SOCIAL RETURNS TO DISEASE AND PARASITE CONTROL IN AGRICULTURE: WITCHWEED IN THE UNITED STATES

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The U.S. Department of Agriculture now spends more than $150 million annually to control diseases, parasites, and other pests that reduce animal and plant production. These programs and activities are administered by USDA's Animal and Plant Health Inspection Service (APHIS). In recent years, program costs have increased rapidly, and USDA officials have been asked many questions by the Congress, the Office of Management and Budget, and others concerning the need for certain programs. Steadily increasing pressure to reduce Federal spending means that public decisionmakers urgently need reliable aggregate measures of the performance of their programs.

- This study provides *ex ante* estimates of the value to society of the U.S. Department of Agriculture's witchweed program. Program objectives are to contain and eradicate witchweed, a semiparasitic plant which reduces corn and grain sorghum yields. Critical elements which determine the social value are cost of the program, price elasticities of supply and demand, and shifts in supply occurring in the absence of a program.

- Keywords: Witchweed, consumers' surplus, program evaluation, social rate of return, benefit-cost ratio.

One such type of measure, social rate of return to public investment, has been estimated for agricultural research in the United States—by several researchers (*4, 5, 12,*).[2] Results are very favorable, indicating rates of return ranging from 30 to 55 percent. A study of public investment in cotton research in Brazil reports a return of at least 77 percent (*2*). However, with a few noteworthy exceptions, much less attention has been directed to deriving aggregate estimates of the social value of specific Government programs (*7, 19*).

Primary objectives of the research reported here were to derive benefit-cost ratios and rates of return for APHIS programs to contain and eradicate witchweed in the United States.[3] Witchweed is a semiparasitic plant that reduces corn and grain sorghum yields.

The thesis of our analysis is that public investment in a witchweed program allows a given bundle of private resources to produce a larger output (or, allows a given output to be produced with fewer resources), resulting in an increase in domestic consumption and exports. Utilizing a series of assumptions, we provide aggregate *ex ante* estimates of "real social" effects—effects that expand the total production and consumption potential of American society. A comparative analysis of two alternative witchweed programs appears, in which slow and rapid rates of witchweed spread are assumed and key determinants of social value generated by the programs are discussed.

This analysis has been designed to serve as an input for policy officials and program managers faced with specific decisions concerning witchweed in the United States. Therefore, we attempt to overcome the well-known criticism that studies using economic-surplus methodology are often too aggregate in scope and conducted too long after the fact to help in decision-making.[4] We believe that the methodology and procedures presented here can be applied in measuring the social value of other disease and parasite control programs.

BACKGROUND

"Officially" discovered in North and South Carolina in 1956, witchweed may have been introduced into the United States as early as 1951. It is an annual seed-producing plant which grows to a height of 6 to 12 inches and normally has red and orange flowers. The witchweed seedling attaches itself to the root of a host plant, and it causes extensive stunting. More than 60 species of the grass family serve as hosts.

Witchweed can exist wherever host plants exist. In the United States, it has been restricted to a con-

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[2] Italicized numbers in parentheses refer to items in References at the end of this article.

[3] It is recognized that the two criteria used, present value and internal rate of return, may lead to conflicting conclusions; for example, see (*6*, pp. 27-42). We believe that it is informative to present results for both criteria. Calculation of the internal rate of return requires data on the flow of benefits and costs alone. It does not require an assumed opportunity cost of capital, or social rate of discount, which is critical to the present-value technique.

[4] The strengths and weaknesses of the economic surplus concept as a tool in applied economic analysis have been widely debated. Two recent surveys are provided by Currie, Murphy, Schmitz (*3*) and Mann (*10*).

tiguous area of eastern North and South Carolina. In 1956, severe damage to the corn crop was reported in both States, and in some instances, there were total losses (*16*). In many parts of the world, witchweed causes serious economic losses in corn, grain sorghum, and sugarcane.[5]

Witchweed seeds are spread only short distances by natural means such as wind. However, they can be transferred long distances by artificial means, including relocation of farm machinery, shipment of infested host plants or their seeds, and in soil taken from infested fields. Thus, witchweed is a serious threat to corn and grain sorghum production in the United States (*17*).

