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SIMULATION ANALYSIS TO ESTIMATE THE ECONOMIC IMPACT OF FOOT-AND-MOUTH DISEASE IN THE UNITED STATES

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SIMULATION ANALYSIS TO ESTIMATE THE ECONOMIC IMPACT OF FOOT-AND-MOUTH DISEASE IN THE UNITED STATES[1/]

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This study arose out of a request from the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture to the University of Minnesota for an economic evaluation of alternative control policies if Foot-and-Mouth Disease (FMD) is reintroduced into the United States. The Darien Gap Highway Project[2/] has stimulated increased concern among United States veterinary authorities that the opening of the highway linking North and South America will remove a natural barrier to the spread of animal disease and will increase the chances of FMD introduction from South America to FMD-free countries in Central America and the U.S.

THE DISEASE AND ITS CONTROL

Nature of the Disease

FMD has long been considered as one of the most, if not the most, infectious of all animal diseases. The Merck Veterinary Manual defines it as "an acute, highly communicable virus disease chiefly confined to cloven-footed animals..." The high infectivity of FMD, its worldwide distribution and its plurality of serotypes are features which have made it a major threat to the health of livestock around the world.

In contrast with other highly contagious diseases such as rinderpest, mortality rates in FMD are normally low, particularly in the case of adult animals. Animals usually recover from FMD within about three weeks but the after-effects of the disease can be of large magnitude. These after-effects may bring total losses in a "typical" outbreak to as much as 30 percent of the productivity of the infected animals (Peffer, p. 144).

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The after-effects include permanent tissue damage, abortion, sterility and mastitis. Recovered animals, especially cows, frequently are removed from the breeding and/or milking herd and destroyed or slaughtered for meat purposes (Shahan and Traum, p. 178). FMD rarely affects man; thus the disease is not considered to be a public health hazard.

FMD in the United States

The first recorded incidence of FMD in the United States was in 1870 (Figure 1). The disease was introduced into the country by cattle shipped from England (Meyer, p. 23). Subsequent outbreaks of FMD occurred in 1880, 1884, 1902, 1908, 1914, 1924 (two separate outbreaks) and 1929. The most devastating FMD epidemic ever experienced in this country occurred in 1914. The epidemic started near Niles, Michigan, and between October 1914 and September 1915, it spread through 22 states and the District of Columbia after it gained entry into the Chicago Stockyards. The epidemic resulted in the subsequent destruction of 77,240 cattle, 85,092 swine, 9,767 sheep and 123 goats (Shahan and Traum, op. cit., p. 193).

The 1924 outbreak in California reached epidemic proportions. And, the disease spread to sixteen counties including Los Angeles and San Francisco. More than 109,000 cattle, goats, sheep and swine were depopulated (destroyed) in the course of the eradication program. One added feature of the California epidemic was the involvement of wildlife. During the course of the epidemic, deer in the Stanislaus National Forest became infected after they came in contact with livestock herds driven there for summer pasture. Some 22,000 deer were destroyed before the disease was completely halted (Peffer, p. 149).

