Economic Returns to the Boll Weevil Eradication Program

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Abstract

The economic viability of the Boll Weevil Eradication Program in Alabama, Florida, and Georgia is assessed based on a five-year survey of producers. Results indicate the program increases yield 100 pounds per acre. This implies a 19 percent internal rate of return for producers over a ten-year period.

Key words: cotton, pest management, regional pest control

Boll weevils first infested the United States in the 1890s and since that time have consistently ranked high among insects causing economic crop damage (Taylor *et al.*). Approximately seven out of 12 million acres of U.S. cotton are infested with the boll weevil (Carlson *et al.*). In the southeastern United States, cotton is exposed to insect infestations for approximately 100 days during fruit set. The insects, particularly the boll weevil, cause damage that results in an estimated seven to 20 percent reduction in yields (Carlson and Suguiyama).

Inexpensive synthetic organic products introduced to agriculture after World War II allowed southeastern cotton producers to adhere to a "sterile field" philosophy. This results in up to 20 insecticide applications per season, compared to only one or two applications for soybean pest control. Prior to any boll weevil eradication (BWE) program within the U.S., 64.1 million pounds of insecticides per season were applied for control of cotton insects, at a cost of over $200 million annually (Ridgway *et al.*). Such high levels of insecticide use are costly to producers and may result in serious environmental degradation. Agricultural pesticide and chemical nutrient applications are causes of groundwater contamination in 37 states (Nielsen and Lee). Both the high dollar costs and possible environmental problems related to boll weevil control resulted in producers, with USDA cooperation, establishing the Southeastern BWE Program. BWE, presently active in Alabama, Florida, and Georgia, has the single purpose of eliminating this insect pest.

In terms of reduced insect numbers, the BWE program in Alabama, Florida, and Georgia appears successful. In some cases, populations were reduced from over 50 million boll weevils to only three weevils per 1000 acres (Lambert). However, this apparent biological success may not translate into economic feasibility. Accordingly, the purpose of this paper is to analyze the benefits and costs of BWE in Alabama, Florida, and Georgia. The analysis is based on five years of producer-survey data concerning costs and yields.

BWE Program

In 1978, the first BWE program began as a trial experiment on 20,000 acres of cotton in the

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northeastern corner of North Carolina. From there the program spread first into all of North and South Carolina and subsequently covered parts of Alabama, Florida, and Georgia. The Animal and Plant Health Inspection Service (APHIS) administers the program and conducts and/or oversees all program pesticide applications, surveys, and trap monitoring. Cotton producers pay 70 percent of the program costs, with USDA financing the remainder. Szmedra *et al.* provide a discussion of the mechanics underlying the program.

When boll weevil infestation is high, cotton requires relatively early applications of insecticides to mitigate weevils' effects. Once insecticides are applied in a given crop season, the beneficial insects are also reduced, so that pest reinfestations are no longer mitigated by beneficials. Continued insecticide applications are thus required throughout the remainder of a season. Insecticides may also have undesirable effects on a cotton plant. Tests in North Carolina indicate that early applications of methyl parathion can result in a 30 percent yield reduction by delaying the maturation process of the cotton plant (Grube and Carlson). This yield reduction is relative to untreated and uninfested cotton, and such insecticide applications would take place only if producers believe that the infestation, left untreated, would result in even higher losses.

BWE Program Evaluation

A comparison of discounted program benefits with discounted costs is employed in this evaluation for assessing the net benefits to producers of the BWE program. Program costs are evaluated in terms of both private costs and full costs. Private costs are the per-acre assessments made to cotton producers. Full costs include the private costs plus government costs. These full costs were $23.00 in 1986, $48.00 in 1987, and $35.00 per year for 1988 through 1990. Per-acre assessments against producers were 70 percent of these full costs. Program costs in 1986 and 1987 represent start-up costs, with the program actually starting in 1988. After 1990 producers contribute a ten-dollar-per-acre maintenance cost to prevent reinfestation.

Benefits from the BWE program are much more difficult to measure. A substantial reduction of the boll weevil population changes cotton producers' production practices, potentially allowing higher yields with lower insecticide costs. The resulting increase in per-acre profits for cotton may result in expanded cotton acreage. These BWE effects were discovered in North and South Carolina by Carlson *et al.* and by Carlson and Suguiyama.

