Chapter 25

BENEFIT-COST ANALYSIS OF INTEGRATED PEST MANAGEMENT PROGRAMS

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INTRODUCTION

During the last decade interest in the economics of Integrated Pest Management (IPM) has been strong. It has often been argued that there is a need to perform benefit-cost analyses on programs in major crops like cotton. As Reichelderfer (1982) indicates, there is a great deal of enthusiasm for IPM but without concrete economic analyses to support general claims of success, the evidence may be less than convincing. In this chapter, several issues germane to our experience in benefit-cost analysis of IPM cotton programs will be addressed. We will discuss conceptual approaches and apparent paradoxes in measuring benefits and costs, describe the data needs, and examine some examples of studies which have investigated the economics of cotton IPM.

APPROACHES TO IPM EVALUATIONS

IPM approaches to pest control usually involve a systems paradigm (example, pattern, or model) and focus on the development of flexible pest management systems which include the substitution of information for chemical, mechanical and energy inputs. Wetzstein (1988) discusses two pathways to IPM assessments: (a) the integrated crop and pest management approach which emphasizes the system and its component linkages; and (b) the value of information paradigm which focuses on the quality of information, the substitution process, and the sequential nature of decision making as advocated by Antle (1983). This pathway deals with the diffusion of new technologies and differences in the ability to process and use information. The results of economic analyses will be partially dependent upon which of these two assessment approaches are followed. In the United States, the integrated crop and pest management approach has been the predominant choice for empirical work.

WHY BENEFIT-COST ANALYSIS?

The most common analyses of IPM programs focus upon the impacts that IPM adoption has on the per acre yields and costs of production of the adopting farmers.

Because of their incomplete nature, these farm level evaluations are often referred to as partial budgeting studies. While these analyses are useful and are a key first step to more complete examinations, they ignore many of the actual benefits and costs that could determine the true success of the programs. More complete benefit-cost analyses will also examine the effects on aggregate supply and market prices, changes in income distributions, and impacts on non-participating producers. In addition, when benefits accrue to more than one group, information can be generated that is useful in determining appropriate jurisdictional boundaries for sharing in costs and setting regulations. Without the more complete analyses, difficulties are encountered in generalizing beyond the narrow impacts of isolated studies. Due to selection and choice-based sampling biases, generalizing impacts from experiences of voluntary adopters to non-participants who have opted not to adopt the IPM technology should be viewed with caution (Hall and Duncan, 1984). Unfortunately, most of the economic evaluations performed to date are not complete benefit-cost analyses and arguably could be considered as nothing more than a string of case studies (Reichelderfer, 1982).

The effects of IPM programs that are not accounted for in the farm level case study analyses can be divided into intraregional and interregional impacts (Reichelderfer, 1982). The substitution process replacing chemical, mechanical and energy inputs with information and labor can have intraregional consequences upon the economy in which an IPM program has been adopted on a full scale basis. If the acreage of the affected crop does not expand, the demand for the inputs being replaced will drop while yields and/or producers' income will rise. As these changes work themselves through the economy with their associated multiplier effects, they can force redistributions of income and economic activity. The interregional effects can be manifested in two forms. First and primary, as comparative advantages in agricultural production adjust to the changes in yields and costs of production generated by the adoption of the IPM program, resource allocations could be affected and regional shifts in production acreages could result. Secondary effects could surface if the IPM programs in one region impact on migration and population densities of mobile pests in another region.

All of these effects should be considered in a complete benefit-cost analysis of IPM adoption. However, the effects which have the greatest potential to alter conclusions generalized from firm level economic studies are the aggregate supply and market price effects. It is conceivable that as IPM programs either raise yields or reduce production costs, the total supply of the commodity is increased, creating downward pressure on market prices. Due to inelastic demands, aggregate farm incomes actually decline since percentage decreases in farm prices can exceed percentages increases in sales. Hence major benefactors of IPM research and adoption can turn out to be consumers and early adopters.

