AN ECONOMIC IMPACT EVALUATION OF GOVERNMENT PROGRAMS: THE CASE OF BRUCELLOSIS CONTROL IN THE UNITED STATES

Chun-Ian Liu

Public spending in government programs to control animal and plant diseases, parasites, and other pests that reduce agricultural production amounts to more than $150 million annually [3]. These programs and activities are administered by the Animal and Plant Health Inspection Service (APHIS), U.S. Department of Agriculture. 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 about the need for certain programs. Because of steadily increasing pressure to reduce federal spending, public decision makers urgently need reliable aggregate measures of the performance of their programs.

The objective of this article is to present an economic impact evaluation of the APHIS program alternatives for controlling brucellosis through the year 2000. Brucellosis is a specific, infectious disease of animals and man that reduces beef and milk production. In the U.S., eradication of brucellosis is the final goal, and the public sector has been involved in various brucellosis control programs over several decades. To make recommendations to the public decision makers about programs for controlling brucellosis, APHIS in 1977 evaluated alternative funding situations and their impacts on infection under six brucellosis program options [1]. The APHIS study was primarily a technical evaluation with all price relationships held constant and the differences in prices due to the different brucellosis control alternatives were not considered. For a complete program evaluation, it is necessary to account for the effects of price differences, potential long-range growth in the supply and demand conditions in food and agriculture, and subsequent economic adjustments likely under alternative programs for controlling brucellosis in beef and dairy cattle. Thus, on the basis of the technical information provided by the APHIS study, the Economics, Statistics, and Cooperatives Service (ESCS) analytical capability was used to evaluate the economic consequences of the alternative brucellosis programs.

EMPIRICAL PROCEDURES

The economic evaluation centered primarily on the impacts of beef and milk price changes, supply response, and consumer demand under alternative brucellosis programs. No assessment of the gains or losses to other livestock and grain producers was made nor was the human health dimension explored in this evaluation. Six brucellosis program alternatives were analyzed.

1. Adoption of a 10-year eradication program.
2. Continuation of the present program.
3. A reduced level of funding for the present program.
4. No federal program with 100 percent farmer vaccination.
5. No federal program with 50 percent farmer vaccination.
6. No federal program with no farmer vaccination.

Based on the rate of disease spread estimated by APHIS, an empirical model, the ESCS National-Interregional Agricultural Projections (NIRAP) system [7], was used to derive annual projections of production and prices for beef, milk, and other major commodities, as well as aggregate farm output under each of the six brucellosis program alternatives. The commodities production and utilization (CPU) component of the NIRAP system was used to project prices and quantities for beef and milk from 1978 to 2000 under all programs. The CPU component, a multicommodity model, simulates price-quantity responses of 21 commodities, given a set of exogenous variables. Constant elasticities of demand and supply equations were specified for each commodity at farm level.[1]

Chun-Ian Liu is an Agricultural Economist, Economics, Statistics, and Cooperatives Service, USDA.

The analysis should be attributed only to the author. It should not be considered as official information of the Economics, Statistics, and Cooperatives Service, USDA.

[1]Direct price demand elasticities for beef and milk used in the model are −0.68 and −0.32, and direct price supply elasticities are 0.55 and 0.25, respectively [5]. Because the demand and supply equations are nonlinear, a numerical technique, Newton-Raphson iteration method, was used to find equilibrium solutions [6].

The exogenous variables specified a future scenario or "economic environment" in which commodity prices and quantities were projected. These variables were the impacts of domestic population and economic growth, changes in world agricultural trade, technological change in farm production, and general inflation on the demand and supply for farm output. Under the baseline scenario, for example, a U.S. Census Series II population projection was assumed, representing an annual growth rate of 0.9 percent to 1990 and about 0.7 percent from 1990 to 2000. Per capita disposable income in the U.S. was assumed to grow at 2.2 percent per year, about the same rate as observed during the last 25 years. Agricultural productivity projections were based on a 3 percent annual increase in agricultural research and extension expenditures. Trends in U.S. exports and imports depended on a continuation of current agricultural trade policies, with food production in developing countries continuing to grow slightly faster than population [4].

