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The Cotton Acreage Effects of Boll Weevil Eradication: A County-Level Analysis

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ABSTRACT

The success of the Boll Weevil Eradication (BWE) Program is believed to be one factor underlying the recent increase in cotton acreage in the Southeast. We find weak evidence that the initial, eradication phase of the BWE program decreases cotton acreage, and strong evidence that the second, maintenance phase of the program increases acreage. The full benefits associated with a BWE program may not become apparent until acreage adjustments occur, four to five years after program initiation. Our results indicate that for a representative sample county neglecting acreage effects may lead to underestimation of BWE program net benefits by 9 percent-12 percent.

Key Words: *acreage effects and policy evaluation, boll weevil eradication program, cotton, integrated pest management* (IPM).

Observers consider the success of the Boll Weevil Eradication (BWE) program to be one of the primary factors behind the dramatic increase in Southeastern cotton acreage over the past decade. Early studies (Carlson and Suguiyama; Carlson, Sappie and Hammig) indicated that the BWE program increased both cotton yield and acreage. Recent studies (Ahoussoussi, Wetzstein and Duffy) confirmed positive yield effects, but results regarding the effects of the BWE program on cotton acreage have been mixed (Ahoussoussi, Wetzstein, and Duffy; Duffy, Cain, Young, and Wetzstein). This paper estimates the long-run effect of the BWE program on cotton acreage using a 31-year time series of observations on 25 counties in North Carolina, South Carolina, and Georgia. We hypothesize that the initial three-year eradication phase of the BWE program temporarily decreases cotton acreage, while the post-eradication phase of the program increases cotton acreage. Our results support these hypotheses.

Since it first infested U.S. cotton crops in the 1890s, the boll weevil has ranked as one of the major economic pests facing agricultural producers. Boll weevils can reduce cotton yields by 7 to 20 percent (Carlson and Suguiyama), and the traditional means of fighting boll weevil infestations were costly. Cotton producers practiced an expensive "sterile field"

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pest control program, which required up to 20 applications of pesticides per growing season (Ahoussoussi, Wetzstein, and Duffy). Intensive application early in the growing season reduced beneficial insect populations and led to yield-reducing outbreaks of secondary pests unless applications were continued for the remainder of the growing season. Such intensive chemical application may have further reduced cotton yields by stunting the development of the cotton plant itself (Grube and Carlson). Intensive chemical use may have also contributed to environmental degradation and human health risks (Suguiyama and Osteen).

Low cotton yields, increasing agricultural chemical costs, and increasing environmental concern eventually led to the consideration of Integrated Pest Management (IPM) (Stern, Smith, van den Bosch and Hagen) as an alternative to sterile field pest control methods in cotton. Three basic practices distinguish IPM: the use of crop scouts to determine pest populations, the use of economic thresholds to determine when pest treatments are necessary, and the use of biological controls and other non-chemical means of pest control. IPM techniques may be used either by individual producers to monitor and control pest populations or by groups of producers in a cooperative regional effort to control or eradicate pests.

The BWE Program

The Boll Weevil Eradication (BWE) program is a regional IPM program for boll weevil control. Boll weevil eradication began as a trial program in the northeastern corner of the Cotton Belt (Virginia and North Carolina) in 1978, and has since expanded southward and westward. The BWE program was originally scheduled to expand throughout North and South Carolina in 1987. Promising results in the trial region resulted in the accelerated expansion of the program throughout North and South Carolina in 1983 (Carlson, *et al.* 1989). Areas in Georgia, Florida and southern Alabama entered the BWE program in 1987. Administered by the federal government, the BWE program in each region consists of two phases. The three-year "eradication" phase aims to eliminate boll weevil populations through intensive, regionally coordinated pesticide application. The "post-eradication" or monitoring phase of the BWE program consists of field monitoring and reinfestation prevention activities. The intensive eradication phase takes about two calendar years and extends over parts of three growing seasons. In the latter part of the first eradication year, insecticides are heavily applied to cotton fields to eliminate overwintering weevils. In the second year, boll weevil populations are monitored in cotton fields, and fields with sufficiently high boll weevil populations are again treated with insecticides. In the third year, in the early part of the season., eradication focuses on eliminating weevils that have overwintered from the second year. In the latter part of the third growing season, field monitoring continues, and fields with sufficiently high weevil populations are treated with insecticides. Monitoring continues in the fourth and successive growing seasons.

The BWE program is administered by state agricultural departments, regional Boll Weevil Eradication Foundations, and the Animal and Plant Health Inspection Service (APHIS) of the USDA (USDA 1997). As a regional eradication effort, a BWE program requires the cooperation of all cotton producers in an eradication region. Accordingly, before an eradication program is implemented, two-thirds of cotton producers within a proposed eradication region must approve the program through a referendum. Once approved, all cotton producers within the region must pay program fees to cover a share of eradication costs. Producers were responsible for 49 percent of eradication costs in North Carolina. In Georgia, Florida and Alabama producers were responsible for 70 percent of eradication costs, although a portion of producer costs were paid by the state government in Alabama (Szmedra, McClendon and Wetzstein; Duffy, Cain, Young and Wetzstein). Remaining costs are paid by the federal government and the states. Producers must also pay relatively small per-acre fees after eradication to finance continued monitoring, spot insecticide treatments and program administration.

With the expansion of BWE programs throughout the Southeast and into other production regions, information concerning the economic benefits and costs of these programs is becoming increasingly important to producers, land owners and government policy makers. A BWE program benefits cotton producers by increasing cotton yields and decreasing insecticide costs. An eradication program may also benefit landowners by increasing land rents and values. In addition, the long-run reduction in pesticide use associated with a BWE program may generate environmental benefits. However, these benefits must be weighed against the costs of BWE programs, including eradication and post-eradication fees paid by cotton producers and government cost-sharing expenses.

BWE Literature Review

BWE research efforts have been motivated by the need to evaluate the economic returns to existing BWE programs and to estimate the potential returns to geographic expansion. Generally, studies have found that eradication programs generate positive net benefits *on pre-eradication cotton acreage* due to increased yields and decreased pesticide use (Carlson and Suguiyama; Ahouissoussi, Wetzstein, and Duffy). However, because BWE programs may cause significant crop switching and acreage expansion (Carlson; Duffy, Cain, Young, and Wetzstein), an assessment of acreage effects is necessary. Strong acreage changes will affect estimates of the net benefits associated with BWE programs. If acreage effects are neglected, it is likely that program costs, primarily associated with the eradication phase of BWE programs, will be overestimated *ex ante,* since cotton producers will reduce cotton acreage during the eradication phase of a BWE program in response to per-acre eradication fees. Similarly, neglecting acreage effects may lead to *ex ante* underestimation of BWE program benefits, since the eradication of the boll weevil will induce producers to increase their cotton acreage *ex post.* In addition, strong acreage effects might impact acreages of substitute crops.

While BWE programs also might have affected government expenditures on agricultural support programs under earlier farm legislation, the Federal Agriculture Improvement and Reform Act (FAIR) of 1996 completely decoupled payments from acreage and production. Under FAIR, growers receive seven years of market transition payments based on previous program participation, regardless of current cropping decisions.

Analytical support for the proposition that the BWE program in North Carolina, South Carolina, and Georgia has increased cotton acreage has been mixed. A preliminary study by Carlson, Sappie, and Hammig found that the BWE program had reversed a downward trend in North and South Carolina cotton acreage. In contrast, preliminary results by Ahuoissoussi and Ahouissoussi, Wetzstein, and Duffy based on eradication phase data from the BWE program in Alabama, Georgia, and Florida found no detectable acreage effect; however, these authors anticipated that data from the post-eradication period of the BWE program in this region would indicate acreage effects. Duffy, Cain, Young, and Wetzstein's farm decision simulation model indicated that the BWE program would significantly increase cotton acres on representative south Alabama farms with and without initial cotton base acres. However, the model also predicted that the BWE program would have smaller acreage effects on a representative north Alabama farm due to smaller yield gains from the BWE program.

Data and Trends

The data set used in this analysis includes information on county cotton acreages, cotton and substitute crop prices, government commodity program variables, and BWE program participation for 25 counties in North Carolina, South Carolina, and Georgia for 1965 through 1995. In this section, counties are matched with BWE program participation dates, and general trends in the data series are identified and briefly discussed.

BWE Program Counties and Program Phase Dates

The North Carolina counties in the initial BWE trial region are Edgecomb, Halifax, Northampton, and Nash. For these counties, the eradication phase of the BWE program encompasses 1978, 1979, and 1980, and the post-eradication phase consists of 1981 through 1995 (USDA personal communication 1997).

North Carolina counties in the BWE program expansion region are Chowan, Cleveland, Hoke, Robeson and Scotland. South Carolina counties in the expansion region are Calhoun, Chester, Darlington, Dillon, Lee, Marlboro, Orangeburg, Sumter, and York.[1] For these counties, the eradication phase of the BWE program was 1983, 1984, and 1985, and the post-eradication phase of the program 1986 through 1995.

Although the BWE program expanded into Georgia in 1987, it did not fully get underway until 1988, and fields were not considered fully "clean" of boll weevil until the 1991 season (Brown). Therefore, we assume that the BWE eradication phase in Georgia effectively consists of 1988, 1989, and 1990 and that the post-eradication phase of the program consists of 1991 through 1995. Georgia BWE counties are Bleckley, Brooks, Burke, Calhoun, Colquitt, Crisp, Dooly, and Pulaski.