After witchweed discovery, a Federal quarantine was issued and APHIS developed a program aimed at containing witchweed in North and South Carolina and eventually eradicating it. The program involves three basic tools: (1) a Federal-State quarantine, (2) application of chemical controls, and (3) biometric surveys. Quarantine enforcement and farmer compliance have prevented further spread of witchweed. The North and South Carolina State Departments of Agriculture and APHIS cooperate by furnishing and applying 2,4-D and other chemicals, and farmers plant nonhost crops in some areas.

Today, the American taxpayer can choose from two primary alternatives. One is to have *no witchweed program*. Consequences of this decision are reduced yields of corn and grain sorghum and higher farm production costs as witchweed spreads. Yields on infested acreage could fall about 10 percent and farmer control costs could average more than $11 per acre—without a program. This situation would encourage farmers to shift to nonhost crops, and the users of corn and grain sorghum and products produced from these commodities would reduce their demand and seek lower-priced substitutes.

A second alternative is to *continue a witchweed program*. Consequences are avoidance of reduced yields and higher production costs but only through public spending on a witchweed program.

In our empirical analysis, we divide the second alternative into two budget options, A and B. Budget option A is expected to continue containment, but not achieve eradication. Budget option B, though, is expected to accomplish both containment and complete eradication in 8 years. Program experts anticipate a high probability of success for either option. However, the probability of containment may be somewhat less under budget option A because eradication is not achieved and the possibility of spread by artificial means remains indefinitely.

[5] Sugarcane was excluded from the analysis because reliable estimates of witchweed's effect on yields and future market prices and quantities are not available.

THE ECONOMIC ANALYSIS

Theoretically, the critical elements determining the social value of a witchweed program are its cost, price elasticities of supply and demand, and negative shifts in supply due to witchweed infestation. For supply shifts, the rate of spread, reduction in yield on infested acreage, and increase in farmer control costs are particularly important factors. All these elements were considered in specifying the economic model used to evaluate the witchweed programs.

Structure and Assumptions of Economic Model

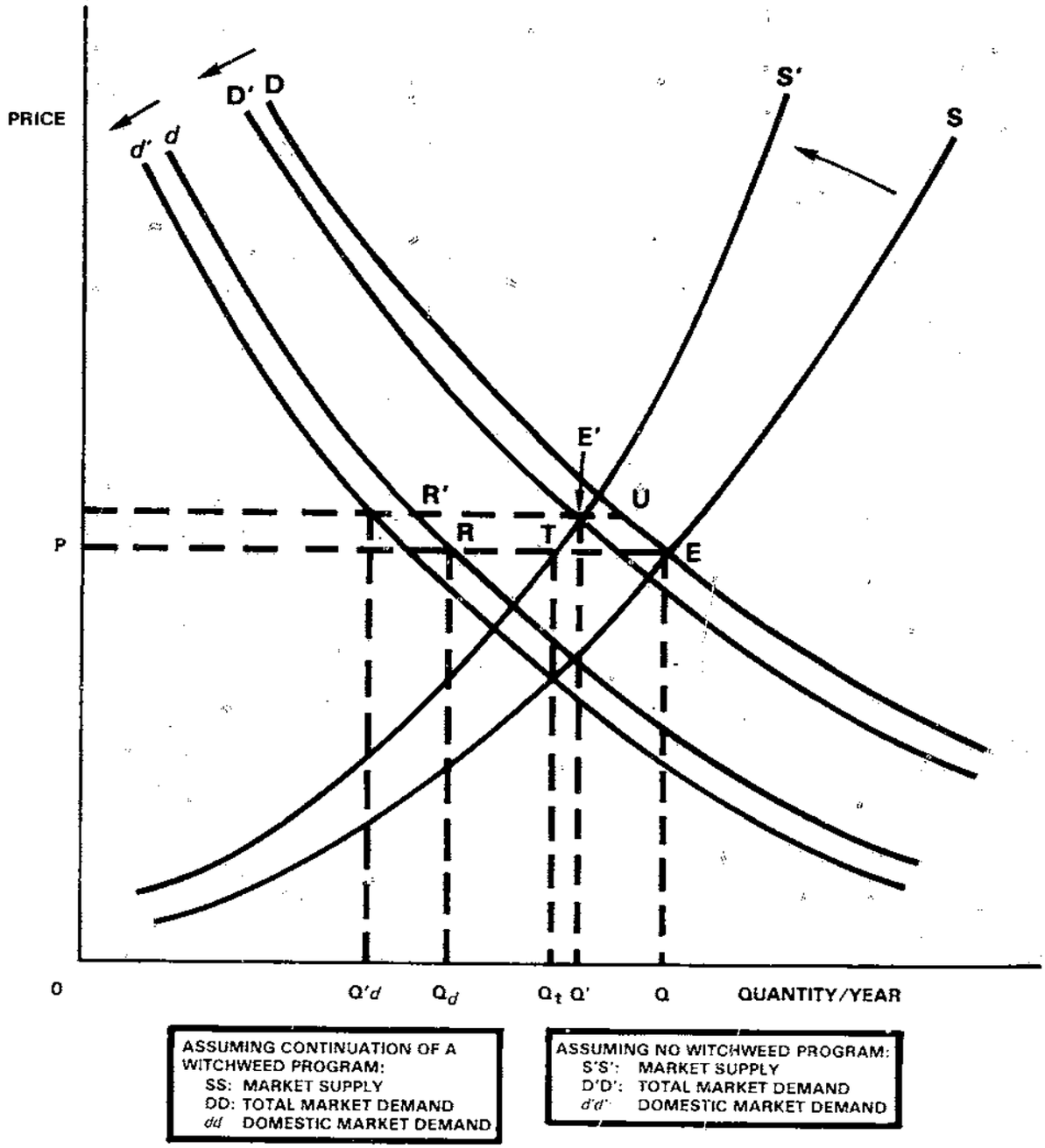
We assume the existence of competitive markets with longrun demand and supply curves for corn and grain sorghum, depicted in the figure.[6] DD represents total market demand after allowing complete quantity adjustments to any price change by domestic (*dd*) and foreign users.[7] SS represents market supply assuming that all factors of production are variable, the rate of return to each factor equals its opportunity costs, and that a witchweed program continues.[8] If the last assumption is dropped, market supply shifts upward and to the left, as shown by S'S'. The magnitude of the shift in supply depends on the rate at which witchweed spreads, the reduction in yield on infested acreage, the increase in farmer control costs, and the opportunities to shift to nonhost crops and other enterprises. Also, total market demand for corn and grain sorghum tends to shift downward and to the left as domestic and foreign users purchase relatively lower priced substitutes.

