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ABSTRACT

Commodity programs for agriculture are intended to provide farm income stability and maintain desirable efficiencies that derive from market based outcomes. A measure of economic efficiency is producer response to market signals. This research measures acreage response of Arkansas field crops that are associated with changes in the U.S. stocks-to-use ratio. Results of this analysis indicate that stocks-to-use is a significant determinant of acreage decisions in Arkansas. The results of the current research indicate that agricultural policies historically establishing price floors have not undermined market response to supply and demand conditions.

Stocks-to-Use Response for Acreage Allocation of Arkansas Field Crops

By Archie Flanders

Commodity programs for agriculture have a dual challenge of addressing public policy objectives of farm income stability and maintaining desirable efficiencies that derive from market based outcomes. Economic theories and historical experience suggest potential conflicts with simultaneous motivations of distributional equity and allocation efficiencies. Theories of public finance and social welfare analysis allow for achieving acceptable levels of distributional equity with public policies that minimize inefficiencies which are inevitable with deviations from market based absolutism. One measure of economic efficiency is producer response to market signals. A measure of distributional equity is the level of income support relative to costs of production.



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U.S. agricultural policy is established by periodic legislation that historically has persisted for approximately five years. Public policy to support agricultural income has attempted to achieve goals of sector equity by establishing price supports at levels guaranteeing gross revenue at satisfactory levels relative to production costs. Income support has established price floors at levels to maintain production stability rather than at levels that incentivize increased production. With the global adoption of public support in agricultural production (Hudson et al., 2009), national governments must evaluate their policies with criteria of remaining competitive while maintaining a desirable level of market efficiency.

The objective of this research is to quantify Arkansas field crop acreage response to signals conveyed by supply and demand equilibrium conditions. Agricultural programs for field crops in the U.S. have a national scope as opposed to having specific policies directed at unique regional production characteristics. Empirical analysis at a state level indicates effects for a region with unique production characteristics operating under public policy with national objectives. Economically efficient responses are state acreage increases as producers follow national signals of decreasing supply relative to demand and state acreage decreases as national supply is increasing relative to demand.

Literature Review and Related Research

Previous research devoted to price response of field crop acreage has either been aggregated at the regional level or has included specified states. Past analyses of acreage response have tended to use

aggregate, time series data for one geographical unit (Duffy, Richardson, and Wohlgenant, 1987; Chavas & Holt, 1990; Ahouissoussi, McIntosh and Wetzstein, 1995; Parrot & McIntosh, 1996; Houston et al., 1999), or panel data using seemingly unrelated regressions (SUR) (Lin & Dismukes, 2007; Liang et al., 2011).

Houston et al. (1999) developed a structural decision model to identify cotton acreage indicators and to forecast plantings in the Southeast U.S. The objective of the analysis was to identify indicators for forecasting Southeastern acreage so that farmers and agribusiness suppliers could respond more efficiently to changes in cotton production and marketing. Cotton price, as well as loan rate and the presence of deficiency payment programs, were significant explanatory variables for cotton acreage in the structural decision model. The results yielded an estimated price elasticity of 1.26 for the 1991-1996. Prices of corn and soybeans as competing crops were not statistically significant indicators for cotton acreage.

Parrot and McIntosh (1996) applied an adaptive regression model which allowed parameter estimates to vary from period to period in time series data for Georgia cotton acreage during 1950-1990. The methodology permitted a detailed analysis of how price expectations have changed over time for cash prices and government programs. Results included cash own-price elasticities that were both greater than unitary and less than unitary for years included in the study period. Cotton acreage was found to be much more responsive to cash price than cotton support prices from government programs.

The average own-price elasticity for cotton acreage was 152 percent greater than the absolute value of soybean cross-price elasticity.

Duffy, Richardson, and Wohlgenant (1987) investigated cotton acreage response for four distinct production regions in the United States during 1959-1983. The research determined acreage response for use in evaluating the effects of potential farm program changes or changes in market prices relative to effective support prices. The own-price variable used in the study is a combination of expected market price and government policy variables. A pooled long-run cotton price elasticity of 0.64 was reported. Competing crop prices had statistically significant effects on cotton acreage in two of the four regions. A partial adjustment approach was hypothesized in recognition of the short-run expense entailed with switching out of (or into) cotton production due primarily to the specialized nature of harvesting equipment. The econometric model applied an instrumental variable for the lagged dependent variable to correct for both autocorrelation and contemporaneous correlation in a Seemingly Unrelated Regression application.