Cotton Acreage

Yearly cotton acres are given by county in Tables 1a–1c. Planted acres are used where the data are available. Where data on planted acres are not available, data on harvested acres are used. (The correlation between planted and harvested acres across all counties and years for which both types of acreage data exist is 0.9971.) For counties numbered 1 to 8, 1965–1980 data are planted acres (Carlson 1992); 1981–1995 data are planted acres (NCDA 1996). For county number 9, 1965–1972 data are harvested acres (Carlson 1992); 1973–1995 data are planted acres (NCDA 1996). For counties numbered 11 to 19, 1965–1979 data are planted acres (Carlson 1992); 1980–1995 data are planted acres (SCASS 1997). (Note: Acreage data for County 12 for years 1991–1993 are missing due to grower confidentiality restrictions. This county is eliminated from the analysis.) For counties numbered 21 to 28, 1965–1971 data are harvested acres (Carlson 1992); 1972–1995 data are planted acres (GAASS 1997). (Note: There are no counties numbered 10 or 20 in the data set.)

We divide the counties into three groups according to the year in which they began the eradication stage of the BWE program. Table 1 reports total cotton acres for the three groups. After falling sharply during the late 1960s and the 1970s, cotton acreage began to increase in all three groups during the 1980s. Overall agricultural acreage was declining in all three states over this period (Table 2). Hence, the increase in cotton acreage cannot be attributed to a general increase in all agricultural acreage in the region.

Substitute Crop Acreage

Table 3 presents acreage trends for the primary substitute crops (wheat, corn and soybeans) in the region. Given that total agricultural acreage has been declining in the region, it is apparent that growers have been shifting acres from substitute crops to cotton. On balance, it appears that North Carolina growers have been shifting a large amount of acreage from corn to cotton, a moderate amount of acreage from soybeans to cotton, and essentially no acreage from wheat to cotton. South Carolina farmers appear to have been shifting a large amount of acreage from soybeans to cotton and moderate amounts of acreage from wheat and corn to cotton. Georgia farmers appear to have been shifting significant acreage from all three substitute crops to cotton.

Cotton Prices

Data on nominal average market price received by growers for cotton (PRECC), nominal cotton futures price (PFUTC), and the producer price index (IPP) are presented in Table 4. Cotton futures prices are Chicago Board of Trade (CBT) "Settle" prices in cents/lb. for

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[1] Chester county, SC, (county number 12) is excluded from the regression model described in the following section because acreage data are not available for this county for some years due to grower confidentiality restrictions.

Table 1a. North Carolina Cotton Acres by Year and County

Year	Edge-combe (1)	Halifax (2)	Nash (3)	North-ampton (4)	Hoke (5)	Robeson (6)	Scotland (7)	Cleve-land (8)	Chowan (9)	Total
1965	13800	29700	16200	30500	13700	50000	16800	19300	2600	192600
1966	9400	19300	10050	22200	9300	29400	9900	13400	930	123880
1967	8750	20200	7450	20900	8000	20500	11100	10400	350	107650
1968	9600	22200	7300	22700	9300	27200	13900	11300	1650	125150
1969	8700	19200	6000	20400	9850	27000	12900	12000	1260	117310
1970	6870	20200	5400	19500	10000	25100	14200	13600	1080	115950
1971	7900	23500	6750	22400	10200	26000	16400	16200	1650	131000
1972	9000	26800	6300	25800	11300	30500	18500	13200	1480	142880
1973	7550	25200	4590	23200	10200	27300	19500	14700	1070	133310
1974	8350	19700	5050	21450	10100	23000	20700	10650	950	119950
1975	3260	7450	1130	7350	3340	9800	10900	3650	365	47245
1976	4470	8170	1040	9450	4770	13450	15050	4960	660	62020
1977	5760	10100	1730	10600	4800	15700	17600	3800	780	70870
1978	3750	3850	590	3980	2480	8900	12900	2040	375	38865
1979	3100	4950	535	5500	2100	7450	12800	1950	725	39110
1980	5950	8900	915	8800	3540	9500	13500	2930	1480	55515
1981	8900	11400	2180	12800	3470	10300	12700	3690	3600	69040
1982	8350	11800	2210	10700	2670	7800	9450	2430	4200	59610
1983	6250	9550	2010	8650	2070	5700	6100	2090	3600	46020
1984	10250	19450	3700	13850	3110	8440	8590	2450	5050	74890
1985	9300	16500	2800	11900	2980	8350	8100	2450	4850	67230
1986	9300	15300	2400	11100	3200	8500	7700	800	4700	63000
1987	9550	18200	3120	11800	3690	9000	8450	2070	5450	71330
1988	11900	22400	3870	16300	4550	10800	9050	2150	7000	88020
1989	10500	19500	2680	15600	3950	9000	8950	1700	5850	77730
1990	14300	28100	4390	22600	6050	11000	10800	2180	8900	108320
1991	26800	43800	15200	34200	8800	17900	13100	2400	14500	176700
1992	24300	39400	13400	30200	8700	17600	11900	2730	11700	159930
1993	23900	39600	11800	32000	10100	18500	11900	2000	12300	162100
1994	30490	43050	15550	35650	11300	20920	13200	2680	14450	187290
1995	49000	60000	27000	50100	16000	29700	16600	3100	20400	271900
Mean	11913	21531	6237	19103	6891	17558	12685	6097	4655	106659

Data set county identification numbers in parentheses.

December contract cotton (as reported in *The Wall Street Journal*) averaged over the last five business days in April. If markets are inactive or closed, the average is taken over the remaining recorded prices for that year.

Data on real cotton futures prices are presented in Table 5. Nominal prices are deflated to 1995 cents/lb. using the producer price index (IPP), with 1982 taken as the base year (i.e., IPP equals 100 in base year 1982) (USDC 1996). Real cotton futures prices were relatively high from 1965 to 1977, declined from 1977 to 1986, and began increasing again in 1986. In 1995, the final year in our data set, the real cotton futures price was at its highest level since 1978. The recent increase in cotton price may explain part of the recent increase in cotton acreage.

Government Support Programs

Changes in government agricultural support programs may affect cotton acreage. We attempt to control for the effects of these chang-

Table 1b. South Carolina Cotton Acres by Year and County

Year	Calhoun (11)	Chester (12)	Darling-ton (13)	Dillon (14)	Lee (15)	Marlboro (16)	Orange-burg (17)	Sumter (18)	York (19)	Total
1965	12130	5850	27430	19770	34470	35070	45130	33330	7390	220570
1966	9930	3610	20010	13720	25510	24660	34350	24560	5010	161360
1967	9060	2860	18990	12170	24670	23950	30630	22330	4090	148750
1968	10620	2960	22440	13630	28770	26030	35900	27720	4230	172300
1969	11250	3330	22350	14340	29480	27270	35050	26240	4680	173990
1970	11280	3740	21620	15040	29130	27780	32500	25030	5300	171420
1971	14940	4140	23830	16760	34930	32290	37560	27020	6530	198000
1972	17080	4580	26390	19660	42020	34840	37100	29340	6680	217690
1973	16630	4060	23120	18240	41100	33190	27230	25610	5740	194920
1974	16540	4000	19850	22300	42110	37270	19890	23680	4810	190450
1975	7820	1500	4900	8310	18330	19820	7770	9490	2530	80470
1976	11940	2140	8010	12400	33480	29960	11690	15520	3000	128140
1977	10240	2470	8190	16510	35770	34690	9530	16160	3510	137070
1978	6990	1210	3400	8160	27070	24470	5460	10410	1780	88950
1979	8880	1420	3950	9610	27950	23590	4980	11080	2000	93460
1980	10400	1470	6350	9200	32500	27200	4370	13800	2290	107580
1981	9900	1760	7000	9550	29700	26900	4800	12300	2550	104460
1982	6900	1340	5200	5650	28000	20500	3380	10700	2190	83860
1983	6100	860	4300	4270	18300	13100	3100	6250	1620	57900
1984	8400	980	7000	6100	26800	18900	7400	11100	2250	88930
1985	8800	1030	10300	6150	27800	19700	7500	12500	2470	96250
1986	8250	830	9950	6950	26400	20200	9000	11800	2310	95690
1987	9100	750	9900	7300	26100	20800	10600	12500	1810	98860
1988	10700	735	12000	8950	30600	24600	11300	14900	2360	116145
1989	9100	660	9750	7500	26200	21000	8650	12800	1960	97620
1990	12100	760	12100	8700	30800	24500	12500	14600	2560	118620
1991	16200	—	18000	11300	36000	27300	17400	17800	2480	146480
1992	15950	—	17040	10880	33630	27800	16790	14600	3160	139850
1993	17340	—	18800	12080	33840	25850	16950	14670	3120	142650
1994	18400	1455	19475	12710	34150	26450	19000	13450	2910	148000
1995	25400	2000	25900	15400	39700	31300	37400	15900	4100	197100
Mean	11883	2232	14437	11720	30816	26161	18223	17329	3465	136050

Data set county identification numbers in parentheses.
"—" indicates missing data.

es by including a measure of government program support in our model. Developing such a measure is difficult because there are multiple cotton programs, and cotton programs have changed over time (Duffy *et al.* 1987, USDA 1989, USDA 1982, USDA 1986, USDA 1991). We report government program variables in Table 6. To capture the combined effects of government support programs and expected cotton price on cotton acreage, Duffy *et al.* (1987) developed a "supply inducing price" for cotton. Duffy *et al.* specified the supply inducing price of cotton as a nonlinear function of an "effective support price" of cotton (a function of government program payment rates and acreage restrictions) and the expected market price of cotton (lagged market price). The nonlinear formulation "allows increasingly more weight to be placed on the expected market price as the expected market price increases with respect to the effective support price." However, as Duffy *et al.* point out, there are many other possible specifications of the supply inducing price.