Finally, IPM impacts on the environment through changes in the quantity and pattern of pesticide use should be documented in a complete analysis. Economic valuations of such changes in pesticide use are difficult to calculate, but displays of quantities of active ingredients of pesticides used with and without the IPM program can still prove to be useful information for policy purposes.

CONCEPTUAL PARADIGMS AND PARADOXICAL ISSUES

It is often proposed that IPM programs will increase farm incomes while reducing the environmental degradation associated with the use of pesticides. However, analytical economic models suggest that this may not always be the case. Taylor (1980) discusses and extends the classical paradoxes that may occur if the adoption of IPM generates higher yields and/or lower production costs at the farm level.

The classical explanation of the process is that as farm level profits to individual producers are increased through higher yields and/or lower production costs, farmers respond by increasing production which results in a new, lower equilibrium market price. Since consumers are not sensitive to price changes, as reflected by inelastic demands, the percentage decrease in price is greater than the percentage increase in sales. As a result, the aggregate income to the group of all farmers declines as the market adjusts to the new technology. Until the market reaches a new equilibrium price level, early adopters will receive higher profits than before. In the end, it is likely that consumers will capture a substantial proportion of the benefits through lower prices, while early adopters benefit until the market has fully adjusted.

Cochrane (1986) supplements this classical paradigm by indicating that in a large degree price support programs of the federal government minimize price adjustments, but the early adopters respond to higher profit levels by expanding and purchasing additional land. This causes land values to rise, which in turn generates higher production costs. The treadmill process then changes the structure of production agriculture in favor of larger farms and may increase the costs of government farm programs.

The classical analysis is predicated, to a certain extent, on the degree of price responsiveness on the part of consumers. This is measured in the price elasticity of demand. Given the rising importance of export markets to United States agriculture, it is often argued that total demands of many commodities are not as elastic as conventional wisdom suggests (Tweeten, 1983). Taylor (1980) extends this classical model by demonstrating that, even under conditions of elastic demands, producer incomes can fall if supply curves reflect marginal costs and the new technology affects supply more at high costs than at low costs.

There is a need to use empirical studies to supplement the analytical models of price and structure adjustments to shifts in supply stimulated by the adoption of new technologies. Without both an analytical and empirical basis, these results cannot transcend from the realm of informed expectations to probable outcomes.

DATA NEEDS

To adequately perform benefit-cost analyses of IPM programs, it is necessary to assemble a variety of information. Foremost on the list is a thorough understanding of the farm level impacts on yields (both quantity and quality), costs of production, and net revenues experienced by known participants as a result of adopting the program. These data are usually expressed in per acre terms. Since slight variations in decision rules and production environments may have significant effects on the economic evaluations of pest control programs, it is essential to include a description of the production setting in the analysis (Reichelderfer, 1982). This provides partial protection against unwarranted generalizations. In addition, alternative pest control programs can affect a farmer's risk in different manners and should also merit attention (Cochran and Boggess, 1988; Horowitz and Lichtenberg, 1993).

To perform regional and national analyses, it is necessary to obtain data on the aggregate effects of widespread adoption. The per acre or farm level benefits must be translated into impacts on the local economy by measuring multiplier effects produced by changes in the mix and magnitude of goods and services exchanged. Part of this aggregation process should focus on the shifts in supply and possible changes in prices of not only the crop being produced but also related goods such as inputs. To accurately assess the latter effects, it is desirable to employ a price endogenous regional or sector model. Significant aggregate effects can also influence distribution of crop production across regions by altering relative profitability and may need to be addressed with a spatial equilibrium model. These more sophisticated models require: (a) data on appropriate multipliers by region and crop; (b) supply and demand specifications (particularly price and cross price elasticities); (c) measures of regional comparative advantage based on relative profitability; and (d) relevant resource constraints.

The cautions on self-selection bias expressed by Reichelderfer (1982) and Hall and Duncan (1984) about identifying differences in characteristics between voluntary participants and non-participants should be heeded in the aggregation process. The multiplication of per acre benefits measured for a small group of early participants by the number of acres historically devoted to the crop to determine potential benefits for an entire region is at best a naive process and should be employed only to provide a crude indication of possible regional effects. Unfortunately, a lack of research resources available for assessments has made this a too frequent necessity.