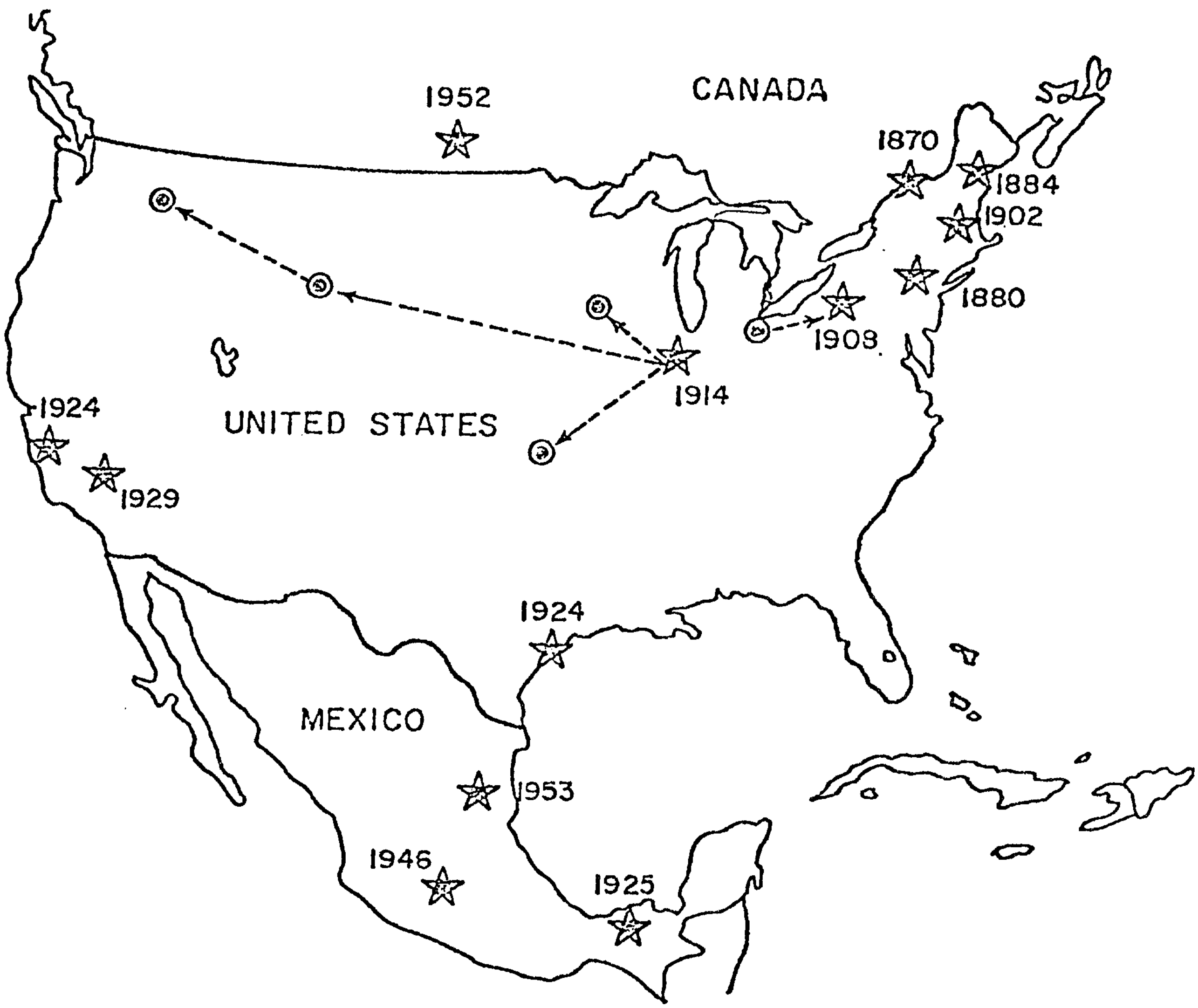

Figure 2. Foot-and-Mouth Disease Outbreaks and Spreads in Canada, U.S. and Mexico (USDA, ARS, 1969)

Prevention and Control of FMD

Control policies for FMD vary substantially around the world. There are, however, three main policies for dealing with the prevention and control of FMD. These policies can be adopted either singly or in combination:

1. Preventive Policy

   This policy, currently practiced by the United States, is intended to prevent the disease from gaining entry in a country by imposing strict controls on imports from non FMD-free countries.

   Importation of animals and animal products to the U.S. is regulated under authority of Section 306(a) of the Tariff Act of 1930. This Act makes it mandatory upon the Secretary of Agriculture to bar importation into the U.S. of cattle, swine, sheep or goats, or fresh, chilled or frozen meats from these species from all countries except those considered by veterinary authorities to be free from FMD and/or rinderpest.

2. Eradication Policy (Stamp-out)

   In all previous outbreaks of FMD in the U.S., control of the disease was successfully accomplished by a stamp-out or slaughter policy. This policy can be summarized as follows:

   a. Complete isolation of infected and exposed premises,
   b. Depopulation of infected and exposed herds,
   c. Cleaning and disinfection of infected premises, and
   d. Payment of indemnities for herds and products destroyed in the course of the eradication program.

   Other countries which have successfully used the stamp-out policy include Canada, Great Britain and Mexico.

3. Vaccination Policy

In some countries it is technically and economically unrealistic to adopt a stamp-out policy every time there is an FMD epidemic because (1) epidemics may be numerous and (2) the depopulation of a large number of herds would be required.

Vaccination policy, even if effectively implemented, will not result in complete elimination of the disease once it has become endemic. Thus, vaccination is probably best designed to limit the number of primary outbreaks and the subsequent spread of FMD once it has become widespread.

With respect to our subsequent benefit-cost analyses, both the eradication and the vaccination policies will only be implemented in the U.S. in the event of an actual outbreak of the disease. We are not predicting that the disease will enter the U.S. Our analysis does assume, however, that if it enters and if no control programs are implemented against it, it will then, for purposes of our analysis, proceed to become endemic. Thus, the benefits of the control programs can be measured against the alternative of endemic FMD.