For the Alabama, Florida, and Georgia evaluation, per-acre yield benefit, YB, is determined by multiplying the change in pounds of lint harvested, ΔY, by the price of cotton lint, P, adding additional sales receipts from cottonseed per pound of lint harvested, S. The YB is then determined by subtracting additional ginning charges, G, harvesting and hauling costs, $0.11, and market preparation costs (bags and ties), $0.03 from these gross benefits

$$YB = \Delta Y(P + S - G - 0.11 - 0.03),$$

(Givan and Mizelle; Givan and Shurley). A price of $0.53 per pound for cotton lint was employed based on the average 1975 through 1989 farm level price. It is assumed that this extra production, ΔY, will not lower the price of cotton significantly, because Southeastern cotton production is less than two percent of world and ten percent of U.S. production.[1] This price is low, given current market situations for cotton, and thus would result in conservative estimates of program benefits. Cottonseed returns, S, were assumed equal to ginning costs, G, as is customary, so these effects cancel each other.

The BWE program could also benefit producers through lower per-acre insecticide costs, so per-acre benefits are the sum of yield benefits and these lower insecticide costs. In addition to these per-acre benefits, the BWE program could also encourage expansion of cotton on acres currently being planted in other commodities (Carlson *et al.*).

Net present value, NPV, of the program is then calculated by subtracting the discounted stream of program costs from the stream of benefits, B.

$$NPV = \sum_{t=0}^{T} \beta^t (B_t - C_t),$$

where C is annual program costs, either full or private, ß and T denote the discount factor and terminal time, respectively, and t is a time subscript.

Cotton Producer Survey

Estimates on the magnitude of change in pounds of lint, ΔY, and insecticide cost, ΔI, were obtained by empirical evaluation based on survey data. Data were obtained on cotton production practices detailing yields, acreage, and insecticide applications before and after the initiation of the BWE program. This evaluation was based on mail surveys and telephone interviews with Alabama, Florida, and Georgia cotton producers in each production season from 1986 through 1990. The first BWE program insecticide applications took place in 1988; thus, the 1986 and 1987 crop year survey information functions as a benchmark against which to measure changes brought about by the program.

In the survey, farmers were asked to provide information on cotton yields and acreage as well as to complete a detailed schedule of insecticide applications. For this schedule, farmers were asked the date of each application, the application method, the amount and kind of insecticide used, number of acres covered, and the target insect. Details of the survey results and a copy of the survey instrument can be found in Ahouissoussi.

The study area comprised the major cotton-producing counties of Alabama, Florida, and Georgia. In Alabama, approximately 63 percent of the 380,000 acres planted in cotton were in the counties surveyed. In Florida, 37,600 acres of cotton were planted in 1990, with approximately 54 percent of the acreage in one survey county, Santa Rosa. For Georgia, an estimated 355,000 acres of cotton were planted in 1990. Of this total acreage, approximately 45 percent was planted in the counties covered by the survey.

A total of 1,919 usable survey observations were obtained over the five years of the survey project. Because some producers rotated out of cotton production during the period, quit farming entirely, or were not available to answer the survey in a particular year, it was not always possible to interview the same producers in every year. Thus, the producers surveyed varied somewhat from year to year. Some producers may not produce cotton continuously because of crop rotation concerns. This explanation may be particularly applicable to peanut producers with small cotton acreage, as large-scale cotton producers in much of the region are not generally following a rotation (Mims *et al.*). Some producers may have switched out of cotton production during the higher cost "start-up" years of the BWE program, with plans to return to cotton production in future years. Table 1 presents summary statistics of the key survey variables.

Changes in cotton yields attributable to the BWE program are difficult to detect from visual inspection of the data in table 1. There is a great deal of year to year variation in cotton yields with no detectable trend. The variations and lack of trend are also apparent in published U.S.D.A statistics presented in parenthesis and may be explained by differing weather conditions and insect pest pressure across years.