Table 1c. Georgia Cotton Acres by Year and County

Year	Dooly (21)	Brooks (22)	Burke (23)	Colquitt (24)	Calhoun (25)	Pulaski (26)	Crisp (27)	Bleckley (28)	Total
1965	19260	7370	26320	20140	4670	7280	9070	5400	99510
1966	15600	4250	19500	12700	3060	4830	6200	3690	69830
1967	14500	2480	12900	12300	2480	3670	5300	3190	56820
1968	21000	3950	23100	18150	3400	5500	7650	4250	87000
1969	25400	3000	20400	16800	3450	6500	7550	5100	88200
1970	27800	2700	21300	15800	3600	6850	7200	4800	90050
1971	38700	2400	20000	16400	3800	9300	11100	7300	109000
1972	43900	3800	25600	22200	5200	12500	16100	12300	141600
1973	49000	2660	23400	19000	4420	12600	14200	13600	138880
1974	50300	4460	23700	24900	5650	15500	14500	15500	154510
1975	32100	2200	8750	9250	2910	7600	4000	7750	74560
1976	51300	3230	21200	14200	3860	10000	11000	12900	127690
1977	46800	3820	22500	12900	4070	8350	9300	11300	119040
1978	28300	3490	16300	9600	1660	5350	3410	6350	74460
1979	43300	3560	19200	5700	2610	10300	5300	9850	99820
1980	45800	7250	17000	7850	5500	12000	7400	6750	109550
1981	37600	15500	16900	11200	6740	8350	6900	4900	108090
1982	27300	16800	13800	12300	6600	5900	4670	4290	91660
1983	21200	13100	9850	7650	4730	6800	4100	3710	71140
1984	24900	24400	12200	14100	5350	9650	4900	4100	99600
1985	29800	25600	15300	18200	6450	11700	8300	5050	120400
1986	31400	21600	12500	17700	5600	12700	7650	5200	114350
1987	26000	22500	11100	20500	6600	11100	5000	4600	107400
1988	34000	26400	14800	27400	8900	14000	9000	6000	140500
1989	28600	21000	12100	23000	7100	11500	5600	4500	113400
1990	38100	24000	16500	27300	9200	15500	6900	6300	143800
1991	31200	26500	20000	31500	8550	15100	7250	7600	147700
1992	41100	25200	20200	31000	8700	18300	10400	8600	163500
1993	44200	30000	23700	39100	10200	20400	15000	10900	193500
1994	50200	36000	29000	47200	13400	20800	23400	14000	234000
1995	64500	45700	40000	63900	21400	27500	36000	19800	318800
Mean	34941	15533	19004	20321	6125	11207	9495	7728	122850

Data set county identification numbers in parentheses.

Rather than formulating supply-inducing prices, in this paper we take a reduced form approach and simply allow expected market price (here measured by futures price) and a measure of effective support price, "PSUPC," to enter the acreage response equation directly. We use Duffy *et al.*'s measure of effective support price (not Duffy *et al.*'s supply-inducing price) as PSUPC for 1965–1981 (see Table 6, 1965–1981). For 1982–1995, we construct new measures of PSUPC as follows (values for PSUPC and its constituent variables are given in Table 5):

$$(1)\quad \text{PSUPC} = \text{TARGC} \times (1 - \text{ARP\%} - \text{PLDC\%} - \text{PIK\%}) + \text{PLDC}\cdot\text{PLDC\%} + \text{PIK}\cdot\text{PIK\%}.$$

TARGC is the target price of cotton and LOANC is the non-recourse loan payment rate for cotton.

ARP percent is the percent reduction in cotton Crop Acreage Base (CAB) required by the Acreage Reduction Program (ARP) in order for growers to receive loan support and deficiency payments (USDA. Various years.

Table 2. Harvested Acreage, All Crops North Carolina, South Carolina and Georgia

	Harvested Acres (1,000)		
Year	GA	NC	SC
1980	5635	5413	2886
1981	6327	5674	3148
1982	6156	5725	3333
1983	5218	4692	2609
1984	5628	5388	2905
1985	5071	5418	2778
1986	3811	4581	2129
1987	3602	4185	1916
1988	3754	4104	2022
1989	4205	4526	2283
1990	3788	4336	2046
1991	3777	4397	1824
1992	3693	4519	1885
1993	3551	4168	1602
1994	3876	4488	1923
1995	3862	4341	1871

Source: USDC. Various years. *Statistical Abstract of the United States*. US Department of Commerce, Bureau of the Census. Washington, DC

Cotton Background for 1985, 1990 and 1995 Farm Legislation. Washington, DC.).

PLDC percent is the maximum percent reduction in cotton CAB on which Paid Land Diversion Program payments can be made in years in which Paid Land Diversion is in effect. PLDC percent is 5 percent in 1983, 10 percent in 1985, and zero in all other years. PLDC is the payment rate in cents per pound on cotton farm program payment yield on acres diverted under PLD program. PLDC is 25 cents/lb (nominal price) in 1983, 30 cents/lb (nominal price) in 1985, and zero in all other years.

PIK% is the percent of CAB diverted under Payment-In-Kind program. Growers could idle between 10 and 30 percent of CAB; we simply assume that growers idle 20 percent of CAB under PIK. The PIK program was used only in 1983; in 1983 PIK percent is equal to 20 percent, and in all other years PIK% is equal to zero. PIK is the expected value of the PIK payment rate in cents per pound. We follow Duffy *et al.* (1987) and simply assume that the expected value of the PIK payment rate is equal to the loan rate for cotton (vari-

Table 3. Trends in Planted Acres (1,000) for Other Program Crops (Wheat, Corn, Soybeans) North Carolina, South Carolina, and Georgia

Year	NC Wheat	NC Corn	NC Soybns.	SC Wheat	SC Corn	SC Soybns.	GA Wheat	GA Corn	GA Soybns.
1979	235	1850	2000	110	570	1700	210	1670	2150
1980	325	1900	2030	205	585	1700	660	1600	2450
1981	600	2000	1920	430	645	1600	1150	1600	2300
1982	700	1740	2150	580	430	1850	1470	900	2400
1983	600	1500	1750	440	320	1480	1060	830	2050
1984	700	1800	1850	400	490	1520	1000	1080	2100
1985	800	1820	1800	460	560	1290	950	1080	1800
1986	525	1600	1640	325	550	1020	640	900	1220
1987	490	1300	1400	290	420	750	550	680	830
1988	510	1100	1370	320	380	800	575	600	930
1989	680	1050	1600	460	390	980	800	610	1150
1990	600	1200	1400	400	390	800	650	660	900
1991	550	1050	1350	300	280	650	500	600	600
1992	600	1150	1400	285	375	690	400	750	650
1993	610	1000	1350	280	330	600	400	650	600
1994	670	1000	1400	370	370	600	440	600	520
1995	720	800	1150	300	290	550	350	400	320

Source: USDA. Various years. *Agricultural Statistics*. USDA. Washington, DC.

Table 4. Average Cotton Price Received by Growers (PRECC), Futures Prices for Cotton (PFUTC), Corn (PFUTN), and Soybeans (PFUTS), and Index of Producer Prices (IPP)

Year	PRECC Cents/lb	PFUTC Cents/lb	PFUTN $/bu	PFUTS $/bu	IPP Index
1965	28.03	29.994	1.219	2.5665	31.1
1966	20.64	22.252	1.212	2.8145	33.1
1967	25.39	25.95	1.358	2.7725	31.3
1968	22.02	30.402	1.2095	2.634	31.8
1969	20.94	26.158	1.2035	2.3565	33.9
1970	21.86	25.84	1.2205	2.6065	35.2
1971	28.07	29.944	1.394	2.8205	36
1972	27.2	32.286	1.285	3.204	39.9
1973	44.4	44.94	1.597	4.4385	54.5
1974	42.7	58.43	2.5445	5.4535	61.4
1975	51.1	48.206	2.6145	5.242	61.6
1976	63.8	61.806	2.6445	5.043	63.4
1977	52.1	68.308	2.5785	7.13	65.5
1978	58.1	61.41	2.4835	6.066	73.4
1979	62.3	62.264	2.6825	7.0575	85.9
1980	74.4	73.444	2.9455	6.5455	95.3
1981	54	81.718	3.7655	8.3555	103
1982	59.1	73.494	2.9605	6.836	100
1983	66	72.176	3.0155	6.815	101.3
1984	57.5	75.654	3.032	7.1805	103.5
1985	56.8	64.884	2.6585	6.153	95.8
1986	51.5	37.144	1.9555	5.1065	87.7
1987	63.7	62.078	1.861	5.1805	93.7
1988	55.6	55.608	2.245	6.959	96
1989	63.6	65.276	2.638	7.1695	103.1
1990	67.1	66.638	2.6885	6.4165	108.9
1991	56.8	71.25	2.56	6.175	101.2
1992	53.7	62.98	2.498	5.962	100.4
1993	58.1	61.198	2.379	5.992	102.4
1994	72	72.365	2.526875	6.229375	101.8
1995	75.4	78.93	2.625	5.9535	102.7

Source: USDA. Various years. *Cotton and Wool Situation and Outlook Yearbook.* USDA-ERS. Washington, DC.
Source: USDC. 1996. *US Statistical Abstract* 1996. Table No. 751. Producer Price Index, Crude Materials, Total. US Department of Commerce. Washington, DC.

able LOANC). Hence, PIK equals LOANC in 1983 and zero in other years.

Several other government programs have the potential to affect cotton acreage decisions but are not included in the model. Below we explain the reasons for not including these programs in the effective support price measure, PSUPC.

Despite sometimes large government expenditures on Deficiency Loan Payments (USDA 1995a), marketing loans do not raise the effective support price of cotton to growers; rather, they represent a different means of ensuring that growers receive the loan rate. (The government uses the Marketing Loan Program to reduce large, government-owned Commodity Credit Corporation (CCC) cotton stocks while maintaining loan support for growers. The government records expenditures on Deficiency Loan Payments as losses on CCC loan activity.) Hence, we omit consideration of the Marketing Loan Program in our model of cotton acreage.

