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Georgia Cotton Acreage Response to the Boll Weevil Eradication Program

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ABSTRACT

An adaptive regression model is employed for estimating pre- and post-boll weevil eradication cotton-acreage response. Results indicate cotton acreage becoming more inelastic to own- and cross-price changes. As a result of this shift in acreage response and yield increases from eradication, net producer benefits on average are $88.73 per acre.

Key Words: *adaptive regression, pest eradication, producer surplus.*

Agricultural pests, such as insects, which have the ability to emigrate in and out of fields pose difficulties for individual field control, and thus collective pest control across all fields may provide a more effective control mechanism. The Boll Weevil Eradication (BWE) program is such a collective pest-control mechanism. In 1978, the goal of the initial trial BWE program, located in North Carolina and Virginia, was eliminating the insect pest. The success of this initial experimental BWE program spurred its expansion into all of North and South Carolina. Subsequent to the completion of this BWE program expansion, a program evaluation by Carlson, Sappie, and Hammig found a tangibly smaller boll weevil population facilitated higher yields, lower pesticide costs, and increased cotton acreage.

Such evaluations are useful as BWE expands westward. Expansion requires two-thirds of the cotton producers within a region voting for a BWE program. Without reliable estimates on the effect of BWE, producers will face increased uncertainty concerning BWE benefits and costs. A major benefit of BWE is enhanced returns associated with an increase in post-eradication cotton acreage. However, the results of a later study for Alabama, Georgia, and Florida, by Ahouissoussi, Wetzstein, and Duffy, indicated no significant relation between BWE and acreage. This insignificance may be due to the lack of data on post BWE cotton acreage. Their results are based on just five years of data covering only the eradication phase.

Since this eradication phase, in Georgia cotton acreage has increased from a historical low of 120,000 planted acres in 1983 to 1.5 million acres in 1995 (Georgia Agricultural Facts). While recent jumps in cotton prices certainly explain a part of this increase, it is hypothesized the BWE program may also account for this increased acreage. As the BWE program continues to expand westward, estimates on the acreage response of BWE would

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provide producers with additional information on the benefits and costs of the program.

The overall focus of this paper is to determine whether the net increase in planted-cotton acreage directly associated with BWE, as documented in the Carolinas, is likewise evident in Georgia. Specifically, the effect BWE has on the elasticity and magnitude of cotton acreage response to price changes is empirically estimated. Based on these estimates, the producer benefits from expanding cotton acreage are calculated. These benefits will provide insights for producers facing a vote for entrance into a BWE program. The analysis is based on 30 years, from 1966 to 1995, covering the period prior to BWE, 1966 to 1986; the eradication phase, 1987 to 1990; and the post eradication phase, 1991 to 1995. A Cooley-Prescott adaptive regression model is employed for estimation. This time-varying model permits parameters to vary according to the suitable periods in the data (Parrot and McIntosh).

Theoretical Model

Prior to the BWE program, cotton mainly served as a rotation crop for more profitable crops such as peanuts. Price fluctuations between cotton and alternative rotation crops (soybean and corn) would result in cotton being brought in and out of a rotation. Thus, employing a rational expectation model, analogous to Ahouissoussi, McIntosh, and Wetzstein, a producer will maximize expected profits from cotton in period t + 1, $\pi^e_{cot,t+1}$, subject to the condition this profit maximizing level is greater than expected profits from an alternative rotation crop, $\pi^e_{A,t+1}$. Specifically

$$(1) \quad \max \pi^e_{cot,t+1} = p^e_{cot,t+1} q^e_{cot,t+1} - \bar{r}\bar{x},$$
$$\text{s.t.} \quad R = \pi^e_{cot,t+1}/\pi^e_{A,t+1} \geq 1,$$

where $p^e_{cot,t+1}$ and $q^e_{cot,t+1}$ denote expected cotton price and the cotton production function, respectively, $\bar{r}$ and $\bar{x}$ represent the input price and quantity vectors, respectively, and R is the ratio of expected cotton profits to the profits from an alternative crop. The alternative profit function, $\pi^e_{A,t+1}$, is a function of alternative rotation crop prices and input prices.