STUDIES OF REGIONAL AND NATIONAL IMPACTS OF IPM PROGRAMS ON PRODUCER INCOME, CONSUMER SURPLUS AND LOCAL ECONOMIES

Although the incidence of complete economic studies on the impacts that IPM programs may have on the local, regional and state economies is not as frequent as desired, a few analyses do surface in the literature. The difficulties and expense of collecting timely and accurate data pose major problems in closing the gap between what theoretical paradigms suggest be done and what is actually achieved in empirical study. The following survey of the empirical literature will provide a summary of the findings on the aggregate economic impacts of IPM adoption.

ARKANSAS BOLLWORM MANAGEMENT COMMUNITY

Since 1975 in the state of Arkansas, cotton farmers have voluntarily organized bollworm management communities (BMC) in an attempt to manage the populations of bollworm, *Helicoverpa zea* (Boddie) and tobacco budworm, *Heliothis virescens* (F.) over large land areas rather than by the more common field-by-field approaches. The intent is to coordinate control decisions so that all cotton fields in a bollworm management community will be treated within a three-day interval. In 1988, there were approximately 150,000 acres in six bollworm management communities in the state of Arkansas. Formal assessments of the economic impacts of the bollworm management community are found in Parvin *et al.* (1984), Cochran *et al.* (1985) and Scott *et al.* (1983).

Parvin *et al.* (1984) compared the performance of the bollworm management communities to control areas in adjacent counties to identify farm level benefits from participation. Significant differences in yields, insect control costs and net returns per acre were discovered. Yields were increased by 23 pounds of lint per acre; insect control costs were lowered by $1.85 per acre; and net revenue was increased by $18.57 per acre. Cochran *et al.* (1985) use these data to estimate that the bollworm management community program increased producers' incomes in 1984 by $1.5 million and reduced pesticide use by 92,000 pounds of active ingredients.

As an indirect benefit, it was hypothesized that the bollworm management communities function as an effective mechanism for technology transfer and information dissemination. Scott *et al.* (1983) measured the effect that participation in a bollworm management community has on the adoption of all production practices (not just pest management) recommended by the cooperative extension service. It was discovered that participation in a bollworm management community increases the percentage of adoption of the recommended practices by about 11 percent.

TEXAS ROLLING PLAINS UNIFORM PLANTING DATE COTTON SYSTEM

An IPM program designed to control intense infestations of boll weevils and reduce high production costs is the delayed uniform planting date system (UPD) employed in the Texas Rolling Plains since 1973 (Masud *et al.*, 1984; Masud *et al.*, 1985a). By delaying the planting until around May 20, ninety percent of overwintering boll weevils emerge and die before oviposition and feeding sites in the plants are produced. Using data from 27 counties in the years between 1970 to 1981, Masud *et al.* (1984) performed an economic analysis consisting of regressions on per acre yields, partial budgeting and an examination of regional impacts.

A regression model was developed to measure the impact that adoption of the program has upon the farm level yield. The results show that the uniform planting date program increased yields by about 25 pounds of lint per acre, after accounting for the impacts of other factors such as rainfall, temperature, fall freeze dates, and the total number of cotton acres planted in the region. The next step in the analysis was a partial budgeting study that identified the per acre differences in costs of production and net returns between the region's cotton produced under the program and that outside the program. Masud *et al.* (1984) found that total per acre variable costs for the uniform planting date cotton were $5.68 lower and net returns to land, management, overhead and risk were $21.36 per acre higher. The reduction in variable production costs was related to decreases in the use of insecticides, cottonseed and labor. Based upon the coefficients of variation of yields and net returns, risks associated with the program were also less than the conventional control systems in seven of nine years.