Average cotton acreage per farm increased during this period, rising from an average of 228 acres surveyed in 1986 to 371 acres per farm surveyed in 1990. In only one of the survey years, 1989, did acreage per farm decline from the preceding year.

Per acre costs of insecticides do not include application costs, any pest scouting, or BWE program payments. The mean application costs were $1.78 for ground and $1.48 for air application. Boll weevil costs of $1.06 and $1.21 for 1986 and 1987 are consistent with published data of $0.84 and $1.25 for corresponding years (Douce and McPherson, 1988; Douce and Suber). Comparable costs for 1988, 1989, and 1990 are not available. Summary statistics on per-acre insecticide costs do not reveal any strong effects of the BWE program. In the years after BWE program initiation, 1988 through 1990, other insects costs are higher, compared with the pre-program years, 1986 and 1987. This may not fit conventional wisdom of entomologists that when the boll weevil is eradicated, there will be more beneficials and less secondary insects pest outbreaks and thus less use of insecticides. Unfortunately, during the survey

Table 1. Individual Producers Survey Summary Statistics

Variable	Mean	Standard Deviation	Maximum	Minimum
1986				
Yield[a]	503.00 (556)	361.60	1400	0
Cotton Acreage	228.22	289.71	2600	0
Boll Weevil Costs[b]	1.06	0.61	3	0
Other Insects Costs[c]	13.10	9.73	98	0
Number of Applications[d]	11.82	7.19	47	1
1987				
Yield[a]	613.93 (626)	238.70	1400	0
Cotton Acreage	275.00	361.79	2600	3
Boll Weevil Costs[b]	1.21	1.00	10	0
Other Insects Costs[c]	13.61	10.77	116	0
Number of Applications[d]	10.73	6.67	35	1
1988				
Yield[a]	465.61 (538)	256.14	1200	0
Cotton Acreage	305.94	398.63	4122	4
Boll Weevil Costs[b]	2.28	4.11	29	0
Other Insects Costs[c]	56.68	63.03	486	0
Number of Applications[d]	6.48	5.03	33	1
1989				
Yield[a]	623.96 (586)	223.32	1217	0
Cotton Acreage	294.82	380.26	3500	4
Boll Weevil Costs[b]	1.54	1.89	11	0
Other Insects Costs[c]	24.58	28.23	250	0
Number of Applications[d]	7.23	4.85	33	1
1990				
Yield[a]	483.09 (552)	217.98	1100	16
Cotton Acreage	371.27	439.91	3450	0
Boll Weevil Costs[b]	1.01	0.72	4	0
Other Insects Costs[c]	36.88	42.84	320	0
Number of Applications[d]	3.55	2.73	16	1

[a] Average of Alabama, Georgia, and Florida yields, published in U.S.D.A. Agricultural Statistics, appears in parenthesis.
[b] Individual producer's costs per acre per application, not including application costs.
[c] Sum of individual producer's costs per acre per application for each insecticide other than for boll weevils, not including application costs.
[d] Individual producer's number of boll weevil applications per acre.

period 1988 through 1990, there was a major outbreak of beet armyworm. This resulted in average beet armyworm insecticide costs for Georgia increasing from $16.56 for years 1986 and 1987 to $39.15 for years 1988 through 1990 (Douce and McPherson; Douce and Suber). The average number of boll weevil applications fell somewhat from approximately 11 per season over the 1986 through 1988 period to around seven and 3.5 per season in 1989 and 1990, respectively. The standard deviation and maximum number of boll weevil applications indicate a steady decline.

Estimation on Changes in Yield

Cotton yield is affected by many factors, including rainfall, temperature, soil quality, pest control practices, planting dates, fertilizer use, seed variety, and managerial ability. The market price of cotton is an economic factor which may affect yield by providing incentives for higher use of inputs, such as fertilizer, to increase yields. From a biological perspective, the BWE program should cause a yield gain both by eliminating direct damage from the insects themselves and also by reducing the requirement for early-season insecticide applications. With no early-season boll weevil insecticide applications, natural predators of other cotton pests are preserved, which may reduce later-season insecticide applications. Also early-season insecticide applications adversely affect plant development, which partially offsets the positive impact on yields by the insecticide reducing boll weevil populations. This reduction in the boll weevil population may provide opportunities for an improved integrated pest control program targeting other cotton pests.