The empirical model was used to generate baseline projections and other projections under alternative brucellosis programs. Continuation of the present program was assumed to coincide with current ESCS baseline projections for food and agriculture; thus government programs that have been in effect in the recent past such as brucellosis control were implicitly assumed to continue in the future. Other scenarios selected for analysis differed from the baseline only with respect to APHIS brucellosis program alternatives. Price and quantity projections for beef and milk generated by NIRAP under all programs were used to calculate program benefits, changes in consumers' and producers' benefits, and benefit/cost ratios.

SUPPLY RESPONSE TO BRUCELLOSIS CONTROL PROGRAMS

In theoretical terms, the critical elements determining the social value of a brucellosis program are its costs, the price elasticities of supply and demand, and the negative shifts in supply due to brucellosis infestation. The magnitude of the shift in supply depends on the rate of spread, the reduction in beef and milk production due to brucellosis, and costs for farmers adopting protection measures such as only buying animals from brucellosis-free herds and farmer quarantine. The APHIS estimated rate of spread and estimated constant price of economic losses due to each program alternative were used as the basis for estimating the shifts in producers' supply response under each specific program. Supply responses under each program were then "allowed" to interact with baseline demand conditions in determining production, market clearing prices, and commodity utilization under each program alternative.

Independent of price effects, the estimated shifts in beef supply indicate beef producers would supply from 0.03 percent additional output in 1978 to 0.2 percent more by the year 2000 under the 10-year eradication program (Table 1).[2] Other brucellosis control alternatives such as the reduced present program and no federal program with 100 percent, 50 percent, and no farmer vaccination practices represent higher production costs in comparison with the present program. Thus, the net shifts in supply functions due to brucellosis are negative under such alternatives. The greatest negative response accompanies the no program/no vaccination practice; producers would decrease production 0.034 percent in 1978 and 6.2 percent by the year 2000. The same pattern of supply response occurs in milk production but the magnitudes are generally smaller.

When these shifts in supply response interact with baseline demand conditions, production and price projections are derived (Table 2).[3] Because the brucellosis control programs decrease losses, costs associated with brucellosis in producing beef and milk are reduced and thus production is increased beyond the level that would occur without a program. Beef production increases from 25.2 billion pounds in 1978 to 31.4 billion in 1990 and 36.4 billion in 2000 under the 10-year eradication program whereas production would be limited to 27.4 billion and 26.5 billion pounds, respectively, in 1990 and 2000 with no federal program and no farmer vaccination practice. The production estimates of 30.9 and 35.4 billion pounds, respectively, in 1990 and 2000 under the current program are only 1-3 percent less than those with eradication.

Production responses for milk are also greater under more effective brucellosis control programs but these adjustments are of a fairly insignificant magnitude. The government purchase and marketing order programs provide price support for the dairy sector. To the extent that the brucellosis control succeeds, the reduction in losses and costs of production would increase output. If brucellosis control results in a greater volume of government purchases over the planning horizon, public

[2]Shifts in market supply due to brucellosis infestation for beef and dairy are estimated as the differences between the losses under a specific brucellosis program and the present program divided by the value of production for beef and milk under the current program.

[3]Price and quantity projections under alternative programs were derived by allowing new beef and milk supply functions under alternative programs to interact with baseline demand conditions to generate the new equilibrium solution.