The cotton acreage response function may be estimated by representing the expected production function as a multiple of planted cotton acres, $A_{cot,t}$, and expected yield. First-order conditions for (1) determine the following cotton acreage response function

$$(2) \quad A_{cot,t} = g[p^e_{cot,t+1}, \bar{r}, R(p^e_{cot,t+1}, p^e_{c,t+1}, p^e_{s,t+1}, \bar{r})],$$

where $p^e_{c,t+1}$ and $p^e_{s,t+1}$ represent the expected price of corn and soybean, respectively.

As noted by Shumway, single-equation estimates may not fully maintain or test all restrictions imposed by economic theory. However, satisfaction of all theoretical properties requires a full systems approach which may not be tractable. Even if a full systems approach is tractable, data may limit estimation. Simpler models such as (2) can yield tractable relations among variables, yielding valuable insights. For example, given the acreage response function (2) is homogeneous of degree zero and employing Euler's Theorem, (2) yields

$$(3) \quad \frac{\partial A_{cot,t}}{\partial p^e_{cot,t+1}} p^e_{cot,t+1} + \frac{\partial A_{cot,t}}{\partial \bar{r}} \bar{r} + \frac{\partial A_{cot,t}}{\partial R} R = 0.$$

Dividing through by $A_{cot,t}$ converts (3) into elasticity form, and then rearranging terms

$$\epsilon_{p_{cot}} = -\epsilon_{\bar{r}} - \epsilon_R,$$

where ϵ_{pcot}, $\epsilon_{\bar{r}}$, and ϵ_R are the elasticities of acreage with respect to cotton price, input price vector, and profit ratio, respectively. An increase in cotton profits relative to alternative crops (an increase in R) has a positive response on cotton acreage. Thus with $\epsilon_R > 0$ and holding $\epsilon_{\bar{r}}$ constant, the elasticity of cotton acreage with respect to price, ϵ_{pcot}, will become more inelastic as cotton profits increase relative to competing crops. A larger cotton-price change will be required to produce a given change in cotton acreage, because the alternatives to cotton in a rotation are less attractive.

Figure 1 illustrates this effect of improved

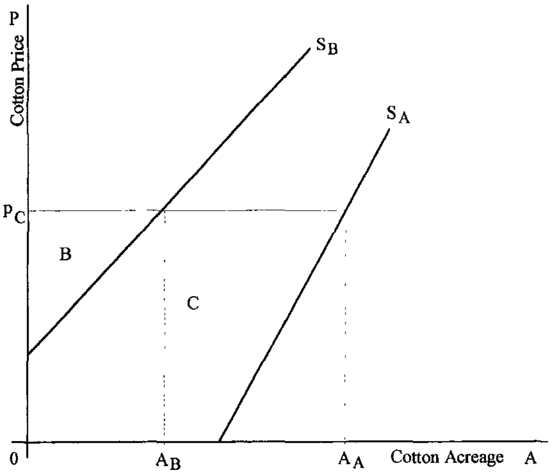

Figure 1. Acreage Supply Curves before, S_B, and after, S_A, Eradication

cotton profitability on acreage supply curves. It is hypothesized the BWE program has resulted in not only a shift in the acreage supply curve, from S_B, before eradication to S_A, after eradication, but also resulted in the supply curve becoming more inelastic. Denoting p_c as the price per pound for cotton, the acreage response before BWE is A_B compared with A_A, the post eradication acreage response. Areas B and $B + C$, in Figure 1, are the per-pound producer surplus associated with acreage supply curves S_B and S_A, respectively. Multiplying these per-pound surpluses by the annual yields after, Y_A, and before, Y_B, eradication result in producer surplus estimates of

$$PS_B = BY_B,$$

and

$$PS_A = (B + C)Y_A,$$

where PS_B and PS_A denote producer surplus before and after eradication, respectively. The change in producer surplus, ΔPS, as a result of BWE is then

$$\Delta PS = (B + C)Y_A - BY_B.$$

This change in producer surplus represents aggregate net gains in producer benefits, across all Georgia cotton acreage, above variable costs.[1] Dividing by total cotton acreage would result in net benefits per acre.