Soybean price elasticities were estimated for Georgia acreage response by Ahouissoussi, McIntosh, and Wetzstein (1995). The study attempted to assess the impact of policies for biodiesel made from soybeans. A general method of moments model was applied to time series data for 1951-1990. Corn was found to be a complement for soybean land use. A long-run own-price elasticity for soybeans of 1.205 compares to a cross-price elasticity of 1.819 for corn and -2.113 for wheat.

Other acreage response research applies an expected utility approach. Liang et al. (2011) investigated Southeastern corn, cotton, and soybean acreage response with a seemingly unrelated regression model for 1991-2007. Results indicate that cotton acreage decisions in the Southeast are inelastic. Effects of risk in cotton acreage decisions were mixed with no statistical significance in a linear acreage model and statistical significance in an acreage share model. Lin and Dismukes (2006) apply a system of seemingly unrelated regressions to major field crops in the North Central Region with data for 1991-2001. The objective was to investigate the role of risk in acreage allocations and to examine counter-cyclical payments (CCP) in farmers' acreage decisions. Results suggest that the effects of risk in acreage decisions are not strong. CCP have negligible short-run impacts on production. The authors conclude that CCP may have long-run structural implications to the extent that these payments keep farmers in business. Chavas and Holt (1990) estimate a seemingly unrelated regression model for U.S. corn and soybean acreage with time-series data for 1954-1985. The empirical results indicate that risk is an important consideration in corn-soybean acreage decisions.

Methodology for Acreage Response Analysis

Market equilibrium for field crops requires that:

$$1) \quad S_t - D_t - K_t = 0,$$

where S_t is supply, D_t is demand, and K_t represents the level of commodity stocks in period t . Each variable in equation (1) is a function of prevailing market price, p_t . In addition, supply is determined

by acreage, available production technology, and stochastic factors such as environmental conditions. Each month the World Agricultural Outlook Board reports projected supply, demand, and ending stocks for field crops (USDA, OCE, 2013). Information in these reports indicate market conditions that determine commodity prices in the current period, p_t , as well as expected prices in the subsequent period, p_{t+1} .

Orderly marketing of field crops requires an adequate carryover from one period into the subsequent period so that adequate supply is available until new production is harvested in the current marketing year. Projected ending stocks in the current period are beginning stocks in the subsequent period, and commodity industries develop expectations for optimal levels of stocks. Optimal stocks are commonly referred to as quantity relative to total annual usage, K/D , the stocks-to-use ratio.

Producers make crop acreage decisions with information that is inherent in equation (1). Expected prices reflect market conditions so that production adjusts to maintain an optimal stocks-to-use ratio, K/D . Equilibrium market conditions lead to optimal production in period $t+1$ adjusting, as indicated by the change operator, Δ , such that:

$$2) \quad K_t/D_t + \Delta K_{t+1}/\Delta D_{t+1} = K/D.$$

For crops planted in the spring of each year, producers have market information that is determined by projected ending stocks reported for the previous marketing year. For example, corn

planted in April of 2012 will be reported as data for the 2012 marketing year. Information for projected ending stocks that represents market conditions at the time of 2012 planting is for the 2011 marketing year that is October 2011 through September 2012. Optimal acreage allocations in 2012 are associated with supply adjustments corresponding to projected stocks-to-use in 2011 that satisfies equation (2). Equilibrium in equation (2) depends upon producers observing the market information contained in K/D , as well as the correspondence of projected K_t/D_t and final K_t/D_t . In Arkansas, all wheat production is winter wheat that is planted in the fall of each year. The wheat marketing year is June to May of each year, and there is no overlap between marketing years for Arkansas planting decisions and market information contained in the stocks-to-use ratio. In general, equilibrium in equation (1) is achieved by satisfying equation (2) with acreage allocations, A_t , leading to S_t such that:

$$3) \quad A_t = a(K_{t-1}/D_{t-1})$$

results in $K_t/D_t = K/D$.

Equation 3 is a basic model to account for the correlation of acreage allocation and equilibrium supply and demand. Additional explanatory variables account for observed characteristics in aggregate acreage data. Figure 1 shows that total Arkansas spring planted crop acreage is stable at approximately six million acres during 1980-2012. However, individual crops in Appendix 1 through Appendix 6, including winter wheat, exhibit trends, and adding a time trend variable to the acreage allocation equation accounts for this.