PREVIOUS ECONOMIC RESEARCH

It is generally fair to state that the degree of sophistication of economic analysis in the field of animal health is not as advanced as in the field of human and public health. Only in recent years have "formal" benefit-cost analysis and other quantitative methods been applied to evaluating animal health problems.

Earlier studies in the economics of animal health encountered the same critical problem of lack of adequate data which we did. In addition, however, they generally overlooked some basic principles of benefit-cost analysis such as the need to discount, to a common base period, the future costs and benefits of alternative control policies before comparing them. Another serious deficiency was the lack of evaluation of losses and benefits from a social standpoint. Evaluations were based on the mistaken notion that any reduction in losses brought about by a disease control program would mainly benefit livestock producers. While it is true that some individual producers will typically benefit from the reduced risk of large losses, the ultimate beneficiaries of livestock disease control programs, as a societal group, are consumers.[3/]

One of the few good published studies which has been done was undertaken by Power and Harris in the aftermath of the 1966-67 epidemic of FMD in Great Britain. The authors employed benefit-cost analysis to evaluate alternative FMD control policies. The specific policies considered were (1) a stamp-out or eradication policy and (2) a vaccination policy under which all animals likely to be infected by the disease would be vaccinated twice the first year of the program and once thereafter.

The authors assumed that the social benefits from controlling FMD could be best measured as the costs avoided in the absence of the disease. Since each of the alternative control policies entail some resource costs, these costs were subtracted from the benefits of having the disease under control in order to arrive at a net benefit figure.

In trying to estimate the benefits, the authors were faced with a lack of data regarding an endemic disease situation since Great Britain (as the U.S.) has never allowed FMD to reach an endemic stage. Therefore, data from other countries, primarily South American, were extrapolated to the conditions of Great Britain with appropriate modification by selected experts.

In a second credible benefit-cost study Ellis evaluated different methods for controlling swine fever (hog cholera) in Great Britain for the period of 1963-75. The results were presented in terms of net present value, average rate of return and benefit-cost ratios. Two programs were considered: an eradication program and an alternative control program similar to the one in place prior to 1962. The author cited the problem of netting out the impacts of each of the control policies when he stated that, "since it was mainly a question of additional benefits the author did not feel justified in complicating the present study with adjustments to reflect social cost and benefit..." (p. 4).

METHODOLOGY AND DATA REQUIREMENTS

Even those past disease control benefit-cost studies which have measured losses and benefits from a social perspective have typically had two shortcomings:

1. They have relied on a "comparative statics" approach for computing benefits and costs and
2. They have minimized or ignored treatment of interdependencies between inputs and products in the macro economy. As a result the analyses have been excessively "partial" in scope.

In the case of a large program such as one involving FMD control in the U.S. a dynamic equilibrium-type analysis is clearly required if one is to capture all major impacts and interdependencies affecting a particular policy outcome. While the equilibrium model system utilized in our study is still partial, it is nevertheless general enough to account for the major interdependencies involved in estimating the economic impact of FMD spread and control. And, we do not believe our results are biased by the partial analysis since the cross-elasticities of demand between livestock products and other products are low except for those products which we have included. Also, the scope of our economic analysis is broad enough to capture key factor and product interrelationships on the supply side.

The Model Utilized

Given the obvious advantages of dynamic versus static models in measuring price and output changes over time, an econometric simulation model of the livestock industry using annual data was utilized to develop a set of baseline estimates and to assess, in comparison with this baseline, the impacts associated with alternative FMD control policies. The output results (quantities and prices) generated by the model were then utilized as input data for the subsequent benefit-cost evaluation. It is beyond the scope of this report to describe in detail the livestock sector model used in this analysis, however, a brief outline of its main features is given below.[4/]

The livestock sector model utilized in this study was developed by the Commodity Economic Division of the Economic Research Service. It was developed as a component of a large scale cross-commodity forecasting system. The original ERS livestock model was modified and updated in order to adapt it to the estimation requirements of this project.[5/]

The livestock segment of the forecasting system includes specifications of the beef, pork, chicken, turkey, eggs and dairy sectors. The complete livestock subset of the system consists of 83 equations involving a series of demand equations, supply equations, technical equations and definitional equations. Parameters were derived from annual time series data covering the period 1965-1974.

Each of the livestock commodity submodels determines retail prices, civilian consumption, ending stocks, farm production, inventories and prices. Each retail demand function is estimated by assuming the price at retail to be dependent on consumption and on the prices of substitute and complementary goods.