TABLE 1. ESTIMATED NET CHANGE IN BEEF AND MILK SUPPLY: ALTERNATIVE BRUCELLOSIS CONTROL PROGRAM COMPARED WITH PRESENT PROGRAM, SELECTED YEARS[a]

Year	10-Year eradication	Reduced present program	No program 100% vaccine	No program 50% vaccine	No program no vaccine
			Percent		
Beef					
1978	0.028	-0.001	0.161	0.070	-0.034
1985	0.286	-0.645	-0.650	-1.921	-3.764
1990	0.263	-1.653	-1.425	-3.456	-5.959
1995	0.239	-2.174	-1.891	-4.055	-6.389
2000	0.219	-2.334	-2.089	-4.094	-6.175
Milk					
1978	0.0	0.0	0.0	0.0	0.0
1985	0.023	-0.261	-1.091	-1.437	-1.958
1990	0.024	-0.431	-1.471	-2.191	-3.212
1995	0.023	-0.661	-2.045	-3.260	-4.683
2000	0.023	-0.859	-2.706	-4.013	-5.185

[a]Based on the APHIS estimated rate of spread and constant price economic loss under different programs, net changes in beef and milk supply were estimated as the percentage of the difference between the losses under a specific brucellosis program and the present program divided by the value of beef and milk production under the present program.

TABLE 2. PROJECTIONS OF BEEF AND MILK PRODUCTION AND PRICE UNDER ALTERNATIVE BRUCELLOSIS PROGRAMS, SELECTED YEARS[a]

Year	Present program		Reduced present program		10-Year eradication program		No program 100% vaccination		No program 50% vaccination		No program no vaccination	
	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity
Beef												
1978	0.40	25150.0	0.40	25150.0	0.40	25150.0	0.40	25150.0	0.40	25150.0	0.40	25150.0
1985	0.39	28866.0	0.39	28721.1	0.38	29070.1	0.39	28761.9	0.40	28309.7	0.41	27642.7
1990	0.42	30928.2	0.43	30437.5	0.41	31352.5	0.43	30451.8	0.45	29211.5	0.50	27409.5
1995	0.45	33099.6	0.46	32187.9	0.43	33775.4	0.46	32164.9	0.51	30026.9	0.59	27001.8
2000	0.48	35447.9	0.50	34045.7	0.46	36408.6	0.51	33961.6	0.58	30825.9	0.71	26523.5
Milk												
1978	10.32	1249.0	10.32	1249.0	10.32	1249.0	10.32	1249.0	10.32	1249.0	10.32	1249.1
1985	11.27	1230.2	11.37	1227.5	11.19	1231.6	11.62	1218.5	11.86	1213.8	12.18	1208.0
1990	11.94	1234.9	12.27	1225.9	11.78	1236.8	13.01	1202.2	13.75	1188.9	14.69	1174.2
1995	12.64	1240.3	13.23	1223.8	12.40	1242.6	14.57	1185.4	15.93	1162.6	17.71	1137.8
2000	13.39	1247.1	14.27	1222.5	13.06	1249.7	16.33	1168.8	18.46	1136.3	21.33	1101.8

[a]For beef, production quantity is in million lbs., and price is price received by farmers in 1976 dollars, ($/lb); for milk, production quantity is in million cwt., and price is price received by farmers in 1976 dollars, ($/cwt).

expenditures for the milk price support program could increase as much as $14.7 million per year under the 10-year eradication program [8]. Such secondary costs should be considered in the decision to increase or decrease the brucellosis control effort.

ECONOMIC IMPACT EVALUATION

The benefit/cost analysis technique has been used extensively by analysts of public programs and policies. The recent trend has been to measure changes in consumers' and/or producers' surplus associated with a specific program and to compare these with program costs. Emerson and Plato used this technique in estimating the social value of the USDA Witchweed program [3]. Easter and Norton also used benefit/cost analysis to estimate returns to agricultural research [2].

In this study, the benefit/cost analysis technique was used to evaluate the APHIS brucellosis program alternatives. Projected price and quantity were used to calculate program benefits over a 23-year time horizon (1978-2000). Estimates of changes in consumers' and producers' surpluses (benefits) associated with each program were used to derive net benefits. When such benefits are compared with program costs, benefit/cost ratios and internal rates of return can be calculated.

