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Crop Supply Response under Risk: Impacts of Emerging Issues on Southeastern U.S. Agriculture

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In this paper we consider factors that affect both crop prices and yields in order to examine supply responses of major crops in the Southeast. Due to the variable nature of crop production in the Southeast, previous studies that ignore price and yield risk may fail to capture one of the salient features of the region's agriculture. Our results indicate supply elasticity values for corn, cotton, and soybeans of approximately 0.670, 0.506, and 0.195, respectively. Compared with the results of studies in other regions, corn and cotton acres respond more to price changes and soybean acres respond less to price changes.

Key Words: acreage supply, crop supply response model, risk analysis, Southeast U.S. agriculture

JEL Classifications: Q12, Q13, Q16

Cotton, soybeans, and corn are the three major row crops in the southeast[1] United States. These crops contribute not only to the region's agricultural economy, but are also important nationally. In 2007, planted cotton acreage in the Southeast totaled 4.48 million acres and accounted for about 41% of U.S. cotton acreage and 39% of its total value. In contrast, the share of acreage and value of corn and soybeans is smaller compared with other major corn and soybean regions. Nevertheless, the combined total acreage of corn and soybeans in the Southeast is still over 17 million acres and increasing. A large set of agribusiness input suppliers and output processors associated with crop production also exist, sometimes with significant investments in commodity-specific infrastructure such as cotton gins. Crop acreage in the Southeast tends to fluctuate over time, with these fluctuations becoming more pronounced in recent years. In 2007 total Southeast corn acreage increased 2.57 million acres, a jump of 86% from 2006. Over the same period, planted cotton acres decreased 34% (Figure 1). A variety of factors, including improved crop varieties and price signals, contributed to these relatively large shifts in crop acreage. High fuel prices and increases in the demand for corn to produce ethanol have been widely noted as contributing factors in recent years (Elobeid and Tokgoz, 2008; Malcolm, Aillery, and Weinberg, 2009; Sumner, 2009). As corn prices increase, incentives for

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[1] In this study "Southeast" includes the states of Alabama, Arkansas, Louisiana, Mississippi, Tennessee, Georgia, North Carolina, and South Carolina.

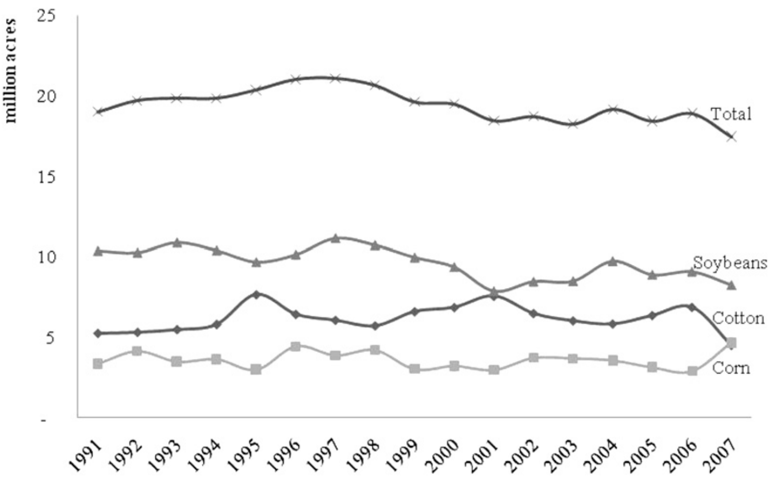

Figure 1. Planted Acreage of Corn, Cotton, and Soybeans in the Southeast: 1991–2007

farmers to grow corn also increase relative to the incentives to produce cotton. Consequently, acreage allocations switch from one crop to another.

Compared with other regions, historical data also indicate that crop acreage in the Southeast may experience more variability than other regions. For instance, compared with corn acreage in Arkansas, Louisiana, Mississippi, and Tennessee from 1980–2007, the standard deviation of the percentage change in acreage in Iowa is 13.68 while in the preceding four states area it is 19.46, although Iowa likely experienced a larger absolute change. The variability in farmers' planting decisions, as reflected in the observed crop acreage changes, warrants further investigation because of the implications for farm policies. Shifts in crop acreage not only affect crop producers but also impact the entire local agribusiness industry, particularly those industries with crop-specific investments. As a major cotton-producing region, the extensive infrastructure investments in the Southeast have few alternative applications. For example, machinery to harvest cotton is not useful for other crops, and post-harvest processing facilities such as gins are only capable of handling cotton (Blaney, 2010). To wit, over 100 active gins in Mississippi and the surrounding area depend on cotton production (Boyd and Hudson, 1999). As cotton producers switch to other crops, the impact on cotton gins may be costly. Therefore, understanding crop supply response in the Southeast may prove valuable for government officials who assess policy options such as commodity programs or renewable fuels policies. Furthermore, economists will find these results relevant when assessing the economic consequences of producers' crop planting decisions on the agribusiness industry.