As addressed in Ahouissoussi, McIntosh, and Wetzstein and explicitly stated in models (1) and (2), theory postulates that relative profitability influences enterprise selection. Thus, in an analysis of acreage planted, it is important to include the components of relative profitability. These include five major factors: the physical production of the crop, expected crop prices, the prices of substitute crops, changes in relative input prices, and government commodity programs (Ahouissoussi, McIntosh, and Wetzstein). Thus, cotton acreage response in period t, A_t, can be affected by the expected price of cotton, P_t; expected price of the substitute crops, soybean, S_t, and corn, C_t; previous cotton acreage allocation, A_{t-1}; and government programs, D_t. Expected prices for cotton, soybean, and corn are derived from harvest futures prices one month prior to planting. The lagged cotton acreage variable assumes a partial adjustment approach to supply response. Producers can amend their intended output by a portion of their ultimate desired acreage. The inherent sunk cost in farming inhibits rapid conversion to and from cotton production. The impact of government programs was incorporated in the model through the inclusion of an effective diversion payment variable. The effective diversion payments were calculated from the announced diversion payment by multiplying these values by one minus the acreage restriction. In this way, the effective diversion payment value reflects the equivalent value of the diversion payment if there were no accompanying acreage restrictions. This concept is originally due to Houck *et al.*, and has been widely used in modeling acreage response (e.g., Duffy, Richardson, and Wohlgenant; Parrott and McIntosh).

[1] The total society benefits from eradication would also include a change in consumer surplus. A measure of such benefits would be important in determining the overall feasibility of eradication and the level of subsidies as incentives for producer adoption. Such estimates would require the demand for producers' cotton which is beyond the scope of this research.

Based on (1) and (2), the following linear regression model was specified

$$(4) \quad A_t = \beta_{1t} + \beta_{2t}A_{t-1} + \beta_{3t}P_t + \beta_{4t}S_t + \beta_{5t}C_t + \beta_{6t}D_t,$$

where the β_{it}'s are the permanent components of the time varying parameters, $i = 1, \ldots, 6$. Following Parrot and McIntosh, a time trend is not included in the model. Instead the parameters themselves are allowed to vary over time. It is hypothesized that a farmer's own price of cotton and lagged cotton acreage should positively influence planted cotton acreage, whereas prices of soybean and corn should elicit a negative cotton acreage response. It is further hypothesized that if government diversion programs are offered program participation will reduce planted acres. Also, the implementation of BWE and the subsequent elimination of the boll weevil should stabilize cotton production. Stabilized production would result in a smaller post-program γ parameter which, as discussed in the Estimation Method section, provides a measure of the relative importance of permanent changes occurring in the Cooley-Prescott regression coefficients.

Data

Cotton acreage data for 1966 to 1995 were obtained from the Georgia Agricultural Statistics Service. For cotton, soybean, and corn futures prices, average prices from the closing daily contract prices of the Chicago Board of Trade were employed. The average cotton price is based on March average prices for a December harvest. March prices were employed given that the cotton planting season begins in April. Similarly, average April prices for a September harvest were employed, given that planting of soybean begins in May. As the corn planting season begins in March, prices from February were used to obtain the average price for a December harvest. Following Parrot and McIntosh, relative prices where obtained by deflating these future prices with a national index of prices paid by farmers for all production items, I_t (USDA, Agricultural Prices). Government program data were obtained from USDA Commodity Fact Sheets for upland cotton.

Estimation Method

The Cooley and Prescott approach assumes that the parameters to be estimated are the sum of both transitory (in the current period) and permanent (continuing into the future) changes. Transitory disturbances in the intercept are treated as the customary additive error term. Permanent elements of parameters fluctuate over time without inclination of returning to a mean value (Cooley and Prescott 1973). Thus, parameters vary from one time period to another on the basis of a nonstationary probabilistic scheme (Judge *et al.*). This feature distinguishes the Cooley and Prescott approach from other time-varying parameter models, such as the return to normality model, which places a more restrictive structure on the parameter variation (Judge *et al.*).