Because of the interaction of many factors in determining cotton yields, the possible yield effects of the BWE program cannot be determined by simple examination of average yields over the study period. Accordingly, a regression model similar to those used by Carlson and Suguiyama and Carlson *et al.* to estimate the yield effects of BWE in the Carolinas was hypothesized and fitted to the data

$$(1)\quad Y_{t,i,j} = \alpha_0 + \beta_1 P_{t-1} + \beta_2 C_{t,i} + \beta_3 AD_{t,j} + \beta_4 BD_{t,j} + \beta_5 R_{t,j} + \beta_6 T_{t,j} + \beta_7 DBWE_t + \beta_8 DS_{t,i} + \Sigma\, \gamma_j D_j,$$

where Y, P, and C denote cotton yield in pounds of lint per acre, lagged yearly average farm level price of cotton per pound, and producer's insecticide costs per acre, respectively. The subscripts t, i, and j represent time, producers, and county, respectively. Armyworm damage, AD, and boll weevil damage, BD, represent county estimates of per acre dollar losses from the respective pest each year (Lambert *et al.*). Weather variables R and T are annual county rainfall in inches and annual average county temperature in degrees Fahrenheit, respectively. BWE program is represented as a dummy variable, DBWE, with a value of zero in the pre-BWE program years of 1986 and 1987 and one otherwise. Another dummy variable is used for cotton scouts, DS, with a value of one if scouts are used by a producer and zero otherwise. The final variables are county-specific dummy variables, D_j.

A one-year lag is used on market price because harvest prices are unknown at planting time. Although a high proportion of cotton producers enroll in farm programs, effective support prices (see Houck and Subotnik) are not the appropriate price variable for estimating yield response. Farm program payments are made on "proven yield," a fixed county-level figure. Thus, increases in yield above the proven yield level would not be eligible for support payments.

The county armyworm and boll weevil damage variables are measures of insect pest infestation. These variables are based on entomologists' subjective estimates of insect damage and infestation. A major component of these estimates are insect counts, taken at various places and times by extension and individual growers throughout the growing season. The damages are calculated as an expected reduction in yield associated with a particular insect infestation and may or may not reflect actual yield loss. For a discussion on the methodology used to estimate damage, refer to Suber and Todd.

It was hypothesized that the BWE program, lagged market price, and the use of scouting would have positive effects on cotton yield. Scouting is a measure of management ability and may serve as a surrogate for overall changes in management. The county armyworm and boll weevil damage variables would normally be assumed to have negative impacts on cotton yield because they indicate the level of expected damage to the crop. However, early estimates of county boll weevil damage may prevent further yield loss, because a higher level of expected county damage would result in a greater BWE program insecticide application effort. These program applications may also reduce other insect pests, and consequently reduce yield loss over the entire growing season. The effect of the insecticide cost variable is also indeterminate. High control costs may imply either high pest densities, intensive management, or both. Increased temperature and rainfall would be expected to result in increased yields, but too much rain near harvest may be detrimental to the crop. Similarly, low temperatures during the growing season may retard growth, but low winter temperatures may reduce insect pressure in the following growing season.

Table 2 presents regression results for cotton yield. The only strong evidence of possible multicollinearity, based on a condition number of 228, exists between the intercept and temperature. The Durbin-Watson statistic was 1.687, within the inconclusive range for testing the null hypothesis of no autocorrelation.

The coefficient associated with BWE has the expected sign and is significant at the ten percent level. This result indicates that the BWE program caused yields to increase by approximately 100 pounds over what they would have been in the absence of the program. These results are comparable to a 69-pound-per-acre yield gain obtained by Carlson *et al.*, who investigated cotton yield gain from the BWE program in North and South Carolina.

As expected, cotton market price and the use of scouting have positive impacts on yield, and armyworm damage has a negative impact. The variable for the individual producers' insecticide costs showed a statistically significant effect on yields, but the value of the estimated coefficient was small, 0.51, indicating a half pound increase in yield per each dollar spent on insect control. The coefficient for the variable concerning measured boll weevil damage is positive, probably suggesting that early expected damage does lead to increased BWE program control and subsequent reduced yield loss. Both rainfall and temperature have positive and significant parameters in this model.