Through the 9th Conservation Reserve Pro-

Table 5. Cotton Effective Support Price, Cotton and Soybean Futures Prices, and Ratios of Soybean to Cotton Prices

Year	Cotton Effective Support Price 1995$ Cents/lb.	Cotton Futures Price 1995$ Cents/lb.	Soybean Futures Price 1995$ $/bu.	Soybean Futures/ Cotton Support Nominal Pr. Lbs./bu.	Soybean Futures/ Cotton Futures Nominal Pr. Lbs./bu
1965	65.38	99.05	8.48	8.56	12.96
1966	47.47	69.04	8.73	12.65	18.40
1967	51.84	85.15	9.10	10.68	17.55
1968	55.23	98.19	8.51	8.66	15.40
1969	56.95	79.25	7.14	9.01	12.53
1970	62.15	75.39	7.60	10.09	12.24
1971	76.17	85.42	8.05	9.42	10.56
1972	69.24	83.10	8.25	9.92	11.91
1973	53.71	84.69	8.36	9.88	15.57
1974	57.71	97.73	9.12	9.33	15.81
1975	62.35	80.37	8.74	10.87	14.02
1976	68.03	100.12	8.17	8.16	12.01
1977	73.69	107.10	11.18	10.44	15.17
1978	71.64	85.92	8.49	9.88	11.85
1979	67.19	74.44	8.44	11.33	12.56
1980	60.67	79.15	7.05	8.91	11.63
1981	67.00	81.48	8.33	10.22	12.43
1982	61.98	75.48	7.02	9.30	11.33
1983	54.80	73.17	6.91	9.44	12.61
1984	60.28	75.07	7.12	9.49	11.82
1985	64.00	69.56	6.60	9.48	10.31
1986	71.14	43.50	5.98	13.75	8.41
1987	65.27	68.04	5.68	8.35	8.70
1988	71.05	59.49	7.44	12.51	10.48
1989	54.84	65.02	7.14	10.98	13.02
1990	60.16	62.84	6.05	9.63	10.06
1991	70.28	72.31	6.27	8.67	8.92
1992	67.11	64.42	6.10	9.47	9.09
1993	67.63	61.38	6.01	9.79	8.89
1994	65.45	73.00	6.28	8.61	9.60
1995	72.90	78.93	5.95	7.54	8.17

gram signup in 1989 (the first nine signups capture approximately 96% of total CRP enrollment) only 1.47 thousand cotton acres were enrolled in CRP in North Carolina, 7.85 thousand in South Carolina and 16.07 thousand in Georgia (USDA 1990). These figures represent less than 5 percent of the average cotton acreage in each state over the signup period. Although CRP contracts began to expire in large numbers nationwide in 1996, any movement of CRP acres back into cotton production in these states probably would be negligible. Furthermore, CRP contracts do not begin to expire in large numbers until 1996, beyond the time period considered in this study. Hence, we omit consideration of the CRP in our model.

The net effect of National Flex Acres and Optional Flex Acres on upland cotton acreage nationwide has been positive but small relative to nationwide upland cotton base acres (Bjorlie 1997). When the flex acres program began in 1991, farms with upland cotton base in North Carolina, South Carolina and Georgia had significant base in several other program crops (three crops with highest acreages:

Table 6. Government Support Program Variables for Upland Cotton

Year	LOANC Cents/lb	TARGC Cents/lb	DEFIC Cents/lb	ARP% Percent	PLDC% Percent	PLDC Cents/lb	PIK% Percent	PIK Cents/lb	PSUPC Cents/lb
1965	29	0	4.35	0	0	0	0	0	19.80
1966	21	0	9.42	0.125	0	0	0	0	15.30
1967	20.2	0	11.53	0.125	0	0	0	0	15.80
1968	20.25	0	12.24	0.05	0	0	0	0	17.10
1969	20.25	0	14.73	0	0	0	0	0	18.80
1970	20.25	0	16.8	0	0	0	0	0	21.30
1971	19.5	0	15	0.2	0	0	0	0	26.70
1972	19.5	0	15	0.2	0	0	0	0	26.90
1973	19.5	0	15	0	0	0	0	0	28.50
1974	27.06	38	0	0	0	0	0	0	34.50
1975	36.12	38	0	0	0	0	0	0	37.40
1976	38.92	43.2	0	0	0	0	0	0	42.00
1977	44.63	47.8	0	0	0	0	0	0	47.00
1978	48	52	0	0	0	0	0	0	51.20
1979	50.23	57.7	0	0	0	0	0	0	56.20
1980	48	58.4	0	0	0	0	0	0	56.30
1981	52.46	70.87	0	0	0	0	0	0	67.20
1982	57.08	71	0	0.15	0	0	0	0	60.35
1983	55	76	0	0.2	0.05	25	0.2	55	54.05
1984	55	81	0	0.25	0	0	0	0	60.75
1985	57.3	81	0	0.2	0.1	30	0	0	59.70
1986	55	81	0	0.25	0	0	0	0	60.75
1987	52.25	79.4	0	0.25	0	0	0	0	59.55
1988	51.8	75.9	0	0.125	0	0	0	0	66.41
1989	50	73.4	0	0.25	0	0	0	0	55.05
1990	50.27	72.9	0	0.125	0	0	0	0	63.79
1991	50.77	72.9	0	0.05	0	0	0	0	69.26
1992	52.35	72.9	0	0.1	0	0	0	0	65.61
1993	52.35	72.9	0	0.075	0	0	0	0	67.43
1994	50	72.9	0	0.11	0	0	0	0	64.88
1995	51.92	72.9	0	0	0	0	0	0	72.90

wheat, corn and soybeans), providing a potentially large flex acreage on which to plant cotton (USDA 1991b). There has been some flexing out of cotton, mainly into soybeans, but flexing into cotton outweighs flexing out of cotton by an order of magnitude (USDA-FSA *News* mimeo). Nonetheless, net flexing into cotton has amounted to only approximately 10 percent of cotton base in North Carolina and South Carolina, and considerably less in Georgia (*USDA-FSA News* mimeo). In our reduced-form model, we implicitly assume that cotton acreage is determined in part by flex acreage decisions, and that these intermediate decisions are themselves functions of included model variables (i.e., cotton price, substitute crop price, effective government support price, the BWE program, and other factors represented by county dummies). Hence, we do not include the flex acreage program variables directly in the model.

Enrollments in the "50–92" program cotton acreage in North Carolina, South Carolina, and Georgia were modest: the median state enrollment over all three states and program years was 4.5 percent of crop acreage base less acreage reduction program requirements, and in no year did 50–92 acreage exceed 10 percent of crop acreage base less acreage reduction program requirements (*USDA-FSA News* mimeo). We therefore assume that the impact of the 50–92 program on cotton acreage in our study area was minimal, and we exclude consideration of 50–92 from our model. This is a conservative assumption from the perspective of rejecting the null hypothesis of no BWE program effect on cotton acreage for the following reason. The 50–92 program came into existence with the 1985 Farm Bill; hence it was present only during the final third of the study period. The post-eradication phase of the BWE program also came fully on line during the later part of the study period (1981 in North Carolina, 1986 for South Carolina and 1991 in Georgia). Hence, the presence of the 50–92 program would be correlated with the presence of the post-eradication phase of the BWE program. Because existence of the 50–92 program would tend to decrease cotton acreage, omitting this factor from the model would tend to bias any estimate of the acreage impact of the post-eradication phase of the BWE program downward, or in favor of the null hypothesis, making rejection of the null hypothesis more difficult.

Changes in crop acreage bases (CABs), farm program payment yields (FPPYs), and cross-compliance restrictions may also affect cotton acreage decisions. For example, Mims, Duffy and Young (1989) have shown that the definition of CAB and the presence or absence of cross-compliance restrictions can affect government program participation decisions, crop-mix and cotton acreage in simulation models of representative cotton farms in northern and southern Alabama. From 1982 to 1995, there were several changes in the definitions of CABs and FPPYs, and several changes in cross-compliance restrictions. In our reduced-form model, government program participation and crop-mix decisions are not modeled directly. Instead, we implicitly assume that cotton acreage is determined in part by these intermediate decisions, and that these intermediate decisions are themselves functions of included model variables.

The real (1995 cents/lb) effective support price of cotton over the sample period is reported in Table 5. The real effective support price of cotton has fluctuated somewhat around a fairly constant level throughout the study period. Fluctuations in the real effective support price may explain some movements in cotton acreage but probably do not account for the recent upward trend in acreage.

Substitute Crop Prices

Changes in the relative prices of substitute crops may have contributed to recent acreage shifts. Data on soybean and corn futures prices (PFUTS and PFUTN, respectively) are presented in Table 4. Corn futures prices are Chicago Board of Trade (CBT) "Settle" prices in cents/bu for December contract corn (5000 bu) as reported in *The Wall Street Journal* averaged over the last five business days in April. Soybean futures prices are Chicago Board of Trade (CBT) "Settle" prices in cents/bu for November contract soybeans (5000 bu) as reported in *The Wall Street Journal* averaged over the last five business days in April. In the event of inactive or closed markets, the averages are taken over the remaining recorded prices for that year and commodity.

Table 5 reveals that the real (1995 $/bu) price of a major substitute crop (soybeans) and the ratio of real substitute crop price to real cotton price and to the real effective support price for cotton all declined over most of the sample period. The declines evident since the late 1980s correspond to the recent period of rapid growth in cotton acreage. Shifts in the relative prices of commodities might indeed explain part of the recent increase in cotton acreage.