As the figure reveals, in the presence of a witchweed program, a larger quantity of corn and grain sorghum clears domestic and export markets at a lower price, increasing the social welfare. Benefits may be measured by the increase in consumers' surplus in the domestic market (area P'R'RP) and the export market (area R'U ER). These gains reflect the willingness of domestic and foreign consumers to pay for the additional grain resulting from a witchweed program, rather than do without it. Whether people actually make these payments or whether they pay

[6] Justification for the use of a longrun planning horizon includes our assumption that the results of this analysis will be considered before decisionmakers have selected either primary alternative or program option, and the fact that the benefits and costs of their decisions accrue over many years. Our assumption of competitive markets is naive for exports because the international grain trade is dominated by a few large firms and commodity flows are strongly influenced by tariffs, subsidies, quotas, and negotiated agreements. However, about 75 percent of U.S. corn and grain sorghum moves through domestic markets which are more competitive.

[7] For a discussion of lengths of run in demand theory, see (*20*, pp. 20-22).

[8] We also assume an increasing-cost industry (that is, resource prices rise with resource usage).



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less, retaining a "consumers' surplus," does not change the social value of the program; it only changes the distribution of benefits.

Producers' surplus is omitted from the analysis following Mishan (*11*, p. 1278): when "all factors are variable in supply, the industry's supply curve necessarily includes all factor prices and, therefore, all rents." In the long run, economic profit (loss) does not exist because the free entry (exit) of resources forces the rate of return in corn and grain sorghum production to a level comparable to that obtainable in other perfectly competitive industries. Specifically, producers receive only an accounting profit equal to the return they could earn in their best alternative.

Of course, there may be shortrun gains or losses to the owners of resources that are particularly suited to corn and grain sorghum production. These gains and

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losses are sometimes called economic rent, and they accrue to the owners of fixed resources. In moving from E to E', returns to factors of production may change. While producers earn no excess profits in the long run, landowners gain if shortrun producers' surplus is capitalized into higher rents for a fixed amount of land. The distribution of shortrun benefits and costs of a witchweed program are discussed later.

In the empirical analysis, market demand is measured at the farm level. It has been shown that consumers' surplus under a factor demand curve is consumers' surplus in the final product market plus any producers' surplus in intervening factor markets (*19, 8, 21*). Because this analysis assumes a longrun time period and competitive markets, P'U EP represents global consumers' surplus in final product markets.