A number of previous studies address regional acreage response issues from different perspectives. Duffy, Richardson, and Wohlgenant (1987) use an econometric model of cotton acreage response to provide regionalized estimates of own-price elasticity of cotton acreage supply for four production regions in the United States. Parrott and McIntosh (1996) examine the relative importance of cash and government support prices in determining cotton production over time in Georgia and conclude the cash price is more important than the government program price in terms of being the price information source and influencing acreage response. Houston et al. (1999) and Dumas and Goodhue (1999) identify leading indicators of regional cotton acreage response. Due to the variable nature of crop production in the Southeast, previous studies that ignore price and yield risk may fail to capture one of the salient features of the region's agriculture (Harri et al., 2009). For example, historically, federal farm policy affected producers' acreage decisions. Prior to the 1990s, farm bills focused on the traditional combination of price supports, supply controls, and income support payments, inhibiting market-driven acreage shifts through penalties for deviations from base acreage (Orden, Paarlberg, and Roe, 1999). The 1990 farm bill initiated changes that moved farmers toward greater market orientation—i.e., lower price supports, greater planting flexibility, and more attention to developing export opportunities for farm products. The 1996 farm bill increased the freedom of producers to respond to market signals. Farm programs like the marketing loan program that truncate the distribution of market prices continue to impact the subjective perceptions of producers on market prices at the time of acreage decisions. In this paper we consider factors that affect both crop prices and yields in order to examine supply responses of major crops in the Southeast. We conclude by exploring the implications of these factors for a variety of stakeholders including producers, the agribusiness industry, and policy makers.

Theoretical Model

A number of studies consider the topic of crop supply response under risk (Askari and Cummings, 1977; Nerlove, 1956, 1958; Rao, 1989). While many of these studies follow Nerlove's seminal work to specify a general supply response function, later studies consider both producer and consumer economic behaviors in a more theoretically consistent manner (Chavas and Holt, 1990; Lee and Helmberger, 1985; Lin, 1977; Lin and Dismukes, 2007). This paper employs an acreage supply response model based on the theoretical framework used by Chavas and Holt (1990) and Lin and Dismukes (2007). We consider both price and yield risks unique to crop production in the Southeast. Furthermore, as Chavas and Holt denote, government price supports in fact truncate the price distribution on which producers base their acreage decisions, indicating the need to accommodate the truncations to the distribution.

We consider a risk averse farm operator household whose preferences are represented by a von Neumann-Morgenstern utility function: $U(W)$ defined on wealth W with $U_W > 0$ and $U_{WW} < 0$. We also assume the farm operator household produces n crops. The number of acres devoted to the ith crop equals A_i and the corresponding yield per acre ($i = 1, \ldots, n$) is y_i. We denote p_i as the market price of the ith crop, c_i as the cost of production per acre of the ith crop, and express the net agricultural revenue (NR) as follows:

$$NR = \sum_{i=1}^{n} p_i y_i A_i - \sum_{i=1}^{n} c_i A_i$$

We assume that at the time crop acreage decisions are made input prices and per acre costs are known while output prices $p = (p_1, \ldots, p_n)$ and crop yields $y = (y_1, \ldots, y_n)$ are uncertain; these assumptions imply that net revenue is a random variable. The farm operator household's decision problem then becomes maximizing the expected utility function (1) by making optimal acreage choices subject to budget constraint (2) and acreage decision constraint (3):

$$\text{(1)} \qquad \underset{A}{Max}\ EU(W)$$

s.t.:

$$\text{(2)} \qquad W_0 + \sum_{i=1}^{n} p_i y_i A_i - \sum_{i=1}^{n} c_i A_i = qG$$

$$\text{(3)} \qquad f(A) = 0$$

where W_0 denotes initial wealth, q is the price index of consumption goods, G is the quantity of household consumption, and $A = (A_1, \ldots, A_n)$ is the acreage choice vector, and $f(A)$ is the production function given current technology. By rearranging the above equations, the maximization problem becomes:

$$\text{(4)} \qquad \underset{A}{Max}\ EU\left[W_0 + \sum_{i=1}^{n} p_i y_i A_i - \sum_{i=1}^{n} c_i A_i\right] \ s.t.:$$

Since both output prices p and crop yields y are random variables with given subjective probability distributions, the theoretical model indicates that at planting time farmers make acreage decisions under both price and production uncertainty. Mathematically, this situation means the farm household's expected utility is maximized over random variables p and y. The empirical specifications below emphasize this point.

Empirical Specifications

The empirical model in this study utilizes state-level data from the eight southeastern states to estimate supply responses for corn, cotton, and soybeans. Farm operator households' acreage decisions are estimated by a panel data set of eight individual states from 1991–2007. Following the acreage response models of Chavas and Holt (1990) and Lin and Dismukes (2007), this study adopts two forms of specification in its estimation: a linear acreage model in Equation (5) and an acreage share model in Equation (6):

$$A_i = a_{1i} + b_{ij}\sum_{j=1}^{3} NR_j + c_{ij}\sum_{j=1}^{3} VAR_i + d_{ij}\sum_{i\neq j,1}^{3} COV_{ij} + e_i W_{0i} + f_i Z_i + \mu_i \tag{5}$$

$$S_i = a_{1i} + b_{ij}\sum_{j=1}^{3} NR_j + c_{ij}\sum_{j=1}^{3} VAR_j + d_{ij}\sum_{i\neq j,1}^{3} COV_{ij} + e_i W_{0i} + f_i Z_i + \mu_i \tag{6}$$