The final steps of this analysis consisted of a regional and state impact assessment. The results of the assessment, covering the years of 1970 to 1981, appear in Table 1. The total annual impact for the region and the state in this time period are reported to be $192 million and $305 million, respectively. Included in this figure is the increased value of production resulting from the conversion of land previously devoted to pasture and grain sorghum to cotton as a benefit of the program. If this conversion is not attributed to the development of the uniform planting date program, the regional impact is lowered to $36 million and the state impact becomes $57 million.

Table 1. Annual estimated economic impact of the uniform planting date cotton production system on the Rolling Plains and state of Texas. (Assessment covers the years 1970 to 1981.)

		Impact	
Gross revenue sources	Gross revenue change	Rolling Plains	State
	($ Million)	($ Million)	
Increased gross revenue from existing cotton acres	+15.13	+36.16	+57.04
Gross revenue from land converted to cotton	+91.59	+218.91	+345.31
Gross revenue from sorghum acres converted to cotton	-17.53	-42.76	-63.62
Gross revenue from pasture converted to cotton	-9.45	-20.31	-33.54
Total	+79.74	+192.00	+305.19

AGGREGATE ANALYSIS OF INCREASED BOLLWORM INFESTATIONS ON THE TEXAS HIGH PLAINS

Another study in the same region as uniform planting date program (High Plains of Texas) examined the aggregate economic implications of increased bollworm infestations (Masud *et al.*, 1985b). The per acre effects of bollworm infestations on net returns are presented in Table 2. Prior to 1975 bollworm attacks were of insignificant importance. Since that time bollworm infestations have increased due to large shifts in crop acreage, hot dry weather, increased pesticide use on other crops, decreased beneficial activity and attempts to harvest late maturing bolls.

Table 2. Per acre impact of alternative bollworm infestation levels, Texas High Plains.

Production system	Bollworm infestation level	Reduction in profits
		($ per acre)
Dryland	None	—
Dryland	Light	4.48
Dryland	Moderate	7.62
Dryland	Heavy	8.82
Irrigated	None	—
Irrigated	Light	7.68
Irrigated	Moderate	8.75
Irrigated	Heavy	13.45

Aggregate economic impacts were determined by establishing first a suitable estimate of the number cotton acres affected, categorized by dryland and irrigated production, bollworm infestation level and year. This was accomplished by conducting a survey of 30 representative farms in a 20-county region. Proportions of acres in each category uncovered in the survey were then multiplied by total acreages published by the Texas Crop and Livestock Reporting Service to produce the acres in each category. Reductions in producers' incomes were then calculated by multiplying the estimated loss per acre for each category by the established number of acres and summing across relevant categories. Average annual losses in producers' income during 1979 to 1981 due to bollworm infestations were estimated to be over $33 million. As part of this loss to the bollworm, cotton production was reduced by almost 32,000 bales in the region. An upper limit on potential losses to bollworm resistance was derived by examining scenarios where no insecticides were applied. In this case, average annual production losses are expected to equal 302,489 bales for the Texas High Plains.

TEXAS SHORT-SEASON COTTON SYSTEMS

In a number of regions in Texas, short-season, narrow-row, cotton-production systems were developed to reduce energy and insecticide use by increasing plant densities, accelerating fruiting through water and fertilizer management, and implementing IPM insect control. Economic analyses were performed for the Winter Garden, Lower Rio Grande Valley, Trans-Pecos, and Coastal Bend regions of Texas (Lacewell and Masud, 1988). However, only in the Coastal Bend area was a regional analysis conducted to identify impacts of the program adoption on the regional economy.

In the Winter Garden region, a partial budgeting study revealed that energy and insecticide use on a per acre basis decreased by 33 percent and 27 percent, respectively as a result of the adoption of the short-season system (Sprott *et al.*, 1976). In addition, yields and net returns were increased respectively by 30 percent and 846 percent. While production costs on a per acre basis were increased, the increases in these costs were offset by increases in yields so that costs per pound of lint were actually reduced.

