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ECONOMICS AND MARKETING

Panel Data Analysis of U.S. Cotton Yields for 2002-2011

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ABSTRACT

Technological innovation in agriculture allows increased production while maintaining inputs at sustainable levels. Cotton yield increases, an annual average of 2.5% from 2002-2011, have been accompanied by acreage decreases. This research develops an aggregate U.S. cotton yield model based upon relevant variables identified in previous research. Results indicate that yield increases are attributable to technology and are not only due to acreage shifts that leave more productive land in cotton production.

Increased crop yields are an indicator of technological innovation to agricultural production systems. That such innovation has occurred in cotton is indicated by the long-term increase in cotton yields in the U.S. since 1960. The increase has not been linear, however, exhibiting variable rates of increase interspersed with periods of stagnant and in some cases, declining yields. The most rapid period of yield increase began in 2002. National trends in crop yield increase are an aggregate of regional production trends which may be influenced by region specific factors. The inclusion of these regional factors in crop yield analyses could be important in understanding the trends.

Previous research related to crop yields has focused on weather, technology, and land as factors influencing crop yields. Weather variables affecting yield are typically precipitation and temperature, or an index that incorporates these factors. Technology is most often included in yield models as a trend with a specified functional form. Land factors affecting yields include considerations of either soil characteristics or acreage quantities.

Tannura, Irwin, and Good (2008) investigated the relationship between weather, technology, and corn and soybean yields in the U.S. Corn Belt. Analysis of multiple regression results showed that corn yields were particularly affected by technology, the magnitude of precipitation during June and July, and the magnitude of temperatures during July and August. The effect of temperatures during May and June appeared to be minimal. Soybean yields were most affected by technology and the magnitude of precipitation during June through August. Tests for structural change did not indicate a significant change in the technology trend for corn or soybeans since the mid-1990s.

Choi and Helmberger (1993) estimated the sensitivity of corn, wheat, and soybean yields to changes in price and land idled. Yields were found to be insensitive to price changes. The research did not find significant evidence that land idling programs significantly affect crop yields.

Foster and Babcock (1993) investigated how changes in federal tobacco policy affected levels and growth of flue-cured tobacco yields. The research used an index of available technologies that was derived from research-station data and that allowed distinguishing effects of new technologies and adoption decisions. The empirical results showed that tobacco yield levels and the responsiveness of yields to changes in available technology depend upon price effects of program design. Specifically, the 1965 drop in land rents and output price, resulting from the shift from acreage allotments to poundage quotas, decreased yield levels by 12 percent, In addition, the movement to poundage quotas decreased the responsiveness of yields to changes in available technology. These findings are consistent with the hypothesis that high land prices lead to high adoption rates of yield-increasing technologies. The growth of yields declined from an annual rate of 4.32 to 0.5 percent because of a change in relative prices and a slowdown in the rate of increase of available technologies.

Geigel and Sundquist (1984) reviewed the literature for models which develop specific relationships between climatic variables and crop yields. The authors found that most past modeling of crop yields had focused on short-term (intraseasonal) "weather" and not long-term "climatic" related variables. In order to fully explain changes in crop yields, these models have also tried to account for the impacts of changing production technologies.

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This research develops an aggregate U.S. cotton yield model based upon relevant variables identified in previous research. Figure 1 shows a distinctively large increase of Olympic cotton yield since 2002, and the research is limited to the 2002-2011 time period. Olympic yields are calculated as five-year moving averages after omitting the maximum and minimum yields. National yield is a result of production factors that have unique state characteristics, and data for the analysis is for upland cotton producing states. Cotton yields have been increasing at a time when cotton acreage has been decreasing. The objective of this research is to investigate the factors affecting U.S. cotton yields and to identify the extent to which acreage shifts have impacted yields.

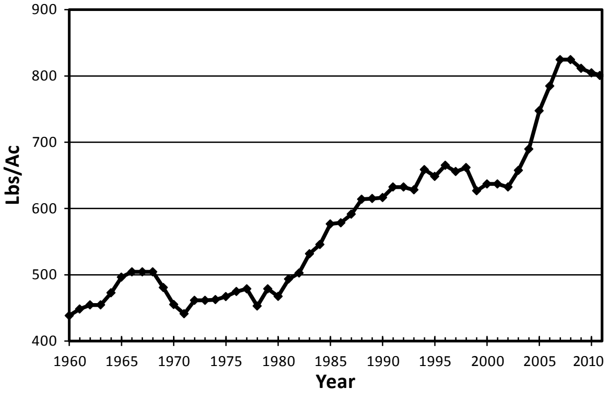

Figure 1. Olympic Average Cotton Yield, U.S., 1960-2011

MATERIALS & METHODS

Yield data for this analysis are aggregated state level data for states with upland cotton production reported by the National Agricultural Statistics Service (USDA, NASS, 2012). Data consist of upland cotton yields for 17 states included in NASS reports during 2002-2011. Panel data consisting of annual observations for upland cotton producing states increases degrees of freedom for statistical analysis as compared to either cross-sectional or time series data. Improved statistical efficiency with panel data is especially important for investigating conditions that are of short duration.