The time-varying parameter model is constructed as follows

$$(5) \quad y_t = X_t'\beta_t \qquad t = 1, 2, \ldots, T.$$

where y_t is the t^{th} observation relating to the dependent variable, X_t is a k component vector of explanatory variables, and β_t is a k component vector of parameters subject to stochastic variation. The changes in the parameters over time are of two types, permanent and transitory. The sources of variation are modeled as

$$(6) \quad \beta_t = \beta_t^p + u_t, \qquad \beta_t^p = \beta_{t-1}^p + v_t,$$

where p signifies the permanent component of the parameters. The terms u_t and v_t are independent normal random vectors with mean vectors zero and covariance structures such that

$$(7) \quad E(u_tu_t') = (1 - \gamma)\sigma^2 \textstyle\sum_u, \qquad E(v_tv_t') = \gamma\sigma^2 \textstyle\sum_v,$$

with $0 \leq \gamma \leq 1$. Σ_μ and Σ_v are assumed known up to scale factors and normalized so that the element corresponding to the intercept is unity. Σ_μ and Σ_ν provide inference concerning the relative variability of the parameters. The relative significance of the permanent element of parameter variation is gauged by the unknown parameter, γ. If γ is close to 1, then permanent changes are large relative to transitory ones.

The goal of estimation is to acquire estimates for γ, σ^2, and the permanent components of β_t. Since the process generating the parameters is not stationary, the maximum likelihood function cannot be defined. However, the likelihood function is defined for the parameter process at some point in time; thus, the process can be "stopped" at a specific point and a well-defined likelihood function constructed. The log likelihood function at a particular point may be written as

$$(8)\quad L(Y;\ \beta,\ \sigma^2,\ \gamma,\ X) = -T/2(\ln 2\pi + \ln \sigma^2 + 1/T \ln|\Omega_{(\gamma)}|) - 1/2\sigma^2(Y - X\beta)'\Omega_{(\gamma)}^{-1}(Y - X\beta).$$

By partially maximizing the log likelihood function with respect to β and σ^2, and substituting these into (8) we can obtain the concentrated likelihood function (Cooley and Prescott 1976)

$$(9)\quad L_c(Y;\ \gamma) = -T/2(\ln 2\pi + 1) - T/2 \ln \sigma^2_{(\gamma)} - 1/2 \ln|\Omega_{(\gamma)}|.$$

Maximization of (8) may now be carried out by maximizing (9) with respect to $\gamma \in [0, 1]$. Equation (9) can be evaluated over a number of points accomplish this, an estimate of γ (e.g., g) is chosen such that

$$(10)\quad L_c(Y;\ g,\ X) \geq L_c(Y;\ \gamma_i,\ X) \quad \text{for all } i.$$

Cooley and Prescott (1976) show that (10) provides a consistent estimator of γ. This indicates that the estimates of β and σ^2 are asymptotically efficient. Cooley and Prescott suggest that it is reasonable to assume, *a priori*, that the permanent and transitory changes are equally important for all parameters. This implies that the matrices Σ_μ and Σ_ν are equal and, if changes in the parameters are not assumed to be correlated, then both matrices can be assumed diagonal.

Model Results

Results from applying the adaptive regression model to (4) are listed in Table 1. Except for 1995, the estimates for γ appear to be larger during pre-program (1966–1985) compared with post-program (1991–1995) eradication. This would support the hypothesis that elimination of the boll weevil will stabilize cotton production. The mean values for γ are 0.29 and 0.20 for the pre-program and post-program time periods, respectively. However, the hypothesis that these mean values are not significantly different cannot be rejected at even a 75-percent confidence level.