Net social benefit due to a witchweed program is found by subtracting program costs from the increase in consumers' surplus. Benefit-cost ratios and rates of return presented here are for American taxpayers. Thus, they include only the consumers' surplus gained in the domestic market. The change in export earnings $(P(Q-Q_d) - P'(Q'-Q'_d))$, increases the opportunity for Americans to purchase and consume foreign goods and services.[9] However, we do not have a direct measure of the surplus Americans gained from consuming foreign goods and services.

Empirical Procedures

A multicommodity model was used to project prices and quantities of corn and grain sorghum from 1981 to 2000, with and without a witchweed program.[10] The empirical model developed by Gerald Plato simulates price-quantity responses of 21 commodities, given a set of exogenous variables. Constant elasticity of demand and supply equations are specified for each commodity at the farm level. Own-price demand elasticities for corn and grain sorghum are −0.58 and −0.64 in the domestic market, and −1.50 in the export market (*15*).[11] The longrun, own-price elasticity of domestic supply is 0.80 for each commodity. Since the equations are nonlinear, a numerical technique, Newton's method, is used to find equilibrium solutions (*1, 13*).

The exogenous variables specify a future scenario or "economic environment" in which commodity prices and quantities are projected. The scenario used here represents trends and "most likely" judgments for the exogenous variables (*14*). For example, we assume a U.S. Census E population projection, which gives an annual growth rate of 0.8 percent. Per capita disposable income in the United States is assumed to grow at 2.6 percent per year, from $5,511 in 1976. Agricultural productivity projections are based on a 3.0-percent annual increase in agricultural research and development expenditures, which cause the index of U.S. agricultural productivity to increase from 111 in 1976 to 135 in 2000 (*9*). Trends in U.S. exports and imports depend on a continuation of current agricultural trade policies, food production in developing countries that grow slightly faster than population, and consumer incomes abroad that gain at rates comparable to those of the sixties.

In solving the empirical model that assumes no witchweed program, the speed at which witchweed seeds spread and infest new acreage becomes crucial. Although the opinions of plant scientists vary widely, if giant foxtail is used as a prototype, there is consensus that witchweed would spread throughout the corn and grain sorghum regions of the United States in 30 to 75 years.[12] Therefore, we consider a slow rate of spread (1.3 percent of corn and grain sorghum acreage infested per year), which means complete infestation in 75 years; and a rapid rate of spread (3.3 percent of corn and grain sorghum acreage infested per year), with complete infestation in 30 years. Because of the manner in which witchweed spreads, plant scientists believe that a constant percentage rate of spread is realistic.

If there is no witchweed program, we assume that farmers adopt private control measures which would hold the reduction in yield on infested acreage to about 10 percent a year.[13] This requires 1.5 herbicidal applications per year at an annual cost of $11.25 per acre (*16*). It is assumed that a 1-percent increase in farmers' control costs results in a 0.20-percent reduction in the supply of corn and grain sorghum, other things constant (*15*). This coefficient reflects the ability of farmers to expand their planting of nonhost crops, such as soybeans, with relatively lower costs of production.

The empirical model was used to make two sets of projections from 1981 to 2000. First, prices and quantities of the 21 commodities are projected, assuming a witchweed program. These projections are based on assumptions underlying the longrun market supply, SS, in the figure. Second, the projections are repeated without a witchweed program, or assuming S'S'. This involves calculating a negative shift in market supply due to witchweed infestation (Q to Q_l in the figure), and allowing movement along the market supply curve to achieve a new equilibrium solution (Q_l to Q' in the figure). The magnitude of the negative shift in market

[9] A decline in market price from P' to P causes export earnings to increase (decrease) if export demand is own-price elastic (inelastic).

[10] The commodity prices and quantities used in calculating program benefits in this article do not constitute official projections of the U.S. Department of Agriculture.

[11] It has been shown that social returns generated in studies of this type are highly sensitive to assumed demand elasticities (*18*). The domestic demand elasticities used here reflect combined uses of corn and grain sorghum in livestock feeding, industrial uses, and human consumption.

[12] Giant foxtail seeds spread by artificial means throughout the United States in 15 to 20 years.

[13] If farmers do not use private control measures, yields are expected to fall 50 to 100 percent.

supply varies directly with the rate of spread of witchweed, the assumed 10-percent reduction in yield on infested acreage, and the responsiveness of farmers in corn and grain sorghum plantings to an increase in the control costs.