BWE Program

In addition to cotton price, substitute crop price and government crop support program effects, it is probable that the BWE program also affected cotton acreage by increasing cotton yields and decreasing pesticide costs. Support for this position might be drawn from casual observation of Table 1, where it appears that cotton acreage began to move upward in the 1978 BWE trial area before it did in the two BWE expansion areas, which had yet to undergo eradication. In the next section of this paper we develop a simple econometric model to identify and measure potential BWE program effects and to distinguish these effects from other possible influences on cotton acreage.

The Model

We develop a model to test for the effects of the Boll Weevil Eradication (BWE) program on cotton acreage. Many factors can influence cotton acreage planting decisions, including the expected price of cotton (including government price support payments), the expected price of substitute crops (including any government price support payments), acreage restriction programs, cotton production costs, the BWE program, county characteristics (such as soil quality and average weather conditions), and random environmental or economic shocks. Farm level decisions associated with acreage choice, crop-mix, input levels, and government program participation are interrelated and complex. In general, such problems can be characterized as discrete/continuous choice, multi-product, constrained profit-maximization problems. Mims, Duffy and Young (1989) and Duffy, Cain, Young and Wetzstein (1994) investigated farm-level decisions for two representative Alabama cotton farms using integer programming simulation models. In this paper we abstract from the details of farm-level models in order to focus on the measurement of the net, "reduced-form" impact of the BWE program on cotton acreage.

Modeling cotton acreage response to the BWE program requires identifying which prices are relevant to farmers' planting decisions and how expectations of those prices are formed. There are three basic approaches to estimating the supply responses of agricultural producers when various government programs impact farm decision-making: the first, the partial-equilibrium approach, analyses the effect of each government program separately; the second approach attempts to combine the effects of several government programs into a single supply-inducing price (Duffy, Richardson, and Wohlgenant); and the third approach attempts to discover the individual effect of each government program while addressing multiple programs (Chavas, Pope and Kao). Our model follows this third approach.

We do not model price expectations explicitly. Instead, we specify a reduced form model in which farmers base cotton acreage decisions on real cotton futures price, the real effective support price for cotton (see discussion), real soybeans futures price[2], and BWE program dummy variables.

We specify the following log-linear form for the empirical model:

$$(2)\quad \text{acres}_{it} = \exp(d_i)\cdot(\text{pfutc}_t\cdot 100/\text{ipp}_t)^{b1} \times (\text{psupc}_t\cdot 100/\text{ipp}_t)^{b2}\cdot(\text{pfuts}_t\cdot 100/\text{ipp}_t)^{b3} \times \exp(b4\cdot \text{eit}_{it})\cdot\exp(b5\cdot \text{fit}_{it})\cdot\exp(u_{it}),$$

where i is a county index and t is a yearly time index. Acres is annual county total upland cotton acres. Pfutc_t is the nominal futures price for cotton (cents/lb.), and pfuts_t is the nominal futures price for soybeans ($'s/bushel). Variable psupc_t is the nominal effective support price for cotton (cents/lb.). As described in the Data section of the text, psupc_t follows Duffy, Richardson, and Wohlgenant (1987) for 1965–1981 and is constructed by the authors for 1982–1995. Variable ipp_t is the producer price index (ipp equals 100 in base year 1982). Variables d_i are dummy variables used to distinguish counties. Variables eit_{it} and fit_{it} are "0–1" dummy variables indicating the eradication phase and post-eradication phase, respectively, of the BWE program in county i. The time index, t, runs from 1 (1965) to 31 (1995). Variables u_{it} are normally distributed

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[2] As cotton's primary competitor for acreage in the Southeast (Glade, Meyer and MacDonald), soybeans were selected as the substitute crop. The futures price series of corn was also considered for inclusion in the model. However, because the price series of corn and soybeans are highly correlated (correlation = 0.938), the corn price series was omitted from the model to avoid multicollinearity problems. To the extent that the prices of substitute crops other than soybeans affect cotton acreage, these effects would be captured mainly by the coefficient on soybean price in our model, given the high correlation between substitute crop price series.

error terms, and b1 . . . b5 are model parameters to be estimated.

Cotton futures price and cotton support price are anticipated to have positive effects on cotton acres, while soybean futures price is expected to have a negative effect.

The two phases of the BWE program are hypothesized to have opposite effects on cotton acreage relative to the pre-program period. The BWE eradication phase dummy variable is hypothesized to decrease cotton acreage for two reasons. First, producers apply more pesticides and pay relatively large BWE program fees during eradication. Crop yield benefits may not offset these expenses. Second, the heavy use of pesticides during eradication may reduce populations of beneficial insects, increasing the possibility of infestation by secondary pests. For example, serious secondary outbreaks of aphids and beet armyworm devastated the 1995 cotton crop in the Texas Rio Grande Valley. Many producers believed that this outbreak was due to the boll weevil eradication program in effect for the 1995 crop year. The repeated applications of malathion used to eliminate the boll weevils, they argued, destroyed beneficial insects including spiders and wasps (Verhovek). We hypothesize that reductions in expected crop yield due to secondary pest infestations are a second reason cotton acreage may decrease during the eradication phase of the BWE program.

The BWE post-eradication phase dummy variable is hypothesized to increase cotton acreage. After eradication, larger crop yields and reduced pesticide costs are expected to generate significant net program benefits and lead to increased cotton acreage.

Finally, the county dummy variables are intended to capture the idiosyncratic characteristics of each county, such as county size, average crop yields, soil quality and average weather conditions, that influence mean county cotton acreage but that do not vary over time. As can be seen in Tables 1a–1c, mean (averaged over time) acres vary substantially across counties, from 3,465 to 34,941 acres.

Results

We estimate the log-log form of Equation 2 using statistical regression under three econometric specifications corresponding to different assumptions regarding heteroskedasticity across counties, autocorrelation across years and contemporaneous correlation across counties. Regression results are summarized in Table 7. Each column reports coefficients for the variables listed on the left-hand side for a different model specification.

The ordinary least squares model (OLS) is highly significant (F-test p-value < 0.01) and explains approximately 60 percent of the variation in the dependent variable (Adjusted R-square = 0.5869). The coefficient estimates for logged real cotton futures price (b1), logged real soybean futures price (b3), the eradication stage of the BWE program (eit), and the post-eradication stage of the boll weevil program dummy (fit) are significant at the 95-percent level. However, the Durbin-Watson test rejects the null hypothesis of no autocorrelation across time periods. In addition, the null hypothesis of no heteroskedasticity across counties is rejected by a Breusch-Pagan-Godfrey test. Hence, we next estimate the model using a pooled time-series cross-section estimation procedure (Kmenta) which corrects for first-order autocorrelation across time periods and for heteroskedasticity across counties. Results are reported in the column labeled POOL.

A likelihood ratio test comparing the log of the likelihood function of the restricted model (ordinary least squares) with that of the less restricted model (pooled time-series cross-section) rejects the ordinary least squares joint restrictions of no first-order autocorrelation across time periods and homoskedasticity across counties at the 95-percent significance level. Compared with ordinary least squares, the pooled time-series cross-section estimation method reduces the mean squared error (MSE) of the estimation by an order of magnitude, from 0.33377 to 0.03335. For the pooled time-series cross-section regression, coefficient estimates for logged real cotton futures price (b1), logged real effective cotton support price (b2), the eradication stage of the BWE program (eit) and the post-eradication stage of the boll weevil program (fit) are significant at the 95-percent level.

Table 7. Regression Results

Variable	Coefficient	OLS Estimate (S.E.)	POOL Estimate (S.E.)	PARKS Estimate (S.E.)
Real cotton futures price	b1	0.959* (0.170)	0.696* (0.065)	0.746* (0.072)
Real cotton effective support price	b2	0.019 (0.192)	0.571* (0.091)	0.589* (0.089)
Real soybean futures price	b3	−1.132* (0.222)	0.040 (0.089)	−0.049 (0.090)
Eradication phase	b4	−0.340* (0.079)	−0.098* (0.045)	−0.028 (0.019)
Post-eradication phase	b5	0.189* (0.074)	0.203* (0.049)	0.242* (0.024)
County	d_1	7.145* (0.976)	3.897* (0.536)	3.616* (0.498)
Dummies	d_2	7.774* (0.976)	4.420* (0.499)	4.215* (0.480)
	d_3	6.277* (0.976)	3.178* (0.631)	2.891* (0.523)
	d_4	7.681* (0.976)	4.309* (0.482)	4.137* (0.466)
	d_5	6.675* (0.973)	3.339* (0.490)	3.152* (0.464)
	d_6	7.628* (0.973)	4.264* (0.467)	4.104* (0.455)
	d_7	7.413* (0.973)	3.937* (0.439)	3.806* (0.440)
	d_8	6.350* (0.973)	2.983* (0.614)	2.773* (0.584)
	d_9	5.838* (0.973)	2.688* (0.880)	2.439* (0.756)
	d_{11}	7.333* (0.973)	3.854* (0.435)	3.728* (0.440)
	d_{13}	7.411* (0.973)	4.019* (0.488)	3.851* (0.485)
	d_{14}	7.297* (0.973)	3.833* (0.444)	3.730* (0.443)
	d_{15}	8.324* (0.973)	4.831* (0.430)	4.693* (0.437)
	d_{16}	8.155* (0.973)	4.667* (0.432)	4.539* (0.437)
	d_{17}	7.532* (0.973)	4.312* (0.555)	4.083* (0.522)
	d_{18}	7.69* (0.973)	4.223* (0.457)	4.066* (0.448)
	d_{19}	6.064* (0.973)	2.622* (0.454)	2.501* (0.450)
	d_{21}	8.438* (0.970)	4.940* (0.436)	4.775* (0.441)
	d_{22}	7.134* (0.970)	3.882* (0.802)	3.715* (0.633)
	d_{23}	7.835* (0.970)	4.350* (0.431)	4.233* (0.437)
	d_{24}	7.810* (0.970)	4.401* (0.472)	4.194* (0.458)
	d_{25}	6.611* (0.970)	3.177* (0.467)	2.988* (0.455)
	d_{26}	7.256* (0.970)	3.777* (0.452)	3.625* (0.450)
	d_{27}	7.042* (0.970)	3.571* (0.442)	3.424* (0.442)
	d_{28}	6.868* (0.970)	3.396* (0.449)	3.268* (0.450)

Because counties may experience contemporaneous shocks, we also estimate Equation 2 using Parks' time-series cross-section estimation method (Parks; Kmenta) which allows for first-order autocorrelation across time periods, heteroskedasticity across counties, and contemporaneous correlation across counties. Results are reported in the column labeled PARKS. A likelihood ratio test rejects the restriction of no contemporaneous correlation across counties at the 95-percent significance level. The MSE for the Parks method regression is 0.032981, only slightly less than that for the pooled regression. For the Parks method regression, logged real cotton futures price (b1), logged real effective cotton support price (b2), and the post-eradication stage of the boll weevil program (fit) are significant at the 95-percent level.