Derived farm demand equations were also estimated by relating the price at the farm to retail price, number of slaughter animals and processing industry wage rates. Other functions included in the livestock forecast system included investment demand equations, product supply equations, product stock equations, inventory accounting equations, technical conversion equations and supply-demand identities.[6/]

Data Characteristics

As is often the case, some of the key data needed for the economic analyses were available in reliable form from secondary sources and other data could be estimated with a good deal of precision by the authors. Still other data could only be approximated. Space does not permit elaboration of all data sources here though most of these data will be published elsewhere. In general, however, we feel the data developed are very adequate for the analysis performed.

The year-by-year simulation analysis was carried to 1990 and thus required the forecasting of the time paths to 1990 of more than 40 exogenous variables. Among the most important exogenous variables are: population, income, price of corn, price of soybeans, red meat exports, wage rates in the food and kindred product industries, etc.[7/]

SIMULATION ALTERNATIVES

Benchmark

The first simulation run is a baseline projection for the period 1976 to 1990 with the U.S. continuing free of FMD and with current preventive policies (including inspection and import controls) remaining in effect. It is assumed that this 15-year time span will capture most of the benefit-cost impacts for the disease impacts and control alternatives which follow. Though we believe the baseline projections are reasonable, their main purpose is not so much as a forecast of the future but as a benchmark against which to judge the impacts of alternative scenarios for FMD incidence and control.[8/] This is the only one of our four simulation scenarios which assumes an absence of FMD.

Endemic FMD

The second simulation assumes that FMD is introduced into the U.S. at the beginning of the 15-year period and becomes endemic. An endemic situation is defined as a situation where FMD is continuously present in the country and its incidence has periodic peaks. These peaks are known to occur in the absence of public control such as compulsory vaccination. Our objective in considering an endemic situation is to use the economic losses attached thereto as the benefits against which the costs of alternative control programs can be evaluated.

Data from European and other countries indicate that the interval between major epidemic peaks of FMD ranges from five to ten years. It can reasonably be expected (as is assumed in our analysis) that if FMD is left uncontrolled within the U.S. as many as three major epidemics will occur during the 15-year period chosen for the analysis. Given the complete susceptibility of the U.S. livestock population to FMD, veterinary experts predict that from 40 to 75 percent[9/] of the susceptible livestock will be infected during the initial introduction of the disease. Subsequent major epidemic peaks will be less severe and will probably involve only about 40 percent of susceptible livestock. The infection rate during the intervals between major epidemics is assumed to drop to very low levels.

Endemic FMD (compulsory vaccination)

The third simulation alternative assumes that a nationwide compulsory vaccination for all cattle above four months old and all swine and sheep above three months old will be undertaken twice during the first year and annually thereafter. It is assumed again that FMD is introduced at the beginning of the 15-year period and the vaccination program is fully operational about one year after the introduction of the disease. Under a vaccination policy FMD will not be completely eradicated but the major epidemics will be virtually eliminated. The infection rate is projected to average only about 0.2 percent a year under a vaccination program. This low infection rate is the result of both the large immune population and the reduced transmission rate of the disease.

Eradication (stamp-out)

A final simulation was undertaken to reflect the impact of an eradication policy implemented under a "worst possible" outbreak situation. For this simulation it is hypothesized that an outbreak of proportional magnitude to the British FMD outbreak in 1966-67 occurs in the United States, again at the outset of the 15-year period. During the eradication program in Britain more than 400,000 animals were depopulated before the disease was completely eradicated. Extrapolating to U.S. conditions such an epidemic would involve the slaughter of about two million animals or about one percent of U.S. susceptible livestock.

It is recognized that the extent and magnitude of FMD outbreaks depend on many epidemiological and technical factors. Our purpose, however, is to estimate the impact of a "low probability but extremely bad situation" which is combatted through an eradication program. All other outbreaks which involve the depopulation of fewer animals will obviously have lower eradication costs and higher benefit-cost ratios.

We believe the above sequence used for describing the scenarios which we simulated is the most easily followed. One should not, however, confuse this sequence with that for control program implementation should the disease actually be reintroduced to the U.S. Eradication is the first control program mounted against an actual outbreak of the disease. And, a vaccination program would only be activated if eradication is no longer an economically, technically or politically feasible alternative.

RESULTS OF SIMULATION

For each of the simulation alternatives considered the model generates values for 91 endogenous variables over the period 1976-1990. Consequently, a total of 5,460 values are provided. In the interest of space and conciseness only some of the data on selected variables most relevant to the economic analysis are presented here. These include consumption quantities and retail prices for beef, pork, chicken and milk. Benchmark simulation results for these variables are presented in Table 1. Tables 2 and 3 provide a year-by-year estimate of the deviations in values of the variables from the benchmark solution under endemic, vaccination and eradication alternatives, respectively. These deviations appear to be reasonable and the sequence and timing of the adjustments to the impact of FMD trace out an expected sequential pattern. There is, however, little a priori information regarding their range of acceptability.