Price and quantity observations generated by the empirical model are used to calculate program benefits over the long run. From a practical standpoint, it should be recognized that the discount factor to be applied to program benefits and costs in the 25th year is 0.09, assuming a 10-percent annual rate of discount. Therefore, the flow of benefits and costs beyond 2000 will not significantly alter results of this analysis.

INTERPRETATION OF RESULTS

Aggregate *ex ante* benefit-cost ratios and social rates of return indicate that a witchweed program is a desirable public investment. The results presented here are based on specific assumptions about economic-surplus methodology, demand and supply elasticities, exogenous variables, rate of spread of witchweed, reduction in yield on infested acreage, private control measures and costs, and Government program options and costs.

The Results

Projected annual benefits and costs in 1976 dollars appear in table 1. If the decision is made in favor of budget option A, containment could be achieved, but not eradication. Annual program costs of $6.0 million from 1977 to 2000 are not sufficient to allow an intensive and widespread application of chemicals. Thus, annual cost outlays must continue indefinitely to achieve containment in North and South Carolina.

If the eradication program is adopted (budget option B), containment and complete eradication could be achieved in 8 years. Annual costs would peak at about $12.0 million in 1980 and 1981. Biometric surveys and related activities would be necessary for 9 years after eradication is achieved. Discounted at the annual rate of 10 percent, the present values of cost flows under budget options A and B are $57.4 million and $52.1 million, respectively.

Annual benefits are measured by the increase in consumers' surplus in the domestic market due to a witchweed program. (The increase is area P'R'RP in the figure.[14] The consumption of the additional corn and grain sorghum creates this surplus, one which domestic consumers would be willing to forego if necessary. The benefits presented in table 1 vary directly with time and the rate at which witchweed spreads. Based on the recommendation of plant scientists, we assume an innoculation period of 4 years. If a decision had been made to have no witchweed program beginning in 1977, significant losses in production would not appear until the end of the innoculation period, or 1981. Also, we assume no measurable differences in benefits under the two alternative programs. Eradicating witchweed in North and South Carolina by 1984, as opposed to absolute containment, will not significantly increase the production of corn and grain sorghum in the United States. There-

Table 1—Projections of annual benefits and costs of witchweed programs, 1977 to 2000[1]

Year	Benefits: Slow rate of witchweed spread[2]	Benefits: Rapid rate of witchweed spread[2]	Costs: Budget option A: Continue current program[3]	Costs: Budget option B: Eradication program
	Million dollars			
1977	0	0		4.1
1978	0	0		8.2
1979	0	0		11.3
1980	0	0		11.9
1981	6.6	17.5		11.6
1982	14.5	35.9		9.0
1983	21.7	54.8		6.2
1984	29.5	74.0		3.3
1985	37.4	93.6		2.0
1986	45.6	114.2		1.4
1987	53.8	134.9		1.3
1988	62.5	156.3		1.3
1989	71.6	178.1		1.3
1990	79.9	200.4		0.6
1991	88.9	229.7		0.6
1992	98.0	254.2		0.6
1993	107.4	279.2		0.6
1994	124.4	305.0		0
1995	126.8	330.9		0
1996	136.5	357.8		0
				0
1997	146.7	385.2		0
1998	156.7	412.9		0
1999	167.2	441.5		0
2000	177.6	470.8		0

[1] Benefits and costs are in 1976 dollars. [2] Assumed annual rates of spread are 1.3 percent and 3.3 percent, respectively. [3] 6.0 for each year but 1977, when figure is 4.1.

[14] The algebraic expression is:

$$\text{area } P'R'RP = \int_{P}^{P'} NP^{\alpha}\, dP,$$

where the domestic demand equation (dd) is collapsed into two dimensions: $Q = NP^{\alpha}$, by letting the intercept term, N, include all other parameters and variables.

fore, annual benefits are assumed to be equal under the two budget options.[15]

Benefit-cost ratios and social rates of return appear in table 2. A 10-percent annual rate of discount was applied in calculating the present value of future benefits and costs. The social rate of return (r) is the time discount factor which makes the stream of net social benefits (NSB) equal to zero, or

$$\sum_{t} \mathrm{NSB}_t (1 + r)^{-t} = 0 \qquad t = 0, 1, \ldots 23^{16}$$

Annual net social benefits are found by subtracting program costs from benefits.