$$\sum_{i=1}^{4} S_i = 1 \tag{7}$$

where A_i is the acreage for the ith crop in thousands of acres; S_i is the acreage share for the ith crop; i is defined so that 1 = corn, 2 = cotton, 3 = soybeans, and 4 = other crops; NR_j is the expected net returns (dollars per acre) for the jth commodity; VAR_j is the expected variance of revenues (dollars per acre) for the jth commodity; COV_{ij} is the expected covariance of net revenues (dollars per acre) between the ith and jth commodities for $i \neq j$; W_{0i} is the farm household initial net worth (in millions of dollars) for the ith commodity; Z_i represents all other explanatory variables (e.g., idled acreage under the Acreage Reduction Program (ARP) of the 1990 farm bill, state dummies, and a lagged dependent variable, A_{it-1} or S_{it-1}) for the ith commodity; and μ is the error term.

In contrast to the Lin and Dismukes (2007) study on the supply responses of corn, soybeans, and wheat for the north central region, we substitute cotton for wheat in the specification as cotton is the major crop competing with corn and soybeans in the Southeast. Next we discuss the calculations of the right-hand side variables in Equations (5) and (6). Farmers' expected prices at planting are the new crop harvest time futures prices from the Chicago Board of Trade (corn and soybeans) and the New York Mercantile Exchange (cotton). Expected prices are further adjusted using state-level crop cash prices from the National Agricultural Statistics Service of U.S. Department of Agriculture (USDA) to account for the effects of state basis differences and available marketing price support programs. Using the difference between futures prices and cash prices received by farmers in the month before the delivery month of the futures, we compute a state-specific 5-year moving average basis.

We use a linear trend to estimate the expected yield for each year of the period 1991–2007 and for each state starting with data from 1975–1990 and then adding one year at a time. The expected variance of non-truncated farm prices is calculated as a weighted sum of the squared deviations of the past three farm prices from their expected values with a weighting scheme of 0.5, 0.3, and 0.2 as suggested by Chavas and Holt (1990) and Lin and Dismukes (2007). The expected variance of crop yields is calculated as a weighted sum of the squared deviations of past crop yields from their trend with the same weighting scheme.

Marketing loans and loan deficiency payments provide producers with interim financing at harvest time to meet cash flow needs without having to sell their commodities when market prices are at typical harvest-time lows. Such programs should provide farmers a price guarantee and as a result truncate farmers' subjective price distributions. Following Chavas and Holt (1990), we use the expected mean and variances of non-truncated prices to compute the mean and variances of the truncated farm price distributions.

The expected net returns are then computed using the mean and variance of both truncated price distributions and yields. The expected variances and covariances of revenues are calculated using the same method as in Lin and Dismukes (2007). The expected variances of revenues and the expected covariances of revenues between the ith and jth commodities are computed for each of the three major field crops in the eight states over the 1991–2007 period (see Appendix). Expected means and variances of yields and truncated commodity price means and variances are used to derive the expected variance of revenues and the expected covariance of revenues between any two commodities.

We use farm value of proprietor equity as a proxy for farm operator household initial net worth (USDA Economic Research Service, 2010a). In contrast to other studies that allocate the total value of proprietor equity to each crop by its acreage share, we use the total proprietor equity for all crops based on the consideration that it is likely to introduce the same volatility as acreage if we allocate the proprietor equity by acreage shares. We lag the initial wealth by one year to avoid potential simultaneous bias that otherwise might arise from an increase in farm household's net worth caused by an increase in acreage in the same year.

Other explanatory variables included in the estimation consider the effects of farm programs, geographic location, and adjustment costs. The study period of 1991–2007 covers three farm bills. In the 1990 farm bill ARP set aside idled acreage: 7.5% of base acreage for corn in 1991, 5.0% in 1992, 10.0% in 1993, 0% in 1994, and 7.5% in 1995 (Lin, Riley, and Evans, 1995). For cotton, ARP set aside 5.0% of base acreage in 1991, 10.0% in 1992, 7.5% in 1993, and 11.0% in 1994 (Glade, Meyer, and MacDonald, 1995). Finally, ARP set aside the following shares of base acres for soybeans: 7.5% in 1991, 5.0% in 1992, and 5.0% in 1993 (Ash et al., 1995). The 1996 farm bill discontinued ARP. We investigate the impacts of the three farm bills by including a dummy variable for the year each bill was introduced. However, the parameter estimates for the dummy variables are not statistically significant and thus not reported in our results.

We use a dummy variable for each state to account for the differences that may arise from geographic location, treating Mississippi as the base state. We also consider the potential problem of producers' acreage inertia; that is, the adjustment costs in switching from one crop to another that may inhibit farmers' responses to market signals. Therefore, we add a lagged dependent variable (either for planted acreage or acreage share) to the explanatory variables in the model.

The share equations, similar to the specification of expenditure-share equations for the almost ideal demand system, help explain how the shares of total cropland allocated to specific crops respond to the expected net returns, yield and price risks, initial wealth, and other exogenous variables. The specification explicitly recognizes that as the share of the acreage planted to one commodity such as corn increases, this expanded acreage must come from land planted to competing crops such as soybeans, cotton, or minor field crops. In other words, the sum of the acreage shares equals one, and the share specification stipulates that the total acreage planted to all field crops is fixed.