The own-price effect of cotton futures price on cotton acreage was positive and significant in all three regressions. Our own-price elasticity estimates ranged from 0.69565 to 0.95881 (Table 7). These estimates are within the range of other reported estimates: our estimates are lower than Carlson *et al.*'s estimates of 1.749 for North and South Carolina and 1.482 for North Carolina, South Carolina and Georgia but higher than Duffy *et al.*'s long-run estimate of 0.573 for the Southeastern region as a whole. Table 8 compares our estimated price elasticities to those obtained by previous studies.

Government support programs for cotton,

Table 8. A Comparison of Elasticity Estimates

Study / Sample Period	Dumas and Goodhue 1965–1995	Carlson, Sappie and Hamming 1965–1986	Duffy, Richardson and Wohlgenant 1959–1983
Cotton Futures Price			
NC and SC[b]		1.749	
NC, SC, GA[b]		1.482	
OLS[c]	0.959* (0.170)		
POOLED[c]	0.696* (0.065)		
PARKS[c]	0.746* (0.072)		
Cotton Support Price			
Southeast Region (long-run)[a]			0.573
NC and SC[b]		−0.534	
NC, SC, GA[b]		−0.556	
OLS[c]	0.019 (0.192)		
POOLED[c]	0.571* (0.091)		
PARKS[c]	0.589* (0.086)		
Soybean Futures Price			
NC and SC[b]		−0.581	
NC, SC, GA[b]		−0.642	
OLS[c]	−1.132* (0.222)		
POOLED[c]	0.040 (0.089)		
PARKS[c]	−0.049* (0.090)		

[a] 0.573 value is long-run acreage adjustment elasticity with respect to supply inducing price, evaluated at mean acreage over all sample years.

[b] "NC and SC," and "NC, SC, GA," are the 2 samples used by Carlson, Sappie, and Hammig to estimate the effects of the BWE Program.

[c] OLS, POOLED, and PARKS refer to our three regressions using ordinary least squares, pooled time series correcting for autocorrelation, and heteroskedasticity across counties, and pooled time series correcting for autocorrelation, and heteroskedasticity and contemporaneous correction across counties.

as summarized by the effective support price *psupc*, had a positive and significant effect on cotton acreage during the sample period in the pooled and Parks regressions but was insignificant in the ordinary least squares regression. The estimated elasticity of cotton acreage with respect to the effective support price was 0.57086 in the pooled regression and 0.58931 in the Parks regression. These results are similar in magnitude to Duffy, Richardson and Wohlgenant's estimate of 0.573 for the short-run elasticity of cotton acreage with respect to their measure of "supply-inducing price." The results are also similar in magnitude but opposite in sign to Carlson *et al*'s estimates obtained using ordinary least squares. Carlson *et al.* argue that high effective support prices predict high participation rates by cotton producers, leading to a relatively high number of acres idled to meet program requirements. Conversely, low effective support prices would lead to less government-mandated idling. Changes in farm programs after 1985 (the Carlson *et al* sample ends in 1986) that sought to increase producers' market orientation may have influenced this coefficient estimate. For example, the introduction of flex acre provisions and the 50–92 program may have reduced the correlation between support prices and idled acres.

The 1996 farm bill eliminated the deficiency payment/base acre system, and replaced it with market transition payments to producers that are independent of acreage allocation decisions. The marketing loan program for cotton was continued, with a mandated maximum loan rate of 51.92 cents per pound and a mandated minimum of 50.00 cents per pound. Under the new program, the loan rate may be considered the effective support price. Based on our model's estimates of acreage elasticity with respect to the real effective support price, we can estimate the percentage change in cotton acres due to the change in the effective support price from its 1995 level of 72.90 cents per pound to the mandated maximum and minimum loan rates. Depending on the loan rate, the coefficient from the pooled regression predicts a decline in cotton acreage of 17.6 to 19.4 percent. The Parks regression predicts a decline of 18.1 to 19.9 percent. This calculation provides an estimate of the change in cotton acres that would be expected due to the change in the cotton program alone.

The coefficient estimate for the futures price of soybeans is negative and significant only in the ordinary least squares regression. It is insignificant and positive in the pooled time series cross section regression and insignificant and negative in the Parks regression. The significant estimated elasticity is −1.1317, which is substantially larger in magnitude than Carlson *et al.*'s estimates of −0.581 for North and South Carolina and −0.642 for North Carolina, South Carolina and Georgia. This difference may be due to Carlson *et al.*'s inclusion of corn as a second substitute crop. Overall, our results indicate that the evidence is weak for substitute price effects on cotton acreage over the period considered here.

The BWE program eradication stage dummy variable (eit) has a negative effect on cotton acreage that is significant in the ordinary least squares and pooled regressions. The eradication stage dummy is negative but insignificant in the Parks regression. The estimated negative effect is consistent with the *a priori* hypothesis that the costs associated with the initial eradication phase of the BWE program would cause a temporary decrease in cotton acreage. The estimated percentage change in cotton acreage due to the eradication stage of the BWE program, relative to the pre-eradication situation, is −28.82 percent (calculated as: 100·(exp(b4) − 1)) in the ordinary least squares regression and −9.36 percent in the pooled regression. Our significant estimates are similar to those of Carlson *et al.*, who produced estimates of −15.265 and −33.927 percent for their two- and three-state samples respectively. Hence, there is somewhat strong evidence that the eradication phase of the BWE program causes a moderate reduction in cotton acreage.

The BWE program post-eradication stage dummy variable (*fit*) has a positive effect on cotton acreage that is clearly significant in all three regressions. Our estimates of the percentage change in cotton acres in the post-eradication stage, relative to the pre-eradication situation, range from 20.78 percent to 27.41 percent (calculated as: 100·(exp(b5) − 1)). These estimates fall toward the lower end of the range found by Carlson *et al.*, who obtained estimates of 91.624 percent for their two-state sample, but only 13.886 percent for their three-state sample. Table 9 compares our estimates of the acreage effects of the BWE program to those of previous studies.

Net Benefits of Acreage Effects

The results may be used to estimate the net benefits to growers of the cotton acreage expansion effects induced by the BWE program. We estimate the net benefits of acreage expansion effects using a framework similar to that employed by Carlson (1989) and Ahouissoussi (1992), illustrated in Figure 1.

The net marginal value product of land planted to cotton before eradication is given by D_1. The net marginal value product of acreage planted to the next-best substitute crop is assumed to be relatively constant and is represented by the horizontal line at level r. It is assumed that growers expand cotton acreage until the net marginal value product cotton acreage falls to r; under this assumption, cotton acreage before eradication would be given by A_1. Eradication increases per-acre yields and decreases per-acre pesticide costs. However, after eradication, growers must continue to pay a small annual per-acre BWE program "maintenance" fee to cover continuing boll weevil monitoring and spot suppression efforts. Assuming that the net effect of eradication is to increase the net marginal value product of land planted to cotton from D_1 to

Table 9. Estimated Acreage Effects of BWE Program (percent change in acreage from pre-eradication acreage level[a])

Study	Dumas and Goodhue 1997	Carlson, Sappie and Hammig (1989)
Sample Period	1965–1995	1965–1986
Eradication Stage		
NC and SC[b]		−15.265%
NC, SC, GA[b]		−33.927%
OLS[c]	−28.82%*	
POOLED[c]	−9.36%*	
PARKS[c]	−2.72%	
Post Eradication Stage		
NC and SC[b]		91.624%
NC, SC, GA[b]		13.886%
OLS[c]	20.78%*	
POOLED[c]	22.55%*	
PARKS[c]	27.41%*	

* Indicates result significant at 95% significance level.

[a] Percent change is 100·(exp(b) − 1)), where b is the estimated coefficient of either the eradication stage dummy variable (*eit*) or post-eradication stage dummy variable (*fit*), as appropriate.

[b] "NC and SC," and "NC, SC, GA," are the 2 samples used by Carlson, Sappie and Hammig to estimate the effects of the BWE Program. The first sample includes North Carolina and South Carolina counties only, and the second sample adds Georgia counties.

[c] OLS, POOLED and PARKS refer to our three regressions using ordinary least squares, pooled time series correcting for autocorrelation and heteroskedasticity across counties, and pooled time series correcting for autocorrelation, and heteroskedasticity and contemporaneous correlation across counties.