Table 3 shows the changes in consumer benefits, producer benefits, and the sum of consumer and producer benefits under alternative brucellosis programs for selected years. Consumers gain more from eradication than from the present program, but more from the present program than from the reduced present program or from any of the no federal program/100 percent, 50 percent, and no farmer vaccination alternatives. In year 2000, for example, the undiscounted value of consumer benefits under the 10-year eradication program increases to $1.2 billion more than the estimated value of benefits under the current program. Estimates of changes in consumer benefits under the reduced present program and the three no federal program scenarios are all negative, −$2.1 billion, −$4.6 billion, −$9.6 billion, and −$16.7 billion, respectively.

Projected aggregate beef and dairy producer benefits under brucellosis programs have an opposite relationship. At the national aggregate level, producers gain less benefit under the 10-year eradication program than under the present program, but greater benefit under the reduced present program and under the three no federal program options than under the present program. This outcome is basically due to the inelastic demand for the commodities involved, which causes greater changes in price than in production under brucellosis programs.

The larger absolute value of consumer benefits outweighs the producer benefits to the extent that the same relationships hold for the sum of consumer and producer benefits as hold for the consumer benefits. That is, the 10-year eradication program provides the largest positive flow of the sum of consumer and producer benefits, and the negative changes in the consumer and producer benefits grow progressively larger as brucellosis control effectiveness diminishes in moving from the present program toward the no federal program/no farmer vaccination practice.

Annual program costs were estimated by APHIS for each brucellosis program alternative in 1976 dollars [1]. With the eradication program, containment and complete eradication would be expected in 10 years. Under this program, annual costs would peak at $119 million in 1981. According to the APHIS analysis, the 10-year program would include an additional 10-year surveillance program to ensure that the disease had been eradicated, at a cost of about $20.2 million annually. Discounted at 10 percent annually, the present value of the 23-year cost flow under the 10-year eradication program is $664.9 million. The present program costs are estimated to be $76 million per year, for which the 23-year sum has a discounted present value of $742.4 million. The reduced present program would cost $69

TABLE 3. CHANGES IN BENEFITS UNDER ALTERNATIVE BRUCELLOSIS PROGRAMS RELATIVE TO THE PRESENT PROGRAM, SELECTED YEARS

Year	10-Year eradication program	Reduced present program	No program 100% vaccination	No program 50% vaccination	No program no vaccination
			Million 1976 dollars		
			Consumer benefits		
1978	0	0	0	0	0
1985	234	-210	-477	-1062	-1875
1990	486	-714	-1612	-3357	-5769
1995	796	-1322	-2968	-6166	-10664
2000	1170	-2053	-4575	-9593	-16742
			Aggregate beef and dairy producer benefits		
1978	0	0	0	0	0
1985	-101	91	239	496	837
1990	-205	294	784	1527	2497
1995	-329	506	1394	2695	4412
2000	-475	738	2070	4034	6634
			Sum of consumer and producer benefits		
1978	0	0	0	0	0
1985	134	-119	-237	-566	-1038
1990	281	-420	-828	-1830	-3273
1995	467	-816	-1575	-3471	-6252
2000	696	-1314	-2505	-5559	-10108

million per year with a total discounted present value of $677.6 million. The 100 percent vaccination practice with no federal program would cost $72 million per year for farmer control measures with total discounted present value of $698.3 million. The 50 percent vaccination program would cost $34 million annually with a discounted sum of $328.8 million. If there were no federal program and no farmers' vaccination, the program cost would be zero.

Under the no federal program options with various farm vaccination levels, the costs are predominantly producer costs; under the federal program alternatives, the costs are predominantly, but not totally, taxpayer costs. For example, of the $742.4 million discounted present value of the present program cost, about $60.5 million is producer costs. Thus, the distribution of costs and therefore returns on investment is very different among the program alternatives. From the alternative program cost estimates, the marginal program cost over the present program cost was calculated for deriving benefit/cost ratios. According to the APHIS estimation, the annual program cost of the 10-year eradication program initially is higher than that of the present program, but in the subsequent years the annual cost of the 10-year program is less than that of the present program [1]. The marginal program cost for the 10-year program over the present program cost represents the discounted sum of the positive values over those of the present program in the initial years ($132.3 million). The negative discounted values in the subsequent years are added to the changes in benefits [1]. For other less effective program alternatives, the marginal program costs are computed by subtracting the total discounted values of the alternative program costs from those of the present program.