Some crops have increasing trends during 1980-2012, and other crops have decreasing trends. This indicates acreage transition as farmers switch acreage allocations while total acreage is constant. Consider equation (3) representing corn acreage. A variable representing changes in other crops accounts for acreage transitions that affect corn acreage. For example, let A_t equal corn acreage in period t . Other acreage is the sum of other spring planted crops (cotton, grain sorghum, soybeans, and rice) that may be substituted for corn acreage. The transitional variable for other acreage, OA_t , is the sum of other acreage in period t divided by the sum of other acreage in period $t-1$.

Agricultural management practices often entail a degree of inertia in acreage allocations. Optimal management follows crop rotations that limit continuous cropping, and producers do not completely switch out of one crop into another based on current market conditions. Market conditions are incentives to make marginal adjustments in crop allocations, and the marginal transitions may continue over more than one year in correspondence to prevailing market conditions. Also, some crops have specialized equipment requirements that limit annual acreage changes. Circumstances in which changes in market conditions are prevalent for an extended period may necessitate more than one year for producers to fully respond. Thus, a lagged acreage variable, A_{t-1} , is added to equation (3) to account for allocations following K/T that require more than one period for equilibrium adjustment.

A complete econometric model representing the correlation of crop acreage planted and the stocks-to-use ratio is:

$$4) A_t = \beta_0 + \beta_1(K_{t-1}/D_{t-1}) + \beta_2 T_t + \beta_3 OA_t + \beta_4 A_{t-1} + \varepsilon_t \\ t = 1980 \dots 2012,$$

where T is a time trend, and ε is a random disturbance term that has 0 mean and is assumed uncorrelated with the independent variables. Occurrences such as droughts represent shocks to equilibrium relationships and are captured by the random error term. Ordinary Least Squares (OLS) is applied for parameter estimates of β_0 , β_1 , β_2 , β_3 , and β_4 in equation (4). A potential violation of OLS assumptions is that the random disturbance term is serially correlated, in which case OLS parameter estimates are unbiased, but may overstate the statistical significance (Gujarati & Porter, 2009). Serial correlation is evaluated by Durbin-Watson statistics and, if present, appropriate Yule-Walker estimates are reported (SAS, 2013).

Arkansas agricultural production was subject to numerous programs of public policy during 1980-2012. Parameter estimates in equation (4) represent long-term equilibrium relationships for determinants of acreage response over varying policies. In addition to policies of price support, U.S. public policy potentially increased incentives for acreage in grains through the 2006 ethanol mandate. The acreage response model implies that an increased demand for corn will correspond to an adjustment in acreage that will maintain stocks-to-use at an equilibrium level.

Inclusion of a lagged dependent variable as an explanatory variable presents a situation that violates assumptions of OLS application. The lagged dependent variable is correlated with the disturbance term of equation (4), and parameter

estimates are not unbiased. In time series data, the disturbance term in period t is correlated to some degree with the disturbance term in period $t-1$. In turn, the disturbance term in period $t-1$ is a determinant of the dependent variable in period $t-1$. Thus, an explanatory variable in period t , the lagged dependent variable, is correlated with the disturbance term in period t . The instrumental variable (IV) procedure produces asymptotically unbiased estimates in a situation in which an explanatory variable is correlated with the random disturbance. IV estimation is a two-step procedure where equation (4) is estimated without the lagged dependent variable. The resulting parameter estimates are applied to form predictions for the lagged dependent variable. Equation (4) is then estimated with predicted values of the lagged dependent variable as an explanatory variable (Kennedy, 2001).

Crop acreage is annual data reported for 1981-2012 by the National Agricultural Statistics Service (USDA, NASS, 2013). Annual U.S. stocks-to-use are calculated as the ratio of 1980-2011 ending stocks to the sum of total domestic consumption and marketing year exports (USDA, FAS, 2013). Data values are lagged one year to calculate an instrumental variable for lagged acreage as an explanatory variable. Applying data for acreage and stocks-to-use with a logarithmic specification scales data so that parameter estimates represent proportional changes for the time series. As a result of the double log specification, parameters are elasticity measures. Specification of a logarithmic functional form is consistent with optimal output occurring at levels where production is increasing at a decreasing rate.