We obtained futures price data from the Chicago Board of Trade and the New York Board of Trade (CRB Infotech CD, 2009), state-level production data from surveys by the National Agricultural Statistics Service of USDA (USDA National Agricultural Statistics Service, 2009), and state-level cost data from the Agricultural Resource Management Survey of USDA (USDA Economic Research Service, 2009a).

The seemingly unrelated regressions (SUR) model is used to estimate both the linear acreage and share equation models. We impose symmetry restrictions on the regression coefficients in both models, following Chavas and Holt (1990); Hausman and Leonard (2005); and Lin and Dismukes (2007). In the acreage share models, only the shares of corn, cotton, and soybeans are estimated using pooled time series (1991–2007) and cross-sectional data. The share of minor field crops is left out to avoid the singularity of the disturbance covariance matrix. Some variance and covariance variables are omitted from the model to alleviate the multicollinearity between the expected variance and covariance of revenues or between different covariances (Lin and Dismukes, 2007). Following Chavas and Holt we test for autocorrelation equation-by-equation in the linear acreage model using a Durbin *t*-test. We find no autocorrelation significant in any equation at the 5% level of significance.

Results

Table 1 summarizes the data used in the study. On average, 405,000 acres of corn, 725,000

Table 1. Descriptive Summary of Variables

Variable	Description	N	Mean	SD	Minimum	Maximum
$acre_1$	Corn acreage (thousand acres)	152	405.08	229.52	58.00	1,070.00
$acre_2$	Cotton acreage (thousand acres)	152	725.55	358.34	110.00	1,600.00
$acre_3$	Soybeans acreage (thousand acres)	152	1,197.14	917.21	135.00	3,600.00
s_1	Corn acreage share	152	0.11	0.05	0.01	0.24
s_2	Cotton acreage share	152	0.18	0.08	0.02	0.38
s_3	Soybeans acreage share	152	0.25	0.11	0.04	0.43
NR_1	Corn net revenue ($/acre)	152	47.31	92.86	−174.98	385.73
NR_2	Cotton net revenue ($/acre)	152	81.73	117.71	−113.06	379.33
NR_3	Soybeans net revenue ($/acre)	152	78.82	51.36	−115.37	210.08
VAR_1	Corn variance	152	3,870.97	3,243.04	366.66	19,404.36
VAR_2	Cotton variance	152	22,767.55	11,556.23	3,065.67	59,651.92
VAR_3	Soybeans variance	152	1,565.42	1,158.49	126.41	6,387.10
$cov_{1,2}$	Corn-cotton covariance	152	4,004.50	2,708.88	108.61	13,182.87
$cov_{1,3}$	Corn-soybeans covariance	152	1,381.69	974.11	97.42	6,409.36
$cov_{2,3}$	Cotton-soybeans covariance	152	3,806.88	2,495.61	31.58	10,410.02
fe_1	Farm equity allocated (billion $)	152	15.07	6.72	5.29	32.07
$idle_1$	Corn idled acreage (thousand acres)	152	5.92	14.54	0.00	85.00
$idle_2$	Cotton idled acreage (thousand acres)	152	11.95	28.00	0.00	139.70
$idle_3$	Soybeans idled acreage (thousand acres)	152	11.61	34.59	0.00	240.00
p_1	Corn price ($)	152	2.60	0.51	1.74	4.54
p_2	Cotton price ($)	152	0.56	0.12	0.27	0.80
p_3	Soybeans price ($)	152	6.10	1.26	4.29	11.90
y_1	Corn yield (bushel)	152	104.01	24.48	40.00	169.00
y_2	Cotton yield (pounds)	152	702.27	150.41	314.00	1,114.00
y_3	Soybeans yield (bushel)	152	27.75	6.10	14.00	43.00

acres of cotton, and 1,197,000 acres of soybeans are planted at the state level in the Southeast. The planted acreage for each individual crop varies by state. For example, over the study period North Carolina planted more corn (813,000 acres) and soybeans (1,346,000 acres) than the regional average. Arkansas planted less corn (187,000 acres) but more cotton (947,000 acres) and soybeans (3,303,000 acres) than the regional average. Corn net revenues range from a loss of $174 per acre to a gain of $385 per acre. Similarly, while some states suffered negative net returns, regional-level net returns from cotton and soybeans average approximately $81 and $78 per acre, respectively. Variance and covariance terms of net return of revenues quantify the risks confronting producers.

Table 2 presents the results of the SUR estimation for the linear acreage model and Table 3 for the share model. Expected net returns for corn and cotton are statistically significant and have the expected signs in the equations for both the linear acreage and share models. The expected net return for soybeans has the expected sign in both specifications and is statistically significant in the share equation specification. The magnitudes of variance and covariance terms are similar to what Lin and Dismukes report for the North Central region. In the linear acreage model one variance term is significant, while in the share model two variance terms are statistically significant. These results suggest the effect of risk on acreage response is statistically significant but that the absolute magnitude of the effect is not large.