The 23-year total discounted present values of changes in consumers' benefits (discounted at 10 percent annually) are estimated to be $3.0 billion, −$3.9 billion, −$8.6 billion, −$18.2 billion, and −$31.7 billion, respectively, for the 10-year program, reduced present program, no federal program with 100 percent vaccination, no program/50 percent vaccination, and no program/no vaccination practice (Table 4). For the changes in producer benefits in relation to the present program, the total discounted present values are estimated to be $1.3 billion, $1.5 billion, $4.1 billion, $8.0 billion, and $13.3 billion. For the sum of changes in consumers' and producers' benefits, the discounted benefits sum amounts to $1.7 billion, −$2.4 billion, −$4.5 billion, −$10.2 billion, and −$18.4 billion, respectively. Although discounting reduces the magnitude of program benefits, no real new information is provided for selecting one program over another.

The benefit/cost ratio and internal rate of return calculations for changes in consumer benefits, producer benefits, and the sum of consumer and producer benefits under the five alternatives to the present brucellosis control program are shown in Table 4. The benefit/cost ratios are defined as average marginal in that they measure the average rate of increases (or decreases) in benefits in relation to costs of each alternative in comparison with continuing the present brucellosis program. The internal rate of return is that time discount factor which makes the present value of the stream of benefits equal to the present value of the stream of costs.

The estimated average marginal benefit/cost ratios indicate that under the 10-year eradication program, a public investment of one dollar would increase consumer benefits by 23 dollars (Table 4). In contrast, saving a dollar by not spending it on containing brucellosis under the other program options would reduce consumer benefits from between 43 and 195 dollars. The

TABLE 4. BENEFIT/COST RATIOS, VARIOUS PROGRAM ALTERNATIVES RELATIVE TO THE PRESENT PROGRAM

	Change in benefits[a]	Program costs[a]	Marginal program costs over the present program[b]	Marginal b/c ratio[c]	Internal rate of return[d]
			Million dollars		
Consumer benefits:					
10-Year eradication program	3014.2	664.9	132.3	22.8	47
Reduced present program	-3888.6	677.6	-64.8	-60.0	-40
No program, 100% vaccine	-8601.3	698.3	-44.1	-195.0	-57
No program, 50% vaccine	-18212.5	328.8	-413.5	-44.0	-99
No program, no vaccine	-31748.9	0	-742.4	-42.8	-
Producer benefits:					
10-Year eradication program	-1289.6	664.9	132.3	-9.7	-23
Reduced present program	1524.4	677.6	-64.8	23.5	21
No program, 100% vaccine	4058.6	698.3	-44.1	92.0	37
No program, 50% vaccine	8029.1	328.9	-413.5	19.4	92
No program, no vaccine	13307.4	0	-742.4	17.9	-
Sum of consumer and producer benefits:					
10-Year eradication program	1724.6	664.9	132.3	13.0	26
Reduced present program	-2364.2	677.6	-64.8	-36.5	-28
No program, 100% vaccine	-4542.7	698.3	-44.1	-103.0	-41
No program, 50% vaccine	-10183.3	328.9	-413.8	-24.6	-71
No program, no vaccine	-18441.5	0	-742.4	-24.8	-

[a]Total discounted present value for 23 years (from 1978 to 2000).

[b]See APHIS Brucellosis Program Analysis pp. 8-17 for a discussion of the procedures used to calculate marginal program costs. The discounted present value of the present program cost is $742.4 million 1976 dollars.

[c]A negative ratio indicates that a saving in program cost is more than offset by a loss in benefits.