Results

Parameter estimates for equation (4) are presented in Table 1. Stocks-to-use has a negative correlation with planted acreage for all crops, and is statistically significant for all crops except grain sorghum. Grain sorghum has limited marketing opportunities in Arkansas, and acreage declines are primarily explained as shifts to more profitable crops as total irrigated crop acreage is increasing in the state. Wheat is the crop most responsive to stocks-to-use levels with a parameter estimate of -0.5170. Winter wheat is double-cropped with soybeans in Arkansas and represents a complimentary cropping choice, rather than a crop selection that substitutes for an alternative crop. Farmers choose to plant wheat when market conditions, as determined by the stocks-to-use ratio, are most favorable. Although statistically significant, the stocks-to-use parameter estimate for soybeans is relatively low compared to other crops. Arkansas has much crop acreage that is characterized as a heavy clay soil type. This acreage is most suited for a crop rotation of soybeans and rice, and not optimal for corn or cotton. Soybean acreage serves as a complimentary crop for rice production, which is much less suited for continuous cropping than is soybean production.

The trend variable is statistically significant for corn, soybeans, and wheat. Corn acreage is trending with a positive parameter estimate (0.0234), but soybeans (-0.0052) and wheat (-0.0331) have negative trends. The long-term trend for corn acreage in Appendix 1 is mostly attributable to increased irrigation in Arkansas with acreage increases since 2006 being impacted by relative increases in corn prices. Soybeans with a wheat double-crop are

suitable for non-irrigated production, but corn as an alternative becomes more preferable as producers add irrigated acreage to their operations. Corn is an earlier planted crop, and the conclusion of its production period can limit irrigation pumping demands for farms needing water to flood rice and irrigate later planted soybeans. Corn production enables producers to spread water demand over an extended period of the crop year. Appendix 7 presents irrigated acreage for Arkansas compared to the entire United States and indicates the relative importance of irrigation for Arkansas field crop production (USDA, FSA, 2013). The parameter estimate for other acreage is negative and statistically significant only for corn. This is further evidence that increasing corn acreage in Appendix 1 is attributable to decreased acreage of other crops.

The lagged dependent variable is positive and statistically significant for cotton and rice. This indicates that it takes more than one period for cotton and rice acreage to respond to market conditions entailed in the current stocks-to-use ratio. Cotton has specialized harvesting equipment that causes difficulties in adding acreage when market conditions are favorable. Likewise, operations that are adequately invested in cotton harvesting equipment may have financial constraints to add additional harvesting equipment for increased acreage of other crops. Also, not entailed in market conditions expressed by the stocks-to-use ratio, the residual value of cottonseed revenue returned after ginning may be an inducement for producers to produce cotton. Rice has some specialized agronomic characteristics that could lead to acreage adjustments extending

over more than one crop year. Optimal rice yield is limited by continuous cropping, and producers are encouraged to change fields for their production regularly, but changing total rice acreage is limited by agronomic considerations.

Table 2 presents a summary of Arkansas acreage changes due to the U.S. stocks-to-use ratio. The relevant parameter estimate for grain sorghum is not statistically significant, and it is omitted. Stocks-to-use are subject to much volatility as the average annual change, on a percentage basis, ranges from a low of 39.1 percent for soybeans and a high of 67.1 percent for corn. Soybean acreage has the greatest average annual acreage during 1980-2012 with 3.414 million acres. Multiplying the annual soybean stocks-to-use change by the parameter estimate produces a factor that is applied to 3.414 million acres and results in an average annual acreage change of 119,000 acres. This is 3.5 percent of average annual soybean acreage. Wheat has the greatest average acreage change with 203,000 acres, or 20.6 percent of average acreage. Rice has an average annual acreage change of 133,000 acres which is 9.8 percent of average annual acreage.

Summary

Assessing the stocks-to-use ratio is important in evaluating market conditions for field crop production. This measure is a determinant of supply and demand conditions that affect commodity prices and farm profitability. Forward pricing opportunities and commodity futures prices are entailed in the stocks-to-use ratio. While producers likely seek more direct sources for market information, understanding of supply and

conditions can assist agricultural stakeholders in production decisions.