In contrast, the parameters associated with lagged cotton acreage are all positive and predominately significant at the 5-percent level. Thus, producers take over a year to fully adjust their planting decisions in response to exogenous shocks, such as the BWE. This result partially explains Ahouissoussi, Wetzstein, and Duffy's inability to link cotton crop acreage with BWE. Given their truncated data, they were not able to measure the full acreage-adjustment process.

Parameters associated with cotton price are generally significantly different from zero at the 10-percent level with the hypothesized positive sign. Based on these parameters, the mean own-price elasticities are 1.67 and 0.41 for pre-program and post-program eradication, respectively. These elasticities are significantly different from each other at the 1-percent level, indicating, as hypothesized, a more inelastic acreage response as a result of improved profitability from BWE.

This lack of producer interest in shifting acreage out of cotton is further evident in the cross-price elasticities of cotton acreage with soybean and corn prices. The mean values of these cross-price elasticities are −1.00 and −0.25 for soybean and −0.58 and −0.16 for

Table 1. Parameter Estimates and Asymptotic Standard Errors for Georgia Cotton, 1966–95

Year	γ	Intercept	Lagged Acreage	Cotton Price	Soybean Price	Corn Price	Government Programs
1966	0.98	−17.73	0.38	609.87	−12.07	−4.16	−6.15
		(107.07)[a]	(0.16)**	(256.22)**	(17.53)	(45.01)	(823.35)
1967	0.98	−14.61	0.35	587.36	−11.96	−2.00	−37.21
		(105.68)	(0.20)*	(213.43)**	(17.28)	(44.30)	(781.34)
1968	0.98	23.83	0.28	797.28	−20.47	−36.25	−327.47
		(108.21)	(0.20)	(248.53)**	(15.63)	(40.38)	(857.12)
1969	0.82	6.52	0.50	620.19	−16.86	−15.84	−636.09
		(108.79)	(0.18)**	(260.81)**	(17.82)	(46.35)	(787.37)
1970	0.98	57.12	0.50	214.53	1.60	15.38	−1139.47
		(94.17)	(0.17)**	(154.06)	(15.42)	(23.01)	(667.24)*
1971	0.54	9.53	0.75	633.38	−26.42	−29.52	−18.51
		(117.37)	(0.18)**	(310.84)*	(17.26)	(47.41)	(889.63)
1972	0.20	2.53	0.89	673.67	−41.09	−36.35	−500.32
		(110.22)	(0.15)**	(327.96)**	(18.79)**	(48.58)	(943.65)
1973	0.08	−7.30	0.94	757.55	−46.72	−53.08	−624.88
		(102.15)	(0.14)**	(356.56)**	(19.47)**	(52.69)	(969.87)
1974	0.06	−1.09	0.95	754.96	−47.37	−56.69	−706.22
		(96.99)	(0.14)**	(356.53)**	(19.82)**	(52.43)	(964.00)
1975	0.06	0.17	0.91	761.87	−47.46	−58.23	−727.88
		(94.63)	(0.15)**	(358.17)**	(20.12)**	(53.07)	(968.14)
1976	0.06	8.41	0.91	761.95	−46.41	−62.73	−748.10
		(91.33)	(0.16)**	(356.58)**	(20.25)**	(52.20)	(974.84)
1977	0.00	64.02	1.11	835.79	−58.71	−90.81	−958.50
		(83.57)	(0.11)**	(378.36)**	(20.48)**	(54.36)	(1015.57)
1978	0.32	−15.37	0.41	609.38	−25.58	−39.85	−772.94
		(79.06)	(0.24)*	(326.06)*	(19.23)	(50.69)	(853.39)
1979	0.62	29.65	0.23	558.25	−31.59	−10.00	−996.01
		(62.23)	(0.31)	(280.08)*	(15.70)*	(39.71)	(733.76)
1980[b]	0.00	64.02	1.11	835.79	−58.71	−90.81	−958.50
		(83.57)	(0.11)**	(378.36)**	(20.48)**	(54.36)	(1015.57)
1995	0.98	−14.19	1.47	609.64	−10.81	−6.38	−2.33
		(105.77)	(0.08)**	(261.07)**	(17.70)	(47.93)	(820.32)

[a] Asymptotic Standard errors are in parentheses. Single and double asterisks denote significance at the 0.10 level and the 0.05 level, respectively.