[d]For negative benefit, a negative internal rate of return was obtained by finding the time discount factor which makes the stream of program costs minus benefits equal to zero.

estimated internal rate of return would be 47 percent under the 10-year eradication program and ranges from −40 to −99 percent for the reduced present program and the no program/100 percent and 50 percent vaccination practices compared with the present program.[4]

In terms of the sum of consumer and producer benefits, the estimated average marginal benefit/cost ratios indicate that a one dollar increase in funding to eradicate brucellosis under the 10-year eradication program would increase social benefits by 13 dollars. A saving of one dollar by not using it to contain brucellosis under the other program options would reduce social benefits from 25 to 103 dollars depending on the program alternative. The internal rates of return are estimated to be 26 percent under the 10-year eradication program, and from −28 to −71 percent for the reduced present program and for no program combined with 100 percent and 50 percent vaccination practices, respectively, compared with the present program.

In terms of producer benefits, the average marginal benefit/cost ratios take on a different relationship. Increased program spending causes a decline in aggregate producer benefits and a decline in funding increases producer benefits. The internal rates of return for producers' benefits under the reduced present program and no program with 100 percent and 50 percent vaccination practices are estimated to be 21, 37, and 92 percent, respectively, compared with the present program.

CONCLUSIONS

The application of benefit/cost analysis to evaluate government programs proves to be useful. A major advantage of this type of analysis is that it can be kept simple. The key in the analysis is the reliability of the rate of disease spread and program cost estimates. Extensive data collection and analysis would be required to make an in-depth evaluation of these variables. However, sensitivity analysis can give decision makers a range of returns under different assumptions. Based on the APHIS estimated rate of spread and program costs, the empirical results presented here show that public investment in a brucellosis program yields positive "real social benefits" in excess of program costs. Separation of the benefits into consumer and producer disaggregates indicates that the brucellosis control program is "good consumer economics." That is, controlling brucellosis causes a positive supply response, higher production, and lower prices. Producers' benefits decrease as the program options move toward eradication, but increasing consumer benefits more than offset the decreasing producer benefits as well as program costs. For individual producers, the brucellosis control programs reduce the chance of potentially extreme losses. The desirability of the various program options depends on whether the goal is to benefit consumers, producers, or society in general.

REFERENCES

[1] Beal, V. C., Jr. and H. A. Kryder, Jr. "Brucellosis Program Analysis," Veterinary Services, APHIS, USDA, February 1977.

[2] Easter, K. W. and G. W. Norton. "Potential Returns from Increased Research Budget for the Land Grant Universities," *Agricultural Economics Research*, Volume 29, October 1977, pp. 127-133.

[3] Emerson, P. M. and G. E. Plato. "Social Returns to Disease and Parasite Control in Agriculture: Witchweed in the United States," *Agricultural Economics Research*, Volume 30, January 1978, pp. 15-22.

[4] Liu, C. L., G. E. Plato, and A. G. Smith. "The Demand for Grazing Roughages in the United States: Alternative Futures to the Year 2030," Staff Report, ESCS, USDA, February 1978.

[5] Plato, G. E. "Agricultural Commodity Projections: A Multimarket Equilibrium Approach," unpublished working paper, NEAD/ERS/USDA, 1975.

[6] Plato, G. E. "An Approach to Unique Solution for Constant-Elasticity Commodity Models," *Agricultural Economic Research*, Volume 29, January 1977, pp. 15-18.

[7] Quance, L. and Y. C. Lu. "Application of Systems Science in Projecting Alternative Food and Agricultural Futures," *System Theory Applications to Agricultural Modeling: A Proceedings*, Economics, Statistics, and Cooperatives Service, USDA in cooperation with the National Science Foundation, ESCS-07, February 1978.

[8] Teigen, L. D. and C. M. Carman. "The 10-Year Brucellosis Eradication Program: A Short-Term Analysis," CED/Forecast Support Group working paper, April 1978.

[4]For negative benefits, a negative internal rate of return was obtained by finding the time discount factor which makes the stream of program costs minus benefits equal to zero.