Table 1 presents average annual acreages and yields for states included in the analysis. During the study period, Texas planted 46% of total U.S. cotton acreage. Texas has a relatively high rate of abandonment and harvested 40% of total U.S. acreage. Yield variability represented by coefficient of variation averages 15% for all states. Yield variability is greatest in South Carolina and Virginia. Arizona and California have the highest average yields, as well as the lowest coefficient of variation for yield. Texas has relatively low yields, and averages 33% of total U.S. production.

Table 1. Average Acreage, Percent Abandonment, Yield, and Coefficient of Variation, Upland Cotton, by State, 2002-2011

State	Planted	Harvested	Abandonment	Abandonment	Yield	Yield
		Acres		*Percent*	*lbs./Acre*	*C.V.*
Alabama	**453,500**	**439,500**	**14,000**	**3.1**	**673**	**15.3**
Arizona	**202,730**	**200,910**	**1,820**	**0.9**	**1,416**	**6.7**
Arkansas	**829,500**	**813,000**	**16,500**	**2.0**	**984**	**9.7**
California	**506,700**	**502,700**	**4,000**	**0.8**	**1,394**	**9.1**
Florida	**94,000**	**90,100**	**3,900**	**4.1**	**704**	**18.4**
Georgia	**1,256,000**	**1,222,500**	**33,500**	**2.7**	**783**	**12.6**
Kansas	**69,500**	**62,100**	**7,400**	**10.6**	**599**	**19.1**
Louisiana	**420,500**	**405,300**	**15,200**	**3.6**	**840**	**15.6**
Mississippi	**821,000**	**808,000**	**13,000**	**1.6**	**896**	**11.3**
Missouri	**374,300**	**368,700**	**5,600**	**1.5**	**965**	**9.7**
New Mexico	**57,560**	**52,250**	**5,310**	**9.2**	**986**	**11.4**
North Carolina	**682,500**	**672,300**	**10,200**	**1.5**	**759**	**21.8**
Oklahoma	**242,500**	**182,500**	**60,000**	**24.7**	**692**	**15.2**
South Carolina	**222,600**	**210,300**	**12,300**	**5.5**	**731**	**26.4**
Tennessee	**498,000**	**486,200**	**11,800**	**2.4**	**820**	**13.1**
Texas	**5,761,090**	**4,375,460**	**1,385,630**	**24.1**	**655**	**15.5**
Virginia	**85,300**	**83,900**	**1,400**	**1.6**	**796**	**22.1**

Factors included as explanatory variables for cotton yields are acreage, percent abandonment, climate, and technology. Acreage is planted annual acreage in each state, and abandonment is planted acreage less harvested acreage. Developing a direct climate variable for the cotton production regions within each state is problematic due to the numerous weather variables that impact yield. A proxy variable is postulated to represent the yield effects of annual weather conditions for a crop with growing conditions similar to cotton. All 17 states produce corn, and a proxy variable for climate is developed using the annual percent of a normal corn yield to represent climatic factors impacting cotton yield. Data for this analysis are for all states with upland cotton production reported by the National Agricultural Statistics Service (USDA, NASS, 2012). Technology adoption is represented by a trend variable. This method of representing technology with a comprehensive trend variable encompasses improved yield potential of seed, seed biotechnology, increased irrigation, and all other technological enhancements available for cotton production. Producers make input decisions based on relative prices of commodities and inputs. Offutt, Garcia, and Pinar (1987) conclude that explicit economic factors do not contribute to explaining crop yields when a time trend is included to represent technology, and the technology variable accounts for relevant input considerations. The model for cotton yield is specified with a logarithmic functional form as:

$$\ln Yld_{it} = \beta_{1i} + \beta_2 \ln Ac_{it} + \beta_3 \ln Ab_{it} + \beta_4 \ln C_{it} + \beta_5 T_{it} + \varepsilon_{it},\ i = 1\ldots17;\ t = 2002\ldots2011$$

The dependent variable for econometric estimation is annual cotton yield for each state, Yld_{it}. Explanatory variables are planted acreage, Ac_{it}, percent of planted acreage abandoned, Ab_{it}, climate, C_{it}, and technology, T_{it} is a time trend applied to each state in the panel data model.

The random disturbance term, ε, has mean 0 and is assumed uncorrelated with the independent variables. Parameters β_1, β_2, β_3, β_4, and β_5 are to be estimated. Data for 17 states covering the 2002-2011 period results in 170 observations.