We calculate own-price elasticities from the estimates of the linear acreage model for corn, cotton, and soybeans of 0.670, 0.506, and 0.195, respectively. Similarly, we calculate own-price elasticities for corn, cotton, and soybeans from the estimates of the acreage shares model that equal 0.647, 0.511, and 0.290, respectively. Chavas and Holt (1990) estimate the acreage own-price elasticity of corn for the North Central

Table 2. Estimated Regression Coefficients for the Linear Acreage Model in the Southeastern Region for 1991–2007

Variable	Corn	Cotton	Soybeans
Intercept	283.374***	151.382***	564.810***
	(41.676)	(54.980)	(103.8)
NR_1	1.003***	−0.703***	−0.284*
	(0.136)	(0.084)	(0.156)
NR_2	−0.703***	0.928***	−0.083
	(0.084)	(0.117)	(0.125)
NR_3	−0.284*	−0.083	1.379***
	(0.156)	(0.125)	(0.319)
VAR_1	—	—	−0.005
			(0.008)
VAR_2	—	−0.0005	—
		(0.0007)	
VAR_3	−0.015*	—	0.020
	(0.008)		(0.017)
$COV_{1,2}$	—	—	—
$COV_{1,3}$	0.014	—	0.056*
	(0.011)		(0.038)
$COV_{2,3}$	—	—	—
Wealth	−1.689	7.125***	−6.831**
	(1.958)	(2.690)	(3.079)
A_{t-1}	0.557***	0.708***	0.639***
	(0.064)	(0.041)	(0.047)
Idled	0.040	0.411	0.251
	(0.516)	(0.290)	(0.308)

Notes: Standard errors in parentheses. Durbin *t*-tests of autocorrelation for the corn, cotton, and soybeans equations found values of 0.1944, −0.0723, and −1.6026, respectively, none of which are significant at the 5% level.
*, **, and *** denote significance levels for 10%, 5%, and 1%, respectively.

region to be 0.158 and Lin and Dismukes (2007) calculate a value of 0.170 based on the linear model. We conduct a *t*-test for statistical differences between our estimated own-price coefficient for corn and those of the studies by Chavas and Holt and Lin and Dismukes. We also compare our own-price coefficient for soybeans to the result from Chavas and Holt, and in each case we reject equality of parameters at the 5% level. For the acreage shares model the estimates for the own-price elasticity of corn acreage range from 0.248 (Lin et al., 2000) to 0.345 (Lin and Dismukes, 2007), both less than our estimates of 0.647–0.670. Similarly, the soybean acreage own-price elasticity estimate in our study is 0.195 based on the linear model and 0.290 based on the shares model, both of which are lower than the previous estimates of Chavas and Holt and Lin and Dismukes that range from 0.295–0.441, respectively. Therefore, compared with the results for the North Central region, our results indicate that corn acreage in the Southeast responds more to price changes and soybean acreage responds less. The own-price elasticities we calculate for cotton acreage of 0.506–0.511 are also higher than the estimate of 0.435 by Lin et al. (2000) for the Southeast and Delta regions. Earlier studies by Duffy, Richardson, and Wohlgenant (1987) estimate own-price elasticities for cotton of 0.116 in the Delta and 0.273 in the Southeast. In contrast, our cotton elasticity estimates are more in line with the results of Dumas and Goodhue (1999).

We also compare the predictions of the model for 2008 with actual production for 2008. Net returns were scaled based on changes in expected futures prices from 2007–2008 as well as an upward shift in cost due to higher fertilizer prices that affects corn and cotton more than soybeans. We increased the variances of revenue to reflect the increased market volatility that occurred in the spring of 2008, updated the lagged acreages by 1 year, and held wealth and the covariance constant. The results indicate directional shifts in acreage that match actual production shifts in 2008—an increase in soybean acres and declines in both corn and cotton acres. The model predicts changes in planted acres of corn, cotton, and soybeans from 2007–2008 of −20, −36, and +21%, respectively, compared with actual changes in planted acres of −23, −25, and +29%.

Policy Implications

Farmers face a variety of risk factors when they make planting decisions each year. Our results indicate that while farm acreage decisions in the Southeast are inelastic, they are relatively more elastic than those in the Midwest. Compared with other regions our results also show that acreage responses are relatively more elastic for corn and cotton. Therefore, in light of yield improvements and agricultural price increases in recent years, examining the impacts of risk

Table 3. Estimated Regression Coefficients for the Acreage Shares Model in the Southeastern Region for the Period of 1991–2007

Variable	Corn	Cotton	Soybeans
Intercept	0.0615***	0.0247*	0.1813***
	(0.0106)	(0.0143)	(0.0218)
NR_1	0.000256***	−0.00019***	0.00012***
	(0.000034)	(0.00002)	(0.00003)
NR_2	−0.00019***	0.000229***	−0.00006**
	(0.00002)	(0.00003)	(0.000028)
NR_3	(0.00003)	−0.00006**	0.000436***
	−0.00000774	(0.000028)	(0.000066)
VAR_1	—	—	−0.00000941
			(0.000002267)
VAR_2	—	−0.00000408**	—
		(0.000000201)	
VAR_3	−0.00000285**	—	−0.00000065**
	(0.00000185)		(0.00000364)
$COV_{1,2}$	—	—	—
$COV_{1,3}$	0.00000669*	—	0.00001
	(0.00000307)		(0.000079)
$COV_{2,3}$	—	—	—
Wealth	0.00032	0.0033****	0.00277***
	(0.000497)	(0.0007)	(0.0006)
A_{t-1}	0.000126***	0.000147***	0.0001***
	(0.000017)	(0.00001)	(0.00001)
Idled	0.00019***	0.00005	0.00011**
	(0.00014)	(0.000074)	(0.000065)