D_2, growers respond to the increased returns by increasing cotton acreage from A_1 to A_2. Eradication increases the net returns to cotton production on both pre-eradication cotton acres (A_1) and post-eradication, expansion acres ($A_2 - A_1$). Increased returns on pre-eradication cotton acres can be approximated by area *abce,* and increased returns on post-eradication, expansion acres can be approximated by area *cde.* These areas may be computed as:

(3) $A_1 \cdot (b - a)$, and

(4) $1/2 \cdot (b - a) \cdot (A_2 - A_1)$,

respectively, where b − a is the increase in net marginal value product per acre due to eradication, A_1 is pre-eradication cotton acreage and A_2 is post-eradication cotton acreage.

We assume that the increase in net marginal value product of cotton acreage due to the BWE program (i.e., "b − a" in the figure) can be represented by the increase in per-acre revenue resulting from increased in cotton yields minus BWE program "maintenance" fees. This assumption is conservative in that it may understate the benefits of eradication, since any reductions in pesticide costs are not considered in the benefit calculation. The increase in per-acre revenue due to the BWE program is calculated as the product of the per-acre increase in cotton yield (lbs.) due to the BWE program and cotton price per pound. Carlson, Sappie and Hammig estimated that the BWE program increased cotton yields by 69 pounds per acre; Ahouissoussi, Wetzstein and Duffy estimated the yield effect at 100 pounds per acre. We calculate benefit estimates for each yield estimate. Benefit estimates are calculated for both a "low cotton price scenario," corresponding to a real (1995 dollars, PFUTC deflated by IPP in Table 4) cotton futures price of 59.49 cents/lb in 1988, and a "high cotton price scenario," corresponding to real (1995 dollars) cotton futures price of 78.93 cents/lb in 1995. Based on experience to date, we assume that per-acre BWE program maintenance fees average $10 per cotton acre.

Using our regression results, we estimate baseline cotton acreage in the absence of the BWE program (i.e., A_1) and cotton acreage including expansion effects after the BWE program (i.e., A_2). Estimates of the annual post-eradication net benefits of the BWE program in 1995 dollars for a representative sample county for the two yield estimates and the two cotton price scenarios are then calculated using Equations 3 and 4. These estimates are presented in Table 10. Per-county annual post-eradication net benefits are broken down into two components: (1) benefits accruing from pre-eradication cotton acres and (2) benefits accruing from post-eradication expansion acres. The share of net benefits attributable to cotton acreage expansion is also presented in Table 9. For a representative sample county, neglecting acreage expansion effects would

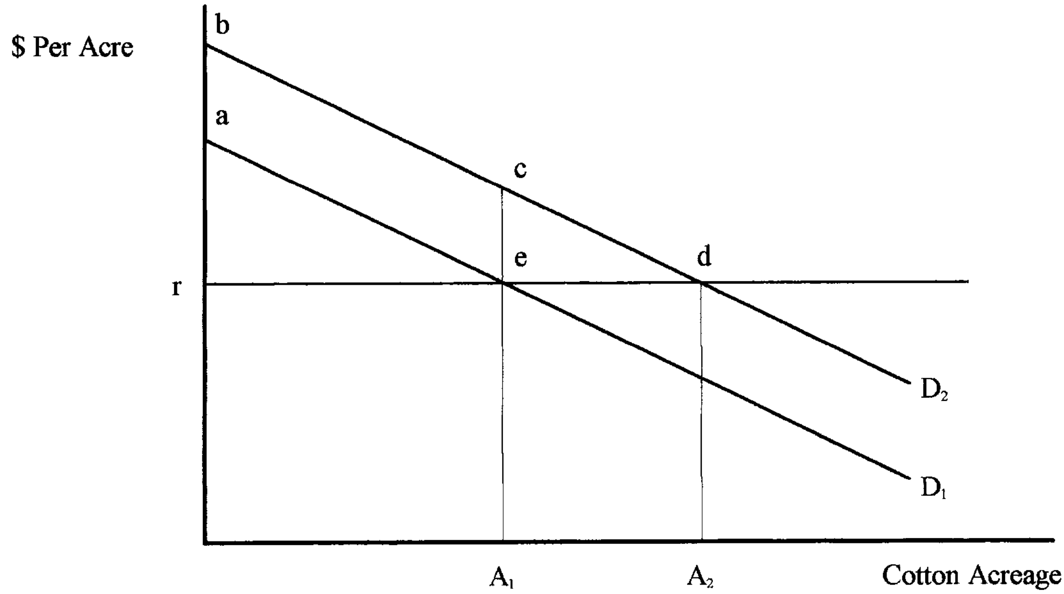

Figure 1. Net Benefits of Cotton Acreage Expansion

lead to underestimation of the net benefits of eradication by 9.4 to 12.1 percent. In 1995 dollars, this amounts to between $31,726 and $132,402 annually per representative county.

Discussion and Conclusions

Our study examines the response of cotton acreage to the Boll Weevil Eradication program in 25 North Carolina, South Carolina, and Georgia counties over a 31-year period. This time series is significantly longer than that available to previous researchers (e.g., Ahouissoussi) and includes observations on the post-eradication phase of the BWE program in Georgia. Since the beginning of the BWE program, cotton acreage has increased ten-fold to 810,000 acres in North Carolina[3]. Georgia cotton acreage has registered an increase of almost 600 percent, and South Carolina has experienced a cotton acreage increase of approximately 130 percent over the same period. Although this dramatic increase in acreage reflects in part an easing of the rules for building acreage bases by new farmers (Carlson 1995), it also reflects the lower pesticide costs and higher yields obtained from the implementation of the BWE program.

Our results provide strong empirical evidence to support the conclusion that the post-eradication phase of the BWE program increased cotton acreage in our study region by 20 to 30 percent. The results provide weaker support for the conclusion that the initial eradication phase of the BWE program reduced cotton acreage. The conclusion that the BWE program caused a significant increase in cotton acreage is further supported by a comparison of cotton acreage changes within our study region with the recent experience of other cotton growing regions, which either did not participate in the BWE program or began participation at a later date. Since the date of initiation of the BWE program in our sample region, other regions did not experience increases in cotton acreage proportional to those experienced in our sample region, even though other regions faced similar prices and government program rules. For example, cotton acres in the Delta states increased by only 35 percent over this period, cotton acreage in the Southwest increased by only 18 percent, and Cali-

[3] Based on a comparison of 1975–1977 average acres (USDA *Agricultural Statistics*) and 1995 acres presented in Table 1. Note that these figures do not correspond directly with the acreage values given in Table 1 because some of the increase in cotton acreage in each state occurred in counties outside our sample.

Table 10. Per-County Annual Post-Eradication Net Benefits of BWE Program ($1995)

	Estimation Method		
	OLS	POOL	PARKS
Per-County Annual Post-Eradication Net Benefits			
Low (1988) Price Scenario			
Carlson *et al.* Yield Est.	$337,079	$405,282	$390,315
Ahouissoussi *et al.* Yield Est.	$537,298	$646,012	$622,154
High (1995) Price Scenario			
Carlson *et al.* Yield Est.	$815,655	$710,683	$708,555
Ahouissoussi *et al.* Yield Est.	$1,264,529	$1,101,789	$1,098,490
Portion of Net Benefits Earned on Pre-BWE Cotton Acreage			
Low (1988) Price Scenario			
Carlson *et al.* Yield Est.	$305,353	$364,217	$343,270
Ahouissoussi *et al.* Yield Est.	$486,727	$580,554	$547,165
High (1995) Price Scenario			
Carlson *et al.* Yield Est.	$738,885	$638,673	$623,152
Ahouissoussi *et al.* Yield Est.	$1,145,510	$990,149	$966,087
Portion of Net Benefits Earned on Expansion Cotton Acreage			
Low (1988) Price Scenario			
Carlson *et al.* Yield Est.	$31,726	$41,065	$47,045
Ahouissoussi *et al.* Yield Est.	$50,571	$65,458	$74,989
High (1995) Price Scenario			
Carlson *et al.* Yield Est.	$76,770	$72,010	$85,403
Ahouissoussi *et al.* Yield Est.	$119,019	$111,639	$132,402
Share of Net Benefits Attributable to Expansion Cotton Acreage			
Low (1988) Price Scenario			
Carlson *et al.* Yield Est.	0.094	0.101	0.121
Ahouissoussi *et al.* Yield Est.	0.094	0.101	0.121
High (1995) Price Scenario			
Carlson *et al.* Yield Est.	0.094	0.101	0.121
Ahouissoussi *et al.* Yield Est.	0.094	0.101	0.121

fornia cotton acreage registered only a 2-percent increase (USDA, *Agricultural Statistics*. 1975–1977 average acres compared to 1995 acres). In contrast, Virginia and Florida, which did participate in the BWE program, registered percentage increases in cotton acreage even larger than those in our sample region (albeit from extremely small initial cotton acreages).

In contrast to the results presented here, the 1992 study by Ahouissoussi and the 1993 study by Ahouissoussi, Wetzstein, and Duffy did not find a detectable change in cotton acreage due to the BWE program. However, these preliminary studies were hampered by the short data time series then available. The more extensive data time series now available has allowed us to detect delayed acreage effects. Our results are supported by the more recent farm-level simulation results of Duffy, Cain, Young and Wetzstein (1994), who find that the boll weevil program would increase acres allotted to cotton by representative south Alabama farms.

Our results provide additional information on the acreage expansion effects and net returns associated with the BWE program in North Carolina, South Carolina, and Georgia. We find that during the eradication stage of the program there is some evidence that cotton acres were 9–29 percent lower (Table 10) than they otherwise would have been in the absence of the program, *ceteris paribus*, probably due to the relatively high per-acre program costs. After eradication, there is relatively strong evidence that cotton acres were 20–27 percent higher (Table 9) than they otherwise would be in the absence of the program, presumably due to the increased cotton yields and reduced insecticide costs resulting from eradication. This information enables better assessment of the net benefits of the existing BWE program in North Carolina, South Carolina and Georgia and may aid decision makers in other cotton growing areas now considering BWE adoption. We estimate that neglecting acreage expansion effects would result in underestimating post-eradication annual net benefits of the BWE program by 9–12 percent for a representative sample county. This amounts to underestimating the net benefits of the post-eradication stage of the BWE program by $31,000 to $132,000 annually per representative sample county, depending on cotton yield and price.