Benefit-cost ratios and rates of return calculated in the study have direct significance for American taxpayers. Program costs represent a public investment financed by taxpayers; program benefits are the increase in consumers' surplus gained in the domestic market. Benefit-cost ratios range from 7 to 1 under budget option A, assuming a slow rate of spread, to 19 to 1 under budget option B, assuming a rapid rate of spread. Social rates of return, however, range from 38 percent under option B, assuming slow spread, to 71 percent under option A, assuming rapid spread. Clearly, public investment in a witchweed program yields positive, real social effects. Program benefits exceed costs in the aggregate, implying that the production and consumption potential of American society is increased. But the decisionmaker is confronted with the dilemma that the two criteria—benefit-cost ratios and social rates of return—result in different conclusions.

When projects are mutually exclusive, such as budget options A and B, benefit-cost ratios reveal which project makes the greatest net present-value contribution to society, for an assumed rate of discount. By the net present-value method, budget option B, the eradication program, is the preferred public investment, as indicated by the benefit-cost ratios in table 2. Nonetheless, determining social rates of return is useful because these compare the actual rate of return to society with the accepted or minimum rate. If the accepted rate of discount is increased from 10 percent, to 14 percent or more, the benefit-cost ratios would favor budget option A, the containment program.

Though its estimated benefit-cost ratios show option B to be the preferred public investment, ratios for the two options come extremely close to one another. This proximity suggests that the rankings could easily be affected by relatively small errors in program cost estimates (table 1). Sensitivity analysis shows that a 10-percent reduction in future annual costs of budget option A would make present-value rankings of the two options approximately equal.

We assume implicitly that program accomplishments are certain. The probability that containment will fail may be higher under budget option A (because eradication is not achieved) than under budget option B. If so, the real social value of the containment program is overestimated relative to the eradication program, as shown in table 2. The decisionmaker must also recognize the possibility that, despite control measures, witchweed may spread to new areas, forcing additional program costs and/or a reduction in the production and consumption of corn and grain sorghum.

Table 2 shows clearly the importance of the rate of spread assumption. Social value of a witchweed pro-

[15] This assumption, along with the present values of program costs presented, suggests that the social value of budget option B will exceed that of A. However, this does not eliminate the need to calculate benefit-cost ratios and social rates of return. The decisionmaker still needs to know whether either program is a desirable social investment. Also, it is interesting to know approximately how much the social values of the two programs differ, and if the two criteria result in the same conclusion.

[16] $T = 0$ represents 1977; $t = 1$ represents 1978; . . . and $t = 23$ represents 2000. The polynomial equation was solved using subroutine POLRT, IBM 360 subroutine package, version III, 1968.

Table 2—Benefit-cost ratios and social rates of return for witchweed program, 1977 to 2000

Type of program and rate of spread of witchweed	Benefit-cost ratio[1]	Social rate of return[2]
	Dollars	*Percent*
Budget option A—continue current program:		
Slow spread	7 to 1	45
Rapid spread	17 to 1	71
Budget option B—eradication program:		
Slow spread	8 to 1	38
Rapid spread	19 to 1	61

[1] The annual rate of discount is 10 percent. [2] The time discount factor which makes the present value of the stream of net social benefits equal to zero.

gram based on benefit-cost ratios is more than doubled, if we assume witchweed spreads rapidly rather than slowly—in the absence of a program. Possibly, the spread of witchweed may be better represented by an "S"-shaped curve, or an exponential function, than by a constant percentage relation. Both of the other alternatives would tend to reduce benefits in the early years of a program, and they would probably lower the estimates of social value.

As mentioned, the presence of a witchweed program also results in additional foreign exchange earnings from the sale of corn and grain sorghum (table 3). In 1974-75, for example, feed grain exports earned about $4.8 billion, making an important contribution to the U.S. balance of payments. The present value of export earnings from a witchweed program—at a 10-percent discount rate—range from $81 million, assuming a slow rate of spread to $204 million, assuming a rapid rate of spread. The resulting consumers' surplus is not reflected in tables 1 and 2. Thus, our estimates of social value are conservative.

Table 3—Average increase in export earnings due to a witchweed program, 5-year intervals, 1981-2000

Years	Slow rate of witchweed spread	Rapid rate of witchweed spread
	Million dollars	
1981-85	20	49
1986-90	61	151
1991-95	115	293
1996-2000	184	465

[1] Export earnings are measured in prices at the farm level.