Note: Standard errors in parentheses.
*, **, and *** denote significance levels for 10%, 5%, and 1%, respectively.

factors on crop acreage decisions becomes useful for providing policy recommendations to producers and other stakeholders in the agriculture industry. In the following sections we use the estimation results from this study to investigate the potential impacts of three emerging issues: (1) new and improved crop varieties resulting from advances in bio-technology; (2) crop price variations induced by the development of ethanol production; and (3) the impact of fertilizer and fuel price increases. Although we include eight states in the Southeast in our study, we use Mississippi to carry out the policy simulations. As a point of reference, Lin and Dismukes (2007) use Illinois for the North Central region. We also conduct simulations for the other seven states in our study and these results are available upon request.

Impact of Bio-Technological Improvement in Crop Varieties. Since commercialization began in 1996, genetically engineered (GE) crop varieties have been adopted widely in the United States. In 2007 GE varieties accounted for 80% of all planted corn, 86% of all upland cotton, and 92% of all planted soybeans in the United States (USDA –Economic Research Service, 2010b). In the Southeast GE varieties are available for all three primary crops, and include the major insect-resistant (*Bt*) and herbicide-tolerant varieties. Compared with conventional varieties, GE varieties have a number of advantages, including reduced input use, higher yields, and less yield variability. All these attributes contributed to the rapid adoption of GE varieties. As bio-technology continues to advance, new varieties replace older varieties. Therefore, the adoption of newer GE varieties appears likely to continue. Our model finds that the acreage allocations among crops in the Southeast are likely to change from year to year depending on farmers' decisions on crops and varieties. We initiate a "shock" to the base case with the adoption of *Bt* cotton to simulate the *ceteris paribus* impact of improved technology on crop acreages.

As an insect-resistant variety, *Bt* cotton has remained popular since its introduction. *Bt* varieties enable farmers to reduce the application of insecticides compared with conventional varieties, and consequently reduce their input costs. Because the companies charge a technology fee for their seeds, when farmers make decisions about using *Bt* varieties they must weigh the savings in input costs and benefits of increased yields with the increased seed costs. Evidence from the first decade of commercialization of GE crops finds that the adoption of insect-resistant varieties will likely fluctuate over time depending on the expected infestation levels of certain insects (Frisvold and Tronstad, 2002). For instance, adoption of *Bt* cotton depends on the expected infestation of *Bt* target pests such as the tobacco budworm, the bollworm, and the pink bollworm. For the purposes of this study we collected information on insecticide cost savings, technology fees, and estimated yield increases for *Bt* cotton in the eight states (Frisvold, Reeves, and Tronstad, 2006). Results in Table 4 show that in the Southeast at the state level *Bt* cotton reduced insecticide cost by approximately $23 per acre and increased yields by 7%. At the same time, a technology fee of approximately $24 was charged per acre. Information in Table 4 is used in the simulation of the impact of *Bt* cotton.[2]

Table 5 reports the effect of *Bt* cotton adoption on Mississippi acreage. In the simulation, the introduction of *Bt* cotton changes farmers' expected yield and input cost structure, which consequently influences their acreage choices. In the base case, on average 615,000, 767,400, and 1,209,700 acres are planted to corn, cotton, and soybeans, respectively. As *Bt* cotton adoption continues, cotton acreage increases to 796,500 acres, an increase of 3.8%. At the same time, corn acreage decreases 3.7%. The impact on soybean acreage of introducing *Bt* cotton is not significant, as the change in soybean acreage is less than 1% compared with the base case. Thus, the widespread adoption of *Bt* cotton has not significantly altered the crop mix in Mississippi, primarily because the cost of technology fees has negated the value of increased yields and reductions in other inputs.

Impact of Ethanol Induced Crop Price Increases. Fuel prices have increased markedly in recent years, leading to significant changes in government ethanol policies. The Energy Independence and Security Act of 2007 established the renewable fuels standard for 2008 at 9.0 billion gallons, more than double the level of renewable fuels required in 2006 (U.S. Congress, 2007). In January of 2008, ethanol production capacity in the United States reached 7.888 billion gallons with another 5.536 billion gallons of productive capacity under construction. The expansion of ethanol demand and production triggered a series of reactions in agriculture. Studies found that as oil prices rose from $40 per barrel to $147 per barrel, the oil price and the growth in ethanol production and use in the United States led to a $4 increase in the price of corn over the same period (Abbot, Hurt, and Tyner, 2008). In 2003, the average corn price for the Southeast was $2.45 per bushel but rose to $3.79 per bushel by 2007. Similarly, soybean prices increased from $7.15 to $9.89 per bushel over the same period. To examine the impact of ethanol-induced corn and soybean price increases on crop acreages in Mississippi, we consider two scenarios: (1) corn and soybean prices and variances both increase by 50% and (2) corn and soybean prices and variances both increase by 100%. In both scenarios the cotton price remains unchanged by assumption, and Table 5 presents these simulation results.