Results of this analysis indicate that stocks-to-use is a significant determinant of acreage decisions in Arkansas. Changes in stocks-to-use are associated with acreage changes in responses that maintain equilibrium of U.S. supply and demand. Wheat acreage is highly optional as an alternative in Arkansas cropping decisions, and it is the most responsive to changes in stock-to-use ratios. Soybeans are more fundamental in Arkansas crop production, especially due to the significant acreage of heavy clay soils in the state, and it is the least responsive to changes in the stocks-to-use ratio. Corn acreage is highly responsive to changes in the stocks-to-use ratio, but acreage is increasing with

a significant trend as total irrigated crop acreage is increasing. Cotton and rice are responsive to changes in stocks-to-use, but the effects are extended over more than one production year.

This research evaluated Arkansas field crops on an individual basis. Future research could expand the current results by simultaneously analyzing crops in relation to each respective stocks-to-use ratio. The results of the current research indicate that agricultural policies historically establishing price floors have not undermined market response to supply and demand conditions. Future research could include regional and national production to further evaluate the impacts of agricultural policy with a larger scope.

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Table 1. Ordinary Least Squares¹ Results for Arkansas Acreage Response, 1981-2012

Explanatory Variable	Corn	¹ Cotton	¹ Grain Sorghum	Rice	¹ Soybean	¹ Wheat
Intercept	** 1.6586	1.0215	5.1167	** 1.6630	** 3.7398	** 6.2088
t-value	2.6100	1.0600	1.1300	2.3500	3.0300	2.9000
Prob > t	0.0146	0.3000	0.2706	0.0264	0.0055	0.0074
Stocks : Use	** -0.2862	** -0.1715	-0.0725	** -0.1550	** -0.0891	** -0.5170
t-value	-2.5500	-2.7300	-0.4600	-3.0900	-2.8500	-2.4000
Prob > t	0.0166	0.0113	0.6463	0.0046	0.0085	0.0238
Trend	* 0.0234	0.0002	-0.0520	0.0004	** -0.0052	** -0.0331
t-value	1.8700	0.0600	-1.1200	0.3600	-2.9600	-2.7300
Prob > t	0.0720	0.9554	0.2724	0.7222	0.0065	0.0110
Other Acreage	* -1.7762	0.1310	-0.4919	-0.5254	-0.1037	NA
t-value	-1.9000	0.2800	-0.3100	-1.6800	-1.4000	NA
Prob > t	0.0677	0.7824	0.7567	0.1038	0.1738	NA
Acreage Lag	0.2245	** 0.7271	-0.8110	** 0.5285	-0.0081	-0.6568
t-value	0.6300	2.1100	-0.4900	2.4400	-0.0200	-1.0900
Prob > t	0.5340	0.0447	0.6251	0.0214	0.9813	0.2847
R ²	0.9148	0.8226	0.7083	0.7130	0.7670	0.6111
Durbin-Watson	1.6074	1.3209	1.4166	2.1270	1.5320	1.8734

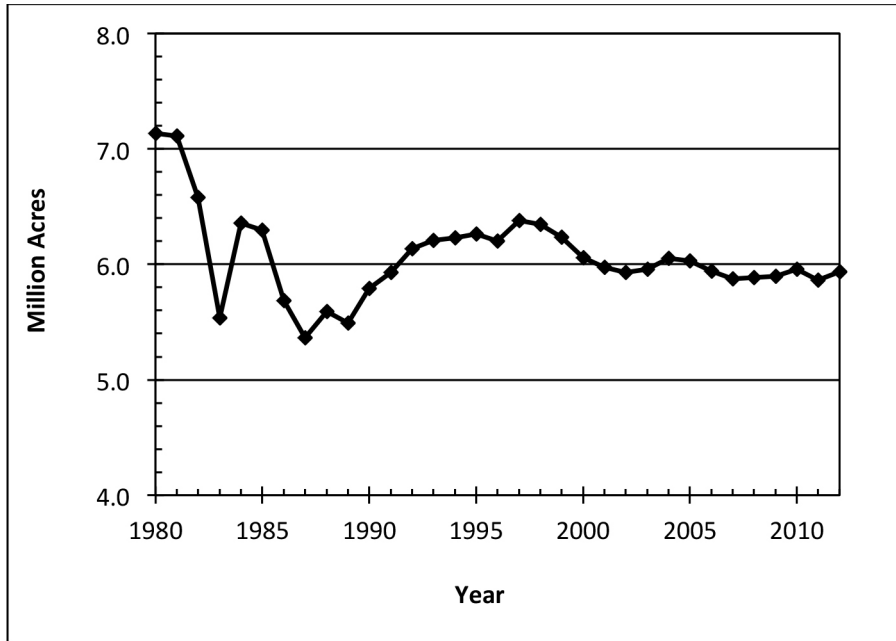
¹Yule-Walker estimates reported based on OLS Durbin-Watson statistics.