Regressions similar in form to the yield regression were also employed for determining BWE program affects on producers' insecticide costs and cotton acreage. Results for these equations indicated no significant relation between BWE and either insecticide cost or acreage per farm. One explanation for no significance between BWE and insecticide cost was the relatively large increase in other insect pests, particularly beet armyworm, in 1988 through 1990. Unfortunately, not since 1977 was there such a widespread outbreak of beet armyworm. This resulted in a significant increase in control costs offsetting any possible gains in decreased costs from BWE. Consequently, these results diverge from results obtained by Carlson *et al.*, who found the BWE program to lower costs and increase acreage in the Carolinas. Overall, for the Alabama-Florida-Georgia area, the BWE program was found to increase yields by approximately 100 pounds an acre, but to have no statistically detectable effect on acreage or variable costs.

Net Present Value Results

The estimate of a 100-pound increase in cotton yields has a standard deviation of 36 pounds per acre. To account for this variation, the net present value of a 64-, 100-, and 136-pound increase in cotton yields was calculated under alternative discount rates and time horizons. Discount rates of five, ten, and 15 percent were used with time horizons of five and ten years, beginning in 1986. Table 3 presents the net present value results to public and private expenditures on BWE based on a 64-, 100-, and 136-pound per acre increase in cotton yields. A five-year time horizon results in positive returns for only the producers' expenditures with optimistic 136-pound gain in yield. Considering a ten-year horizon with an optimistic 136-pound gain, positive net returns also exist for both full program costs and producer's cost share. The internal rate of returns associated with full program costs and producer's cost respectively are 24 and 52 percent, for a 136-pound gain with a ten-year horizon. At a 100-pound gain, producer's share also exhibits positive net returns with an internal rate of return of 19 percent. Such a return is comparable with rates ranging from eight to 30 percent, with a median of 15 and a mean of 17 percent, which private companies commonly consider as favorable for investment projects (Summers). In this ten-year analysis, only program benefits associated with yield gain are considered. Within this longer time period there may be other BWE benefits, including insecticide cost savings, land value increases, and reduced environment degradation. Although survey results did not indicate any decreased cost associated with the BWE program, over a longer horizon with more normal pest infestation rates such an affect might be discovered.

Table 2. Alabama, Florida and Georgia Cotton Yield (lb/ac) Regression Results, 1986-1990

Variable	Estimated Coefficients	Standard Error
Intercept	-1858.07[a]	338.34
BWE Program Dummy	100.46[b]	36.32
Cotton Market Price	17.39[a]	1.95
Grower Pesticide Costs	0.51[a]	0.10
Armyworm Damage	-1.56[a]	0.36
Boll Weevil Damage	8.31[a]	0.91
Scout Dummy	66.50[a]	14.26
Average Rainfall	52.20[a]	11.83
Average Temperature	12.53[a]	4.43
County Dummies		
Bleckley	105.66[a]	23.17
Brooks	223.12[a]	22.37
Calhoun	274.90[a]	24.10
Colquitt	261.06[a]	16.20
Mitchell	350.96[a]	26.46
Morgan	30.59	45.71
Pulaski	125.36[a]	26.89
Santa Rosa	49.50	33.00
Elmore	100.71	60.50
Henry	-82.45	71.06
Lee	-43.51	103.35
Madison	93.66	71.44
F Value	42.01[a]	
R^2	0.31	

[a] .01 significance level
[b] .10 significance level

Table 3. Net Present Value to Public and Private Expenditures for Alternative Yield Gain and Three Discount Rates and Two Time Horizons