The budget comparisons for the Lower Rio Grande Valley displayed similar patterns (Shaunak *et al.*, 1982). The study examined data from 1973 to 1978 and divided the time period into two intervals (1973 to 1975 and 1976 to 1978). Comparisons to conventional practices were made in both dryland and irrigated systems. Net returns above total costs for dryland systems were increased by $57.69 per acre in 1973 to 1975 and $49.25 per acre in 1976 to 1978 by adopting the short-season, narrow-row practices. In the irrigated systems, the difference between time periods was even more drastic. In 1973 to 1975, the net returns per acre were $12.54 higher with the new IPM technology while in 1976 to 1978, the advantage was estimated to be $93.99.

In the Trans-Pecos region, an IPM short-season program increased profits by $186.50 per acre while lowering per acre production costs by 46 percent, nitrogen by 76 percent, pesticides by 71 percent and irrigation by 25 percent (Condra *et al.*, 1975 as cited by Lacewell and Masud, 1988). However, a decrease in yields of 11 percent was also experienced.

The short-season IPM program developed for the Coastal Bend region was evaluated by Masud *et al.* (1980). Adoption of the short-season production systems, among other factors, led to an expansion of the cotton acreage in the region from 50,000 acres in 1975 to over 300,000 acres in 1980. Short- season IPM programs generated higher yields and net returns. Total insect control costs were reduced by $5.72 per acre and total production costs per pound of lint were decreased as well. Costs of production, on a per pound basis, were calculated to be $0.40 to $0.42 for IPM short-season, $0.46 to $0.50 for typical short-season practices and $0.56 for the long-season conventional production system.

A linear programming model was used to estimate the potential impact on net returns to the region if the IPM short-season program were widely adopted in the Coastal Bend region. The model identified which of several alternative production systems would maximize producers' incomes, given the available acreage of each soil type in the region. The IPM CAMD-E cotton and grain sorghum system resulted in the greatest net return to the region, increasing producers' incomes by $34.2 million over the typical CAMD-E cotton and grain sorghum system.

An estimate of the impact that the IPM program has on the regional and state economies can be derived by multiplying the gross revenues calculated by the linear programming model by an appropriate multiplier. This produces an assessment of the value of the additional sales that are generated by the increased economic activity in the region or state due to the new technology. These estimates are presented in Table 3. It can be seen that within the Coastal Bend region approximately $250 million of additional activity can be attributed to the conversion from the CAMD-E cotton and grain sorghum system to the IPM CAMD-E cotton and grain sorghum system. At the state level this figure is $367.74 million.

Table 3. Impact of short-season IPM production systems in the Coastal Bend region and the state of Texas, 1980.

		Regional impact	
System	Gross revenue	Coastal Bend	Texas
	($ Million)		
1. IPM CAMD-E cotton and grain sorghum	292.88	729.40	1101.65
2. IPM SP-37 cotton and grain sorghum	272.96	679.19	1026.46
3. Typical CAMD-E cotton and grain sorghum	185.79	440.05	668.93
4. Grain sorghum	137.37	300.84	498.65

SOUTHEASTERN BOLL WEEVIL ERADICATION PROGRAM

In 1978, a Boll Weevil Eradication Trial (BWET) program was implemented in Virginia and northeastern North Carolina. During the period from 1978 to 1982, eradication activities directed by the Animal and Plant Health Inspection Service (APHIS) of the USDA covered an area of between 16,000 and 43,000 acres of commercial cotton. The area was divided into several zones. In a northeastern section of the area, boll weevils were eradicated and hence this subarea was labeled the Eradication Zone (EZ). It was surrounded by an 85-mile Buffer Zone (BZ), where insect monitoring and control were fostered to prevent reinfestation of boll weevils in the eradication zone. As a result of the program, boll weevil populations in the buffer zone were reduced below levels normally achieved by farmers in the subarea (Carlson and Suguiyama, 1985). An expanded area and its associated buffer zone south and west of the buffer zone were added to the effort in 1983. This expansion represented a transition from a trial program to an operational eradication program.