[b] For years when $\gamma = 0$, the parameter estimates and standard errors are identical. This occurred for years 1977, 1980–1994.

corn for pre-program and post-program eradication, respectively. These pre- and post-program elasticities are also significantly different from each other at the 1-percent level.

The parameters associated with the government diversion variable are generally not significant at the 10-percent level. Only for 1970 is the parameter significant at the 10-percent level. This year is within the time period (1966–1974) that the support program was in place. These results indicate government support has had limited effect on crop acreage, a finding which agrees with the results of Parrott and McIntosh.

BWE Net Benefits

Based on the parameter estimates in Table 1, the benefits of the BWE may be calculated. Taking the pre-program and post-program mean values of lagged acreage, soybean and corn prices, and government programs, the

Table 2. Benefits from BWE

Price[a]		Producer Surplus (millions)		Annual Net Benefit
Deflated	Nominal	Pre-BWE	Post-BWE	Per Acre
0.327	0.589	$5.479	$138.542	$88.73
0.219	0.395	0.389	82.247	54.60
0.404	0.728	12.340	186.748	116.27

[a] Prices listed down the columns are average, low, and high prices from 1986 to 1995.

acreage supply functions illustrated in Figure 1 are

(11) Pre-Program Acreage Supply, S_B:

$$P = 0.1387 + 0.0014A,$$

(12) Post-Program Acreage Supply, S_A:

$$P = -0.4747 + 0.0013A.$$

This represents a significant shift to the right of the acreage supply curve as a result of the BWE. Based on (11) and (12) the areas B and C in Figure 1 were calculated. These areas were based on deflated prices per pound of cotton listed in Table 2. Terms Y_B and Y_A, a five-year average of the last pre-program and post-program annual yields, are 629 pounds. and 731 pounds., respectively. This approximate 100 pound difference as a result of the BWE is consistent with the results found by Ahouissoussi, Wetzstein, and Duffy. Calculating the producer surplus and noting $I = 1.80$ on average from 1991 to 1995, results in a range of changes in producer surplus listed in Table 2. Differences in pre- and post-producer surplus represent aggregate net gain in benefits above variable costs across all Georgia cotton acreage. Dividing by total cotton acreage in 1995 of 1.5 million results in annual net benefits per acre listed in Table 2. These annual net benefits are consistent with the net returns of approximately $70.00 found by Carlson, Sappie, and Hamming.

This increase in net benefits from BWE explains the more inelastic own- and cross-price elasticities in the post-program years compared with the pre-program years. Returns from alternative crops, specifically soybean and corn, are not currently comparable with these benefits and thus limit the acreage response from price shifts. Prior to BWE, returns from Georgia cotton production, if positive, were generally very low. As Table 2 indicates, pre-BWE producer surpluses are relatively small compared to post-BWE surpluses. This accounts for the general decline in cotton acreage prior to BWE. Although not very profitable, cotton served as a rotation crop for more profitable crops such as peanuts. Thus, price fluctuations between cotton and substitute crops would result in cotton being brought in and out of a rotation. However, as the results indicate, post eradication has resulted in cotton production becoming a major source of revenue for Georgia agriculture. BWE has reestablished cotton as a major crop in Georgia with returns well above costs.

Conclusions

Results indicate a significant increase in Georgia cotton acreage as a result of BWE. Although not directly comparable with potential acreage response from BWE in other states, these results do suggest significant shifts in acreage response is possible from BWE. Knowledge of the resulting increase in net benefits from BWE will provide supporting evidence of the potential value for continuing the eradication program westward. The resulting increase in producer surplus offers strong incentive for continued eradication efforts.

On a technical economic theory front, a structural shift in acreage response is apparent as a result of BWE. This suggests a possible shift in the production efficiency frontier for cotton production. Research investigating the hypothesis of improved production efficiency as a result of BWE would offer additional insights into adoption of pest eradication programs.

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