The results indicate that as crop prices increase, farmers allocate more acreage to crops with higher prices. For instance, as corn and soybean prices and variances increase by 50%,

[2] An observed "yield drag" occurred following the introduction of *Bt* varieties, but this yield drag appears to be waning. As most producers now plant GE soybeans, observers believe yield drag is no longer an issue as breeding efforts associated with the Roundup Ready lines approach those of the conventional lines (Manning et al., 2002).

Table 4. *Bt* Cotton Insecticide Cost Savings per Acre, Technology Fees, and Yield Increase

State	*Bt* Cotton Insecticide Cost Savings ($/acre)	*Bt* Cotton Technology Fee ($/acre)	*Bt* Cotton Yield Increase (%)
Alabama	17.30	26.00	7.0
Arkansas	22.80	22.00	7.0
Georgia	27.00	26.00	8.0
Louisiana	34.42	29.75	6.0
Mississippi	23.52	26.00	5.0
North Carolina	18.72	19.25	4.5
South Carolina	22.50	22.50	8.0
Tennessee	20.24	23.79	8.0

Note: Authors' own calculations.

Mississippi corn and soybean acreages increase to 857,900 and 1,325,500 acres, respectively. These increases of 39% and 9%, respectively, from the base case lead to a decrease in cotton acreage of 24%. Similarly, when corn and soybean price variances are assumed to increase by 100%, corn acreage increases from the base case of 614,900 acres to 1,107,100 acres, an increase of 80.05%. Total soybean acres increase 19.8% from 1,209,700 acres in the base case to 1,449,200 acres, while cotton acres again decrease.

The results indicate the magnitude of a *ceteris paribus* shock in crop prices in terms of acreage allocations. Increases in corn and soybean prices allocate more acreage to corn and soybeans, and result in associated impacts on cotton production and cotton-related industries. As the total amount of available land becomes a constraint, increases in other crops imply a decrease in cotton acreage, which negatively affects the cotton ginning industry in the Southeast.

Impact of Fertilizer and Fuel Price Increases. During the same period corn and soybean prices increased fertilizer and fuel prices also increased. A farm survey in Mississippi found phosphate prices increased from $11.73 per hundredweight in 2003 to $41 per hundredweight in 2008 (Mississippi Agricultural and Forestry Experiment Station, 2003, 2008). Similarly, potash prices increased from $9.25 to $28.00 per hundredweight and UAN (a solution of urea and ammonium nitrate in water used as a fertilizer) prices increased from $6.74 to $19.00 per hundredweight in the same period. A similar trend was observed in fuel prices as the price of diesel increased from $0.95 per gallon in 2003 to $3.53 per gallon in 2008. Increases in fertilizer and fuel prices directly result in increases in farmers' variable costs of crop production. We simulate the impacts of fertilizer and fuel price increases using data from Mississippi farm surveys, assuming other factors unchanged (Table 6). The results indicate the increases affect corn acres most, followed by soybean and cotton acres. Our simulations find input shocks reduce corn acreage by 14.65% and increase cotton and soybean acreage by 3.1% and 3.4%, respectively, while the total acres for all major crops experience little change.

Impact of Combined Effects. Since farmers experience variations in both crop and input prices at the same time, we also simulate the combined effects of both output price changes and input price increases (Table 6). We simulate two scenarios of the combined effects. In the first scenario of the combined effects we assume that increases in corn and soybean prices and variances of 50% are combined with input cost increases and *Bt* cotton adoption. In the second scenario of the combined effects we assume that increases in corn and soybean prices and variances of 100% are combined with input cost increases and *Bt* cotton adoption. Our results in Table 6 indicate that the first scenario of the combined effects introduces an increase in total acreage of 5.7% in Mississippi. This scenario allocates more acres to corn and soybeans, which increase by 21.2% and 12.75%, respectively. The same scenario of the combined effects exerts a negative impact on cotton by decreasing its

Table 5. Simulation Results for *Bt* Cotton Adoption and Ethanol Induced Price Variation

Crop	Base Case	With *Bt* Cotton Adoption		Corn and Soybeans with 50% Price Variance Increase		Corn and Soybeans with 100% Price Variance Increase	
	Planted Acreage (thousand acres)	Planted Acreage (thousand acres)	Percent Change	Planted Acreage (thousand acres)	Percent Change	Planted Acreage (thousand acres)	Percent Change
Corn	614.98	592.42	−3.67	857.86	39.49	1,107.06	80.02
Cotton	767.42	796.46	3.78	580.29	−24.38	393.20	−48.76
Soybeans	1,209.68	1,207.01	−0.22	1,325.48	9.57	1,449.23	19.80
Total	2,592.08	2,595.88	0.15	2,763.63	6.62	2,949.49	13.79