Carlson and Suguiyama (1985) identified the benefits and costs and calculated internal rates of return for different groups involved in this boll weevil eradication program. In addition to the eradication and buffer zones, they studied a comparison area to quantify before-and-after changes in net returns, pesticide use, cotton yields and cotton acreage. Public and private program costs were also estimated. It was anticipated that farmers would react to lower insecticide costs, higher yields and program fees by adjusting the amount of acreage planted to cotton. Acreage adjustments were included in the analysis to account for changes in producer' surplus and returns to owners of expanded acreage that might exceed the per acre cost savings generated by fewer insecticide treatments. Changes in the cotton and input prices were ignored as being insignificant due to the fact that the area comprises such a small proportion of United States cotton production and input markets.

Within the eradication zone, insect control costs were reduced from $51 per acre in the before-period to $17 per acre during the program (Table 4). However, not all of this reduction can be attributed directly as a benefit of the eradication program. Insect control costs in the comparison area also declined (by 12 percent) due to lower infestations in the same period. After this adjustment for infestation rates, cost savings due to the program were calculated as $28 per acre. In addition, due to the expansion of cotton acreage as a response to increased profits generated by the eradication program, the value of land not previously devoted to cotton rose. This benefit due to the acreage expansion effect was equal to $8 per acre and raised the total benefits of the eradication program to $34 per acre. It also was estimated that yields were increased from 30

Table 4. Boll weevil eradication benefits: insecticide cost reductions and cotton acreage expansion effects (North Carolina and Virginia).

	Eradication zone	Comparison area	Buffer zone
	($ per acre)		
Average 1974-1977 private insect control costs	51	59	59
Average 1979-1982 private insect control costs	17	52	44
Adjusted eradication insect control cost reduction	28	—	8
Acreage expansion effect	8	—	8
Total benefits to eradication	36	—	16

to 50 pounds of lint per acre due to the program, but since these results were predicated upon experimental plot data and not actual farmer field experiences, yield effects were assumed to be zero to avoid biases in favor of the program.

Eradication program costs, both public and private, were estimated and used in calculating the rates of return for several participating groups. Return on investment when all public and private costs are considered was calculated as 29 percent. Rate of return for the expanded area was estimated at 67 percent. This ignores indirect benefits which might be produced from environmental improvement due to lower pesticide use. Net present values for average growers in the eradication and buffer zones were calculated when only relevant private costs were considered. These values were \$240 and \$69 per acre, respectively. Net present value figures demonstrate the value of a stream of future benefits net of additional costs, expressed in terms of current dollars. Hence, the average growers in each zone benefited considerably from the boll weevil eradication program.

EARLY APPRAISALS OF NATIONAL BENEFITS OF BOLL WEEVIL CONTROL PROGRAMS

In 1974, the United States Department of Agriculture studied the costs and benefits of three alternative federally sponsored boll weevil control programs (Lacewell and Masud, 1988). The national programs evaluated were based on the: (a) Texas High Plains Boll Weevil Containment Program; the (b) Pilot Boll Weevil Eradication Experiment in South Mississippi, Alabama and Louisiana; and (c) the use of accepted pest management practices on a field-by-field basis. The first program was designed to prevent the spread of boll weevils to uninfested acreage while the second was intended to eliminate the boll weevil completely from the United States. The last program assumed the use of the best field-by-field pest management practices available. The benefits and costs for each program over a 15-year (1974-1988) time horizon were calculated and converted to a common base in terms of present values. Benefit-cost ratios were also derived.

For the High Plains program, a benefit-cost ratio of 16:1 (\$273 million in benefits and \$17 million in costs) was estimated. A benefit-cost ratio of 3:1 (\$1,378 million benefits and \$399 million costs) was calculated for the pilot eradication program. Finally, the field-by-field pest management program recorded benefits of \$818 million and costs of \$68 million for a benefit-cost ratio of 12:1.

The study concluded that the High Plains program represented the best investment given limited funds. With unlimited funds, the eradication program would demand attention since it produces the largest net present value.

