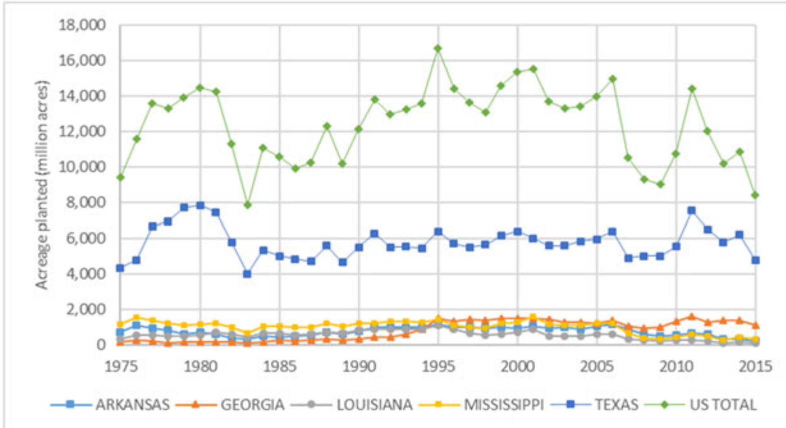

Figure 1. Upland cotton acreage in top five US states and national total from 1975-2015.

The coefficient estimates for the explanatory variables for the three equations are presented in Table 2. Though year-to-year fluctuations occurred in acres planted to each crop, acreage increased for all three over the study period. The average annual increase in planted acreage was 2,351, 2,757, and 2,156 acres for cotton, corn, and grain sorghum, respectively. This positive time trend in planted acreage is possibly attributable to land released from the Conservation Reserve Program (CRP).

Table 2. Coefficient estimates of the regression equations.

Variable	Cotton Acreage		Corn Acreage		Sorghum Acreage	
	Coef.	P value	Coef.	P value	Coef.	P value
Year	2,756.89	0.001	2350.51	<0.001	2156.24	0.039
Lag acreage	0.99	<0.001	0.97	<0.001	0.86	<0.001
Lag F:G price ratio	337,557.20	<0.001	-202314.20	<0.001	-187167.00	<0.001
Farm Bill 1973	92,238.15	0.002	106107.00	<0.001	71765.26	0.051
Farm Bill 1977	61,953.24	0.025	84569.80	<0.001	74991.99	0.026
Farm Bill 1981	52,588.03	0.028	72246.36	<0.001	64871.91	0.027
Farm Bill 1985	37,709.18	0.069	69662.86	<0.001	48344.19	0.057
Farm Bill 1990	32,964.15	0.050	60429.77	<0.001	44584.33	0.030
Farm Bill 1996	6,310.80	0.620	45866.51	<0.001	37745.98	0.015
Farm Bill 2002	-2,482.76	0.767	31273.88	<0.001	7513.65	0.464
Farm Bill 2014	-39,780.85	0.001	-33569.84	<0.001	-5209.39	0.718

Lag acreage significantly and positively influenced planted acreage of all three crops, indicating resource fixity. The coefficient for lag acreage was the highest for cotton, possibly because of the specialized harvesting equipment required for it.

The lag fiber:grain price ratio significantly influenced the planted acreage of all crops. High lag fiber:grain price ratio (i.e., higher expected cotton price relative to the grain price) positively influenced cotton planted acreage. When a decrease in the lag fiber:grain price ratio (i.e., higher price expectation for the grain crops compared to cotton) occurred, the planted acreages of corn and grain sorghum increased.

Various farm bills also influenced acres planted to all three crops. Significant acreage expansion occurred as a result of the 1973 Farm Bill under Secretary Butz. Passage of the 2014 Farm Bill significantly reduced cotton acreage as expected due to the elimination of the cotton support program. Corn acreage planted also showed a significant decrease during this period possible due to changes in the renewable fuel standards. Though not shown in this study, it is likely that corn (and to some degree cotton) acreage was replaced by peanuts, which will be addressed in future research.

Summary

This study analyzed irrigated acreage trends for cotton, corn, and grain sorghum over time in the US Cotton Belt and the driving factors that influence crop choices by producers. The irrigated acreages planted to all three crops showed a positive trend through time. On average, the yearly increase in planted acreage to cotton, corn, and grain sorghum was 2,351, 2,757, and 2,156 acres/year, respectively. The lag acreage of each crop were significant drivers of acreage of that crop. This could be due to suitability of land, technical knowhow about the crop, and design of farm programs. Some researchers argue that the possession of fixed resources to run an enterprise can be the reason for the positive influence of lag acreage on planted acreage (Nelson, Braden, and Roh, 1986).

The lag fiber:grain price ratio significantly influence the acreage planted of all three crops. As expected, the lag fiber:grain price ratio had a positive influence on cotton acreage planted and a negative influence on the planted acreages of corn and grain sorghum. This shows that the lag price provides a good proxy for the price expectation enforcing the rational expectation theory (Muth, 1961).

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