Note: ** Significant at 5%; * significant at 10%.

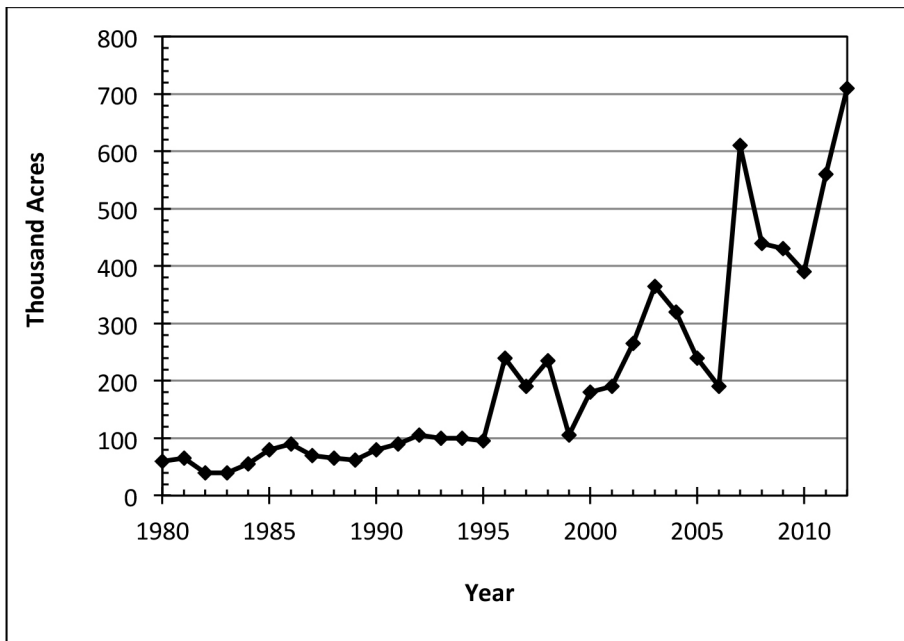
Table 2. Arkansas Planted Acreage Change due to U.S. Stocks : Use Ratio, Arkansas, 1981-2012

	Corn	Cotton	Rice	Soybean	Wheat
Average Annual Change (%), K/D	67.1	47.6	63.2	39.1	39.8
Parameter Estimate, K/D and Acreage	-0.2862	-0.1715	-0.1550	-0.0891	-0.5170
Average Acreage (1,000)	212	792	1,354	3,414	988
Average Acreage Change (1,000)	41	65	133	119	203
Acreage Change, % of Average	19.2	8.2	9.8	3.5	20.6

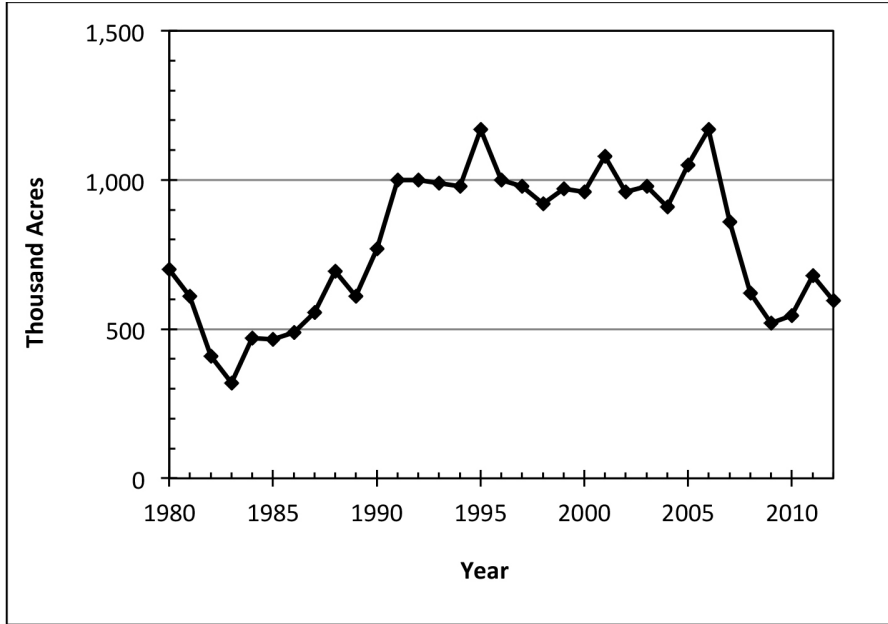
Figure 1. Total Spring Planted Acreage, Arkansas, 1980-2012