Because BWE program costs are mostly front-loaded into the eradication stage of a BWE program, cotton acreage may temporarily decrease during eradication as growers seek to avoid these costs. As a result, there may be significant time lags on the order of four to five years between the implementation of BWE programs and the realization of acreage expansion effects. Eradication-stage evaluations of BWE programs will tend to underestimate program benefits if post-eradication stage acreage expansion effects are neglected.

Although we would expect the qualitative effects of BWE adoption to be similar across regions, the magnitudes of the anticipated changes would likely differ across regions due to differences in yields, the cost of eradication (and resulting BWE program fees), and the importance of pesticides as a component of variable costs. For example, Texas has significantly lower upland cotton yields than North and South Carolina, while Mississippi's yields are somewhat higher. These yield differences translate into differences in the gross benefits associated with implementing BWE programs. On the cost side, because higher temperatures promote boll weevil overwintering, the relatively warmer winters enjoyed by the more southern Cotton Belt states (such as Georgia, Alabama and Mississippi) may lead to higher boll weevil eradication and monitoring costs in these areas, compared to costs in North and South Carolina.

References

Ahouissoussi, N.B.C. *Economic Returns to the Boll Weevil Eradication Program in Alabama, Florida, and Georgia.* M.S. Thesis. Department of Agricultural and Applied Economics, University of Georgia, Athens, Georgia, 1992.

Ahouissoussi, N.B.C., M.E. Wetzstein, and P.A. Duffy. "Economic Returns to the Boll Weevil Eradication Program." *Journal of Agricultural and Applied Economics* 25(1993):46–55.

Bjorlie, Wayne. Personal communication. USDA-Farm Service Agency. March 1997.

Brown, Steve. University of Georgia, College of Agricultural and Environmental Sciences, Cooperative Extension Service, Tifton, Georgia. Personal communication. March 1997.

Carlson, G.A. "Cotton Boll Weevil Eradication: Voting and Crop Switching." Department of Agricultural and Resource Economics. North Carolina State University, Raleigh, North Carolina. Unpublished manuscript. 1991.

Carlson, G.A. 1992. Personal communication. Department of Agricultural and Resource Economics, North Carolina State University, Raleigh, North Carolina, July 1992.

Carlson, G.A. Personal communication. Department of Agricultural and Resource Economics, North Carolina State University, Raleigh, North Carolina, October, 1995.

Carlson, G.A., G. Sappie and M. Hammig. *Economic Returns to Boll Weevil Eradication.* Economic Research Service, United States Department of Agriculture. Agricultural Economic Report No. 621, 1989.

Carlson, G.A. and L. Suguiyama. *Economic Evaluation of Area-Wide Cotton Insect Management: Boll Weevils in the Southeastern United States.* North Carolina Agricultural Research Service. Bulletin 473. 1985.

Chavas, J.-P., R.D. Pope and R.S. Kao. "An Analysis of the Role of Futures Prices, Cash Prices and Government Programs in Acreage Response." *Western Journal of Agricultural Economics* 8(1983):27–33.

Duffy, P.A., D.L. Cain, G.J. Young and M.E. Wetzstein. "Effects of the Boll Weevil Eradication Program on Alabama Cotton Farms." *Journal of Agribusiness* 12(1991):1–14.

Duffy, P.A., J.W. Richardson, and M.K. Wohlgenant. "Regional Cotton Acreage Response." *Southern Journal of Agricultural Economics* 19(1987):99–109.

GAASS. 1997. Computer data file. Georgia Agricultural Statistics Service. Athens, Georgia, February 1997.

Glade, E.H., Jr., L.A. Meyer, S. MacDonald. *Cotton: Background for 1995 Farm Legislation.* Economic Research Service, United States Department of Agriculture. Agricultural Economic Report No. 706, 1995.

Grube, A. and G.A. Carlson. *Economic Analysis of Cotton Insect Control in North Carolina.* Department of Economics and Business, North Carolina State University, Economic Report number 52, 1978.

Heimlich, R.E. and C.T. Osborn. "The Conservation Reserve Program: What Happens When Contracts Expire?" *Choices* (Third quarter 1993 issue).

Judge, G., W. Griffiths, R. Hill, H. Lutkepohl and T. Lee. *The Theory and Practice of Econometrics, Second Edition,* Wiley Publishers, 1985.

Kmenta, J. *Elements of Econometrics, Second Edition.* NY: Macmillan Publishers, 1986.

Mims, A.M., P.A. Duffy and G. Young. "Effects of Alternative Acreage Restriction Provisions on Alabama Cotton Farms." *Southern Journal of Agricultural Economics* 21(1989):85–94.

NCDA. Computer data printout. North Carolina Department of Agriculture, Agricultural Statistics Division, Raleigh, North Carolina, October 1996.

Parks, R.W. "Efficient Estimation of a System of Regression Equations when Disturbances are Both Serially and Contemporaneously Correlated." *Journal of the American Statistical Association* 62(1967):500–509.

SCASS. Mimeo. South Carolina Agricultural Statistical Service. Columbia, South Carolina, October, 1996.

Singletary, H. "North Carolina Boll Weevil Eradication Program Grower, Assessments." Mimeo. North Carolina Department of Agriculture, Plant Industry Division, Raleigh, North Caroina, March 1997.

Stern, V.M., R.F. Smith, R. van den Bosch and K.S. Hagen, "The Integrated Control Concept." *Hilgardia* 29(1959):81–101.

Suguiyama, L. and C. Osteen. "The Economic Importance of Cotton Insects and Mites." USDA Economic Research Service, Agricutural Economic Report Number 599, October, 1988.

Szmedra, P. I., R. W. McClendon, and M. E. Wetzstein. "Economic Efficiency of Boll Weevil Eradication." *Southern Journal of Agricultural Economics* 23(1991):237–245.

USDA. *Provisions of the Agriculture and Food Act of 1981.* By James D. Johnson, Richard W. Rizzi, Sara D. Short, and R. Thomas Fulton, National Economics Division, Economic Research Service, USDA. Agricultural Economic Report No. 483, 1982.

USDA. *Provisions of the Food Security Act of 1985.* By Lawrence K. Glaser. USDA, Economic Research Service, National Economics Division. Agriculture Information Bulletin No. 498, 1986.

USDA. *Cotton: Background for 1990 Farm Legislation.* By Harold Stults, Edward H. Glade, Jr., Scott Sanford, and Leslie A. Meyer. Commodity Economics Division, Economic Research Service, US Department of Agriculture. Staff Report No. AGES 89–42, 1989.

USDA. 1990. The Conservation Reserve Program: Enrollment Statistics for Signup Periods 1–9 and Fiscal year 1989. By C. Tim Osborn, Felix Llacuna, and Michael Linsenbigler. Resources and Technology Division, Economic Research Service, USDA. Statistical Bulletin No. 811.

USDA. *Provisions of the Food, Agriculture, Conservation, and Trade Act of 1990.* Edited by Susan L. Pollack and Lori Lynch. Agriculture and Trade Analysis Division, Economic Research Service, USDA. Agriculture Information Bulletin No. 624, 1991.

USDA. "1991b Economic Implications of Planting Flexibility Provisions for U.S. Upland Cotton Farms." In *Cotton and Wool Situation and Outlook Report,* USDA-ERS CWS-64, May 1991.

USDA. "1991c. New Provisions for Upland Cotton Farm Programs." In: *Cotton and Wool Situation and Outlook Report,* USDA-ERS. CWS-63, 1991.

USDA. *Economic Indicators of the Farm Sector: Costs of Production—Major Field Crops, 1990.* Agriculture and Rural Economy Division, Economic Research Service, USDA, ECIFS 10–4, 1992.

USDA. *1995a. Cotton: Background for 1995 Farm Legislation.* By Edward H. Glade, Jr., Leslie A. Meyer, and Stephen MacDonald. Commercial Agriculture Division, Economic Research Service, USDA Agricultural Economic Report No. 706, 1995.

USDA. *1995b. Upland Cotton: FAS Commodity Fact Sheet.* USDA-Farm Service Agency. Washington, DC, September 1995.

USDA. *1996 Cotton and Wool Situation and Outlook Yearbook.* Commercial Agriculture Division. Economic Research Service, USDA, CWS,1996.

USDA. *1996b. The Cotton Industry in the United States.* Edward H. Glade, Jr., Leslie A. Meyer, and Harold Stults (eds). Commercial Agriculture Division, Economic Research Service, USDA, Agricultural Economic Report No. 739, 1996.

USDA. *News* Mimeo. USDA-Farm Services Agency. Washington, DC. Various years.

USDA. Personal communication with Mr. Bill Grefenstette, U.S. Department of Agriculture, Animal & Plant Health Inspection Service, Boll Weevil Eradication Program, November 4, 1997.

USDC. Table No. 751—"Producer Price Index, Crude Materials, Total." US Statistical Abstract 1996. US Department of Commerce, Bureau of the Census. Washington, DC, 1996.

USDC. *Statistical Abstract of the United States.* US Department of Commerce, Bureau of the Census, Washington, D.C, various years.

Verhovek, S. H. "In South Texas, a Swat at an Old Pest Stirs a Revolt." *New York Times.* January 24, 1996.

White, K.J. *SHAZAM User's Reference Manual Version 8.0.* McGraw-Hill, 1997.