Program Costs	Yield Gain[a]	Horizon (years)	Discount Rate 0.05	Discount Rate 0.10	Discount Rate 0.15	Internal Rate of Return
Public and Private[b]	64	5	$-126.06	$-116.86	$-109.04	-
	100	5	-61.92	-60.81	-59.71	-
	136	5	-12.64	-17.86	-21.98	-
	64	10	-186.61	-160.88	-141.62	-
	100	10	-44.11	-47.87	-50.12	-
	136	10	72.83	44.27	24.01	24%
Private	64	5	-64.93	-61.43	-55.77	-
	100	5	-15.65	-18.48	-20.68	-
	136	5	33.62	24.47	17.04	32
	64	10	-79.17	-71.79	-66.07	-
	100	10	37.77	20.35	8.06	19
	136	10	154.72	112.50	82.20	52

[a]Yield gain is based on 100-pound increase in yields with a standard deviation of 36 pounds.
[b]Producers' expenditures are 70 percent of yearly program costs with public expenditures contributing the remaining 30 percent.

Conclusions

Results of this analysis indicate that private costs of the BWE program are completely covered through program benefits given a yield increase of 100 pounds and a 10-year horizon. However, full costs are not covered until a 136-pound yield increase is assumed, an increase of one standard deviation over the level suggested by regression analysis. Thus, a government subsidy of the program was probably a crucial component of producers' decisions to accept the program. Without this subsidy, producers would probably not have recovered their outlays in a timely fashion. This government subsidy of 30% does not include salaries of APHIS personnel for the management of the program, and thus, assumes the marginal cost of this additional management is zero. If the marginal cost is greater than zero, then the level of the subsidy considered is an under estimate. The government's willingness to subsidize the program most likely stems from expected nonmonetary benefits, such as reduced environment degradation stemming from reduced pesticide levels over the long run.

Widespread pest eradication programs are becoming technically more feasible with improved understanding of pest population dynamics. Proper economic assessment of the net benefits of these programs depends on collection of pest management information from affected producers, a procedure that is often both time consuming and costly. While the five years of data used in this study are sufficient for assessing the short-term program impacts, a longer time series would be useful for a thorough assessment of the program's long-term consequences. In particular, it is expected that over a longer time horizon, the increased profitability of cotton would lead to higher cotton acreage. In the short run, acreage expansion is often limited by machinery and/or farm program concerns. The limited cross-compliance provision and the five-year base calculation in the 1985 Farm Bill may have prevented some farmers from expanding cotton acreage. The 1990 Farm Bill, on the other hand, provides a more favorable climate for acreage expansion.

Results of the analysis indicate that the BWE program was economically justifiable to producers in the short run, given the increase in cotton yields. In this study area weevil elimination is still in progress, so longer term results should be even more favorable. Program officials have predicted that at least one more year will be required for eradication in the eastern part of the study area and perhaps one or two more years in the extreme southern and western areas (Lambert *et al.*, 1991). After the weevil is eliminated, a containment program will be maintained to prevent reinfestation. Once the weevil is controlled, additional research will be required to help producers mitigate current problems with secondary pests. Only then will the full long-run consequences of the program be felt.

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Endnotes

1. This assumption is supported by the Duffy and Wohlgenant model. If a percentage change in yield (supply), δ, measuring the yield effect of BWE, is incorporated into their equation (9a), then Duffy and Wohlgenant's equation 12a becomes

$$dlnP = \frac{-\delta}{(\varepsilon - \alpha_d\eta_d - \alpha_x\eta_x)}$$

where ε, η_d, and η_x denote elasticities of supply, domestic demand, and export demand, respectively, and α_d and α_x are the shares of production sold domestically and exported, respectively. Letting $\varepsilon = 0.3$, $\eta_d = -0.3$, $\eta_x = -2.0$, and $\alpha_d = \alpha_x = 0.5$ (Duffy and Wohlgenant)

$$dlnP = -0.690\delta.$$

As reported in the empirical results, the BWE program may increase yields 100 pounds per acre. This increase in cotton yields, throughout the Southeast, would increase total U.S. production by approximately 100 million pounds. Southeast acreage is about one million harvested acres. U.S. base production of cotton is approximately 12 million bales or 5760 million pounds, so $\delta = 0.017$ and $dlnP = -0.0117$. The effect of the whole Southeast increasing yields per acre by 100 pounds is only a decrease in cotton price of about one percent. Thus, with an initial price of $0.53 per pound, the BWE program in the Southeast would be expected to reduce price by less than a penny a pound, a negligible effect.