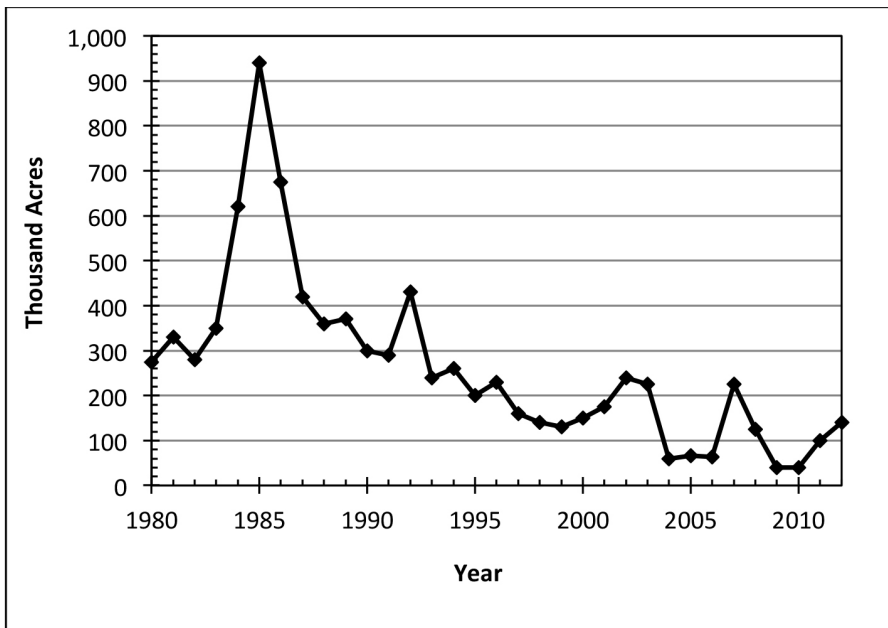
Appendix 1. Corn Acreage Planted, Arkansas, 1980-2012



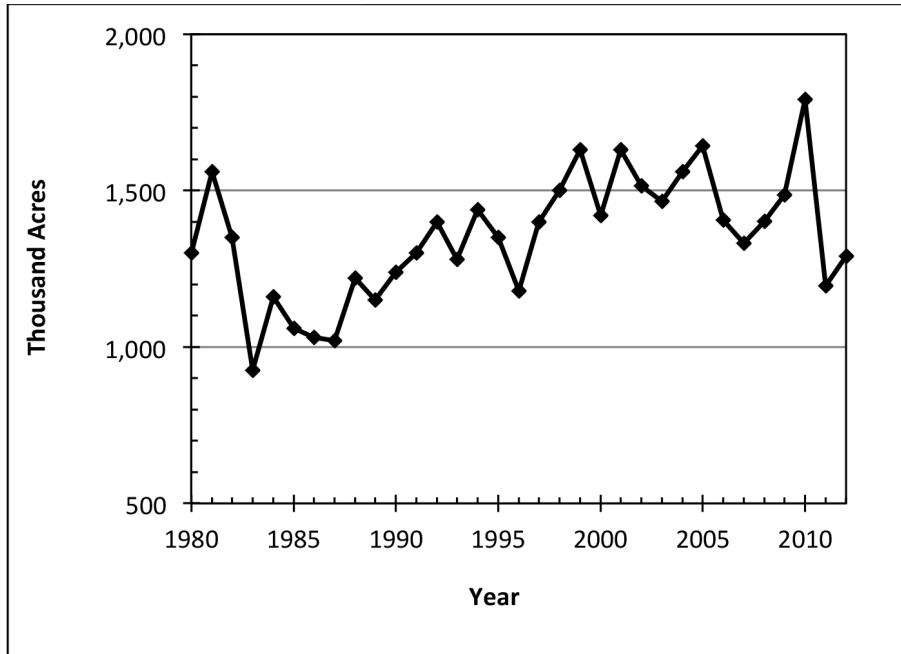
Appendix 2. Cotton Acreage Planted, Arkansas, 1980-2012