NATIONAL AND REGIONAL ANALYSIS OF BOLL WEEVIL CONTROL STRATEGIES

One of the few examples of national evaluations of IPM strategies which examine possible impacts that farm level effects may have on aggregate supply and market prices is the work of Taylor and Lacewell (1977). They examined economic impacts of three boll weevil control strategies at both the regional and national levels. The three control strategies considered were: (a) eradication — the integration of many controls including insecticides for reproduction-diapause control, early stalk destruction, pheromone-baited traps, trap crops, early season insecticide sprays, and massive releases of sterile boll weevils; (b) currently available IPM (1977); and (c) IPM that will be available with 5 to 10 more years of research.

The analysis focused on the estimated effects the adoption of the three alternative strategies would have on consumer surplus, producer surplus and state and federal program costs not transferred directly to producers. Changes in the three performance measures were summed to provide the net social benefits, excluding environmental impacts, associated with each strategy. An interregional activity analysis model of the production of eight crops (cotton, soybeans, corn, sorghum, wheat, barley, rye and oats) in the United States was employed. The model maximizes consumer surplus in 21 consuming regions and producer surplus in 147 producing regions minus transportation costs, subject to resource constraints. It provides a competitive market and spatial equilibrium solution.

Data on the per acre changes in production costs and yields for each strategy were developed from surveys of entomologists in each state who were most familiar with boll weevil control (Pimentel *et al.*, 1976). These data were supplemented by asking the same entomologists to estimate changes in yields and costs if the boll weevil were eradicated.

Results indicate that under these circumstances the present value of changes in consumer and producer surpluses, minus any consideration of transportation costs, for the three strategies are: (a) \$1,431 million for currently available IPM; (b) \$1,890 million for IPM that will be available in 5 to 10 years; and (c) \$1,985 million for eradication. All estimates are in terms of 1973 nominal dollars. However, when non-producer program costs of \$176 million for current IPM and \$1,062 million for eradication are considered, Taylor and Lacewell (1977) conclude that eradication may not be the optimal strategy for either society or producers. Furthermore, they strongly suggest that, in the aggregate, farmers as landowners would not benefit from the widespread adoption of these programs since land values would fall. Consumers would benefit substantially by lower cotton prices.

The model was also used to identify possible shifts in regional production patterns as national adoption of the alternative controls differentially impacts on relative profitability. In many states no major changes were observed. However, in the following situations significant shifts are predicted: (a) 90 percent increase in Alabama with eradication; (b) 92 percent increase in Arizona with the current IPM; (c) 34 percent increase in Arkansas with the two IPM cases; (d) 14 percent and 46 percent decreases in California with current IPM and eradication, respectively; and (e) 38 percent increase in Louisiana for eradication; and (f) 10 percent decline in Mississippi with eradication.

SUMMARY

While few complete benefit-cost analyses of IPM programs have been performed, the economic studies to date generally suggest that IPM in cotton has had a significant positive effect. Studies of the bollworm management communities of Arkansas, the uniform planting date program of the Texas Rolling Plains, the Texas short-season IPM systems, and the Southeastern boll weevil eradication program display benefits which exceed the costs examined. In many cases, the contribution to regional and state economies was estimated to be hundreds of millions of dollars. This evidence implies that the IPM approach has been successful in altering pesticide use patterns, increasing producer incomes, lowering production costs, and making United States cotton more competitive in world markets.

However, several theoretical concerns and paradoxes have not been conclusively handled in empirical studies. The problem of generalizations based on the experiences of voluntary adopters ignores the problems of self-selection biases. The neglect of the market price adjustments fostered by supply shifts which result from higher per acre yields or lower production costs may produce misleading conclusions. Rather than increasing producers' incomes in the long run, IPM adoption may result in higher land values, more expensive government programs, and lower market prices. Benefits may accrue to consumers and early adopters rather than being uniformly distributed to the group of cotton producers as a whole. Additional and more complete analyses are needed to determine the actual significance of these theoretical concerns.