Table 6. Simulation Results for Fertilizer Fuel Cost and Combined Effects of Crop Prices and Cost Increases

Crop	Base Case	Fertilizer Fuel Price (cost) Increase		Combined Price and Input Cost Effect 1		Combined Price and Input Cost Effect 2	
	Planted Acreage (thousand acres)	Planted Acreage (thousand acres)	Percent Change	Planted Acreage (thousand acres)	Percent Change	Planted Acreage (thousand acres)	Percent Change
Corn	614.98	524.89	−14.65	745.21	21.18	994.40	61.70
Cotton	767.42	791.32	3.12	633.24	−17.48	446.15	−41.86
Soybeans	1,209.68	1,250.55	3.38	1,363.68	12.73	1,487.43	22.96
Total	2,592.08	2,566.76	−0.98	2,742.12	5.79	2,927.98	12.96

acreage 17.5%. The second scenario of the combined effects clearly demonstrates the negative impacts on farmers' acreage decisions, despite the influence of corn and soybean prices that result in an increase in total planted acreage of corn, cotton, and soybeans. That is, compared with the results in Table 5 (where we simulate the effect of input costs only), input cost increases result in a smaller increase in corn acreage.

Conclusions

In recent years crop production in the Southeast has experienced a series of emerging issues and exhibited marked fluctuations in acreage. Our results indicate supply elasticity values for corn, cotton, and soybeans of approximately 0.670, 0.506, and 0.195, respectively. Compared with the results of studies in other regions, corn and cotton acres respond more to price changes and soybean acres respond less to price changes. Therefore, factors like continuing developments in bio-technology, shocks to corn and soybean prices induced by the increasing demand for ethanol, and increases in input costs all affect farmers' crop acreage decisions and subsequently related agribusiness sectors in this region.

Our study demonstrates the cost savings and yield effects from improved new crop varieties on acreage decisions, as farmers allocate more acres to new varieties, *ceteris paribus*. The impact of ethanol production in recent years has resulted in relatively large increases in corn and soybean prices, leading farmers to plant more corn and soybeans and less cotton. Higher fertilizer and fuel prices diminish the positive effect of ethanol production on corn and soybean acreage to some degree, as higher input costs reduce the acreage allocated to corn and soybeans.

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Appendix

This appendix provides details on the construction of the variance and covariance variables used in the models. Let price P and yield Y be two random variables. The expected variance of revenues is defined as:

$$E(Y \cdot P - E(Y \cdot P)) = (E(P))^2 \cdot \left(\sigma_y^2\right) + (E(Y))^2 \cdot \left(\sigma_p^2\right) + \left(\sigma_y^2\right) \cdot \left(\sigma_p^2\right) - \rho\left[\rho \cdot \left(\sigma_y^2\right) \cdot \left(\sigma_p^2\right) + 2E(Y) \cdot E(P) \cdot \sigma_y \cdot \sigma_p\right] \quad \text{(A1)}$$

where $E(Y)$ is the expected yield, $E(P)$ is the expected price, σ_y^2 (σ_y) is the variance (the standard deviation) of yield, σ_p^2 (σ_p) is the variance (standard deviation) of prices, and ρ is the correlation coefficient between price and yield. Variances are computed with the weights described in Chavas and Holt (1990).

The expected covariance of revenues between the ith and jth crop is defined as:

$$
\begin{aligned}
(A2)\quad & E[Y_i \cdot P_i - E(Y_i \cdot P_i)] \cdot [Y_j \cdot P_j - E(Y_j \cdot P_j)] \\
&= E(P_i) \cdot E(P_j) \cdot (\rho_{yij} \cdot \sigma_{yi} \cdot \sigma_{yj}) + E(Y_i) \cdot E(Y_j) \cdot (\rho_{pij} \cdot \sigma_{pi} \cdot \sigma_{pj}) \\
&\quad + (\rho_{yij} \cdot \sigma_{yi} \cdot \sigma_{yj}) \cdot (\rho_{pij} \cdot \sigma_{pi} \cdot \sigma_{pj}) - [(\rho_{ypi} \cdot \sigma_{yi} \cdot \sigma_{pi}) \cdot (\rho_{ypi} \cdot \sigma_{yi} \cdot \sigma_{pi})] \\
&\quad - E(Y_j) \cdot E(P_j) \cdot (\rho_{ypi} \cdot \sigma_{yi} \cdot \sigma_{pi}) - E(Y_i) \cdot E(P_i) \cdot (\rho_{ypj} \cdot \sigma_{yj} \cdot \sigma_{pj})
\end{aligned}
$$

where $E(Y_i)$ is the expected yield of the ith crop, $E(P_i)$ is the expected price, $\rho_{yij} \cdot \sigma_{yi} \cdot \sigma_{yj}$ is the covariance of yields between the ith and jth crops, $\rho_{pij} \cdot \sigma_{pi} \cdot \sigma_{pj}$ is the covariance of prices between the ith and jth crops, $\rho_{ypi} \cdot \sigma_{yi} \cdot \sigma_{pi}$ is the covariance of ith crop yields and prices, and $\rho_{ypj} \cdot \sigma_{yj} \cdot \sigma_{pj}$ is the covariance of jth crop yields and prices.