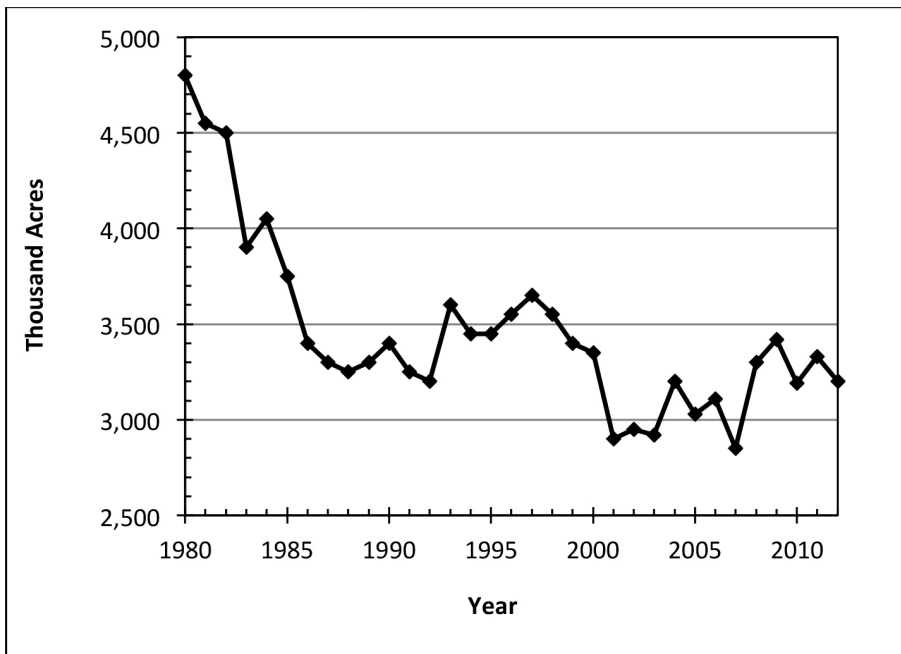
Appendix 3. Grain Sorghum Acreage Planted, Arkansas, 1980-2012



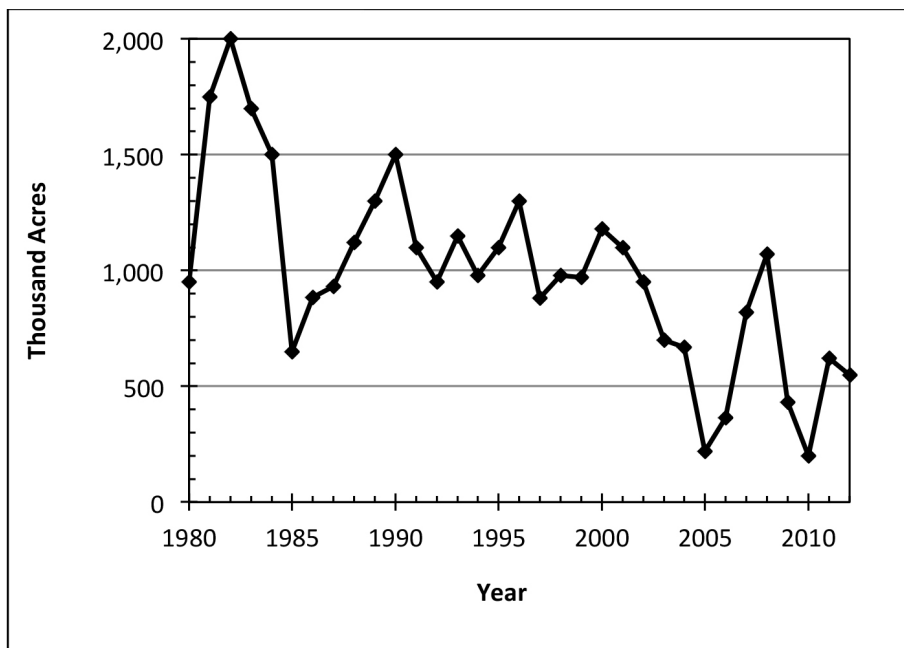
Appendix 4. Rice Acreage Planted, Arkansas, 1980-2012



Appendix 5. Soybean Acreage Planted, Arkansas, 1980-2012



Appendix 6. Winter Wheat Acreage Planted, Arkansas, 1980-2012



Appendix 7. Percent of Acreage Irrigated, Arkansas and U.S., 2012