Shortrun Adjustments

The empirical results reported above pertain to a longrun planning horizon wherein decisionmakers are able to select from a wide variety of different investments and all resources are variable. This is an appropriate time period for measuring the social value of a witchweed program and comparing program options under alternative assumptions. However, all economic agents live in the short run; thus, shortrun benefits and costs cannot be completely ignored.

Farmers in the infested area of North and South Carolina would be primary beneficiaries of a witchweed program through 1980. Because of the program, these producers would avoid annual control costs of $11.25 per acre. A rough estimate of the yearly value of this subsidy is the number of infested acres in 1977 times $11.25 per acre, or slightly more than $4 million. The actual subsidy is probably somewhat less because, in a given year, corn and grain sorghum would probably not be grown on the entire infested acreage. Over time, the subsidy will be capitalized into the price of corn and grain sorghum cropland in the infested area. For example, if the typical buyer of cropland has a 10-year planning horizon and expects to earn a 10-percent rate of return, the subsidy will increase the value of an acre of cropland about $76, other things constant.

Beyond 1980, calculation of shortrun benefits and costs becomes more complicated. Continuing the program prevents witchweed from spreading and allows producers to avoid annual control costs of $11.25 per acre and a 10-percent reduction in yield. Assuming a rapid rate of spread, annual control costs paid by producers in the absence of a program would be $131 million in 1985 and $404 million in 1995. On the other hand, the presence of a program prevents an increase in total revenue. Again, assuming a rapid rate of spread, annual total revenues earned by corn and grain sorghum producers rise by $53 million in 1985 and $177 million in 1995. Without a program, producer benefits from higher corn and grain sorghum prices do not exceed higher annual control costs. Of course, control costs in the absence of a program. Of course, producers who remain outside the infested area for an extended period of time are disadvantaged by the program because they lose an increase in total revenue that would not be accompanied by higher annual control costs.

Consumers derive benefits from a program when the time horizon is long enough so that the spread of witchweed would cause prices to rise and quantities available for consumption to fall. Table 1 shows that annual consumer benefits exceed annual program costs in the sixth year under the most conservative conditions (a slow rate of spread).

CONCLUSIONS AND IMPLICATIONS

Ex ante estimates of longrun social value support the conclusion that public investment in a witchweed program is desirable. The rate of return on such an investment is estimated to be at least 38 percent. Our findings do not necessarily imply that a witchweed program should be funded. There may be other Government programs yielding higher rates of return to which funds should be allocated. However, if funds are not exhausted on programs that would yield higher returns, a witchweed program should be adopted.

Before making a final ranking between budget option A, the containment program, and budget option B, the eradication program, it would be useful to evaluate further several deterministic assumptions of our empirical results. For example, experts could evaluate

merits of containment and eradication programs using the following questions:

- What is the probability that containment will fail, given that eradication is not achieved in North and South Carolina?
- What will be the costs to the Government, producers, and consumers if containment fails?
- What is the probability that the intensive eradication effort will be extended from 8 years to 12 or 15 years?
- Will it be necessary to increase significantly annual program costs above the levels in table 1 to provide containment or achieve eradication in future years?

Empirical results presented here show that budget option B, the eradication program, makes the greatest net present-value contribution to society. This conclusion is based on strict assumptions as to the flow of benefits and costs, and the opportunity cost of capital.

The social value of a witchweed program is strongly influenced by the rate at which witchweed would spread throughout corn and grain sorghum producing areas in the absence of a program. According to best judgments, the number of years for complete infestation will fall somewhere between the two extremes we considered—30 and 75. Plant scientists believe that the probability is low that we can improve the reliability of the rate of spread estimate. Since our most conservative analysis indicates a favorable social value, there seems to be little justification for using additional resources to study and refine the accuracy of the rate of spread measure.

Critics have argued that the only beneficiaries of a witchweed program are farmers in the infested areas of North and South Carolina. This argument is based on extremely-shortrun assumptions. Pure economic profits accruing to farmers in the production of corn and grain sorghum will be rapidly bid away by the entry of new resources. In a longrun framework, the decision to invest in a witchweed program imposes a cost on American taxpayers. But a much greater benefit flows to consumers because witchweed does not spread, making larger quantities of corn and grain sorghum available for domestic consumption and export. Further, society benefits from eradication in the two States if it is highly likely that a containment program would fail and/or the future annual costs of such a program are as great as indicated in table 1.

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