RESULTS

The model in equation (1) is specified so that unobservable effects represented by the intercept term are different for each state, but are time-invariant. Intercept terms are formulated as β_i for each state. The fixed effect intercept varies among the states. Intercepts account for unobservable effects in the model so that consistent parameter estimates can be obtained for the variables of primary interest in equation (1). The least squares dummy variable (LSDV) model is applied by treating one state as a reference and including dummy variables for the other sixteen states. The model intercept is the intercept for the reference state, which is Texas. Dummy variable coefficients represent the difference in intercept values for the other states and the reference state (Gujarati and Porter, 2009). The small number of annual observations presents difficulties in testing for autocorrelation within data for each state. It is assumed that there is no autocorrelation for the error terms associated with the short time series of each state panel. Table 2 shows the results of heteroscedasticity-consistent covariance matrix estimation for the model represented by equation (1).

Table 2. LSDV Regression Results for U.S. Cotton Yield

Variable	Coefficient^z	Std. Error	t Statistic	Prob. > |t|
Intercept	**7.239****	**0.428**	**16.930**	**<0.0001**
Acreage	**-0.120***	**0.050**	**-2.400**	**0.0174**
Abandonment	**-0.108****	**0.020**	**-5.470**	**<0.0001**
Climate	**0.345****	**0.073**	**4.700**	**<0.0001**
Trend	**0.012****	**0.003**	**3.630**	**0.0004**
R-Square		**0.8386**		
F Statistic for No Fixed Effects		**26.6100**		
Prob. > F		**<0.0001**		

^{z} Values followed by * and ** are significant at P<0.02 and P<0.001, respectively.

Regression results are presented in Table 2. R-square of the model is 0.8386, and all explanatory variables are statistically significant at a minimum confidence level of $P<0.02$. The parameter estimate of -0.120 for acreage indicates that during a period of declining acreage, producers have taken land with marginal productivity out of cotton. Decreases in cotton acreage have had a positive impact on yields. A negative coefficient of -0.108 for abandonment indicates an inverse relationship with abandonment and yield. Increases in abandonment indicate stress for the crop and is associated with decreased yield. The proxy variable for climate has a coefficient of 0.345, which indicates annual corn yields above average are positively correlated with increased cotton yields. A trend variable of 0.012 indicates that technology improvements, in isolation from other factors, have increased cotton yields an average of 1.2% per year during 2002-2011.

Increased cotton yields during a period of declining acreage presents the possibility that realized yield increases could be only due to acreage shifts. Producers could potentially remove the least productive acreage out of cotton production, which would result in higher yields. Results in Table 2 do not support a hypothesis that increased cotton yields are only the result of acreage shifts. Statistical significance for technology in Table 2 indicates that increased cotton yields are due to continued technological improvements during a period of decreasing acreage.

DISCUSSION

This research develops an aggregate U.S. cotton yield model based upon relevant variables identified in previous research. U.S. cotton yield increases during 2002-2011 have been accompanied by acreage decreases. National yield is a result of production factors that have unique state characteristics, and data for the analysis is for upland cotton producing states.

Results of this analysis are consistent with a negative correlation between cotton yields and acreage. A negative relationship with abandonment and yield is consistent with factors that lead to increased abandonment being associated with decreased yields. A proxy variable for climate is consistent with a positive relationship with weather and cotton yields as conditions improve for crop development. These three variables control the model for factors that are beyond the inherent capabilities of the prevailing production technology, and technological improvements have increased cotton yields an average of 1.2% per year during 2002-2011.

Increased cotton yields during a period of declining acreage presents the possibility that realized yield increases could be only due to acreage shifts. However, a complete model for cotton production indicates that yield increases are not due to acreage shifts that leave more productive land in cotton production.Conclusions are that technological improvements in the cotton production industry have contributed to increased cotton yields during 2002-2011.

REFERENCES

Choi, J.S. and P.G. Helmberger. 1993. How sensitive are crop yields to price changes and farm programs? J. Agr. and Applied Econ. 25:237-244.

Foster, W.E. and B.A. Babcock. 1993. Commodity policy, price incentives, and the growth in per-acre yields. J. Agr. and Applied Econ. 25:253-265.

Geigel, J.M. and W.B. Sandquist. 1984. A review and evaluation of weather-crop yield models. P84-5. University of Minnesota, Institute of Agriculture, Forestry, and Home Economics, St. Paul, MN.

Gujarati, Damodar N. and Dawn C. Porter. 2009. Basic Econometrics, Fifth Edition, McGraw-Hill Irwin, New York, NY.

Offutt, Susan E., Philip Garcia, and Musa Pinar. 1987. The distribution of gains from technological advance when input quality varies. Amer. J. Agr. Econ. 69:321-327.

Tannura, M. A., S. H. Irwin, and D. L. Good. 2008. Weather, technology, and corn and soybean yields in the U.S. corn belt. Marketing and Outlook Research Report 2008-01, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign. [Online]. Available at http://www.farmdoc.uiuc.edu/marketing/morr/morr_archive.html (verified 1 Feb 2012).

U.S. Department of Agriculture, National Agricultural Statistics Service (NASS), 2012. Quick stats U.S. & all states data – crops. [Online]. Available at http://www.nass.usda.gov:8080/QuickStats/Create_Federal_All.jsp (verified 1 Feb 2012).