The simulation results can be best illustrated by explaining some of the adjustments which occur in the beef and poultry sectors. The strongest effect of FMD is reflected in the beef sector. Here, the initial reduction in beef supplies caused by the disease is accompanied by increased retail prices for beef which stretch over a period of several years. Prices reach levels more than 12 percent above the benchmark value in the first year and peak at approximately 15 percent above the benchmark in the second year. The greater increase in prices in the second year reflects the impact of reduced slaughter during that year as a result of the heavy mortality losses in calves during the first year of the disease epidemic.

Table 1. Benchmark Retail Prices and Civilian Consumption of Selected Livestock Products, 1976-90

	Beef		Pork		Chicken		Milk	
Year	Consumption (mil. lbs.)*	Price (cents/lb)	Consumption (mil. lbs.)*	Price (cents/lb)	Consumption (mil. lbs.)	Price ($/cwt)	Consumption (bil. lbs.)	Price (cents/lb)
1976	27,960	157.77	12,482	151.20	8,188	76.16	50.593	20.90
1977	28,396	156.11	13,693	147.17	8,436	76.34	48.755	22.36
1978	30,249	150.33	14,678	142.46	8,632	76.40	47.082	24.28
1979	31,799	136.29	15,521	137.09	8,821	73.00	45.645	26.32
1980	33,292	132.16	16,052	134.40	8,862	76.39	44.403	28.49
1981	34,451	134.64	16,587	141.12	8,955	79.62	43.612	30.77
1982	35,256	144.55	16,872	147.84	9,037	84.75	42.907	33.06
1983	35,824	154.46	17,263	152.54	9,147	88.98	42.364	35.58
1984	36,369	162.72	17,628	157.92	9,216	94.65	41.961	38.22
1985	37,022	165.20	18,012	162.62	9,305	99.17	41.665	41.11
1986	37,814	165.20	18,302	169.34	9,397	103.98	41.454	44.11
1987	38,698	161.90	18,668	173.38	9,518	107.25	41.318	47.48
1988	39,563	161.90	19,065	177.41	9,613	112.13	41.232	51.09
1989	40,362	163.55	19,479	180.77	9,736	116.05	41.178	55.18
1990	41,056	173.46	19,837	186.82	9,849	121.87	41.148	59.39

*Carcass weight

Table 2. Deviations from Benchmark Prices for Selected Livestock Products

Under Endemic, Vaccination and Eradication FMD Policies, 1976-90

	Endemic				Vaccination Policy				Eradication Policy			
	Beef	Pork	Chicken	Fluid Milk	Beef	Pork	Chicken	Fluid Milk	Beef	Pork	Chicken	Fluid Milk
Year	(¢/1b)*	(¢/1b)*	($/cwt)	(¢/1b)	(¢/1b)*	(¢/1b)*	($/cwt)	(¢/1b)	(¢/1b)*	(¢/1b)*	($/cwt)	(¢/1b)
1976	19.00	8.06	3.47	.84	19.00	8.06	3.47	.84	2.89	.67	.43	.01
1977	23.95	1.34	1.10	.24	23.95	1.34	1.08	.24	2.72	.67	.20	.04
1978	4.96	-3.36	-.52	.48	4.96	-3.36	-.57	.48	2.31	.14	.16	.04
1979	11.56	-.67	1.37	.60	10.74	-.67	1.33	.48	1.24	-.14	.03	.04
1980	1.65	1.34	-.21	.60	0.83	1.34	-.27	.60	0	0	0	.02
1981	19.82	8.06	3.38	.60	0	1.34	.25	.36	-1.07	.07	.01	.01
1982	9.91	1.34	-.93	.24	-7.43	-1.34	-1.09	.12	-1.65	0	-.11	-.01
1983	-11.56	-5.38	-1.57	0	-11.56	.67	-.53	-.24	-1.57	-.07	-.10	-.02
1984	-10.74	-1.34	-.02	-.24	-14.87	0	-1.09	-.48	-1.16	0	-.05	-.04
1985	-23.95	1.34	-1.81	-.36	-14.04	.67	-.57	-.60	-.50	.07	-.01	-.04
1986	20.65	12.10	4.99	-.24	-10.74	-.67	-.69	-.60	.08	.07	.02	-.04
1987	2.48	-1.34	-3.82	-.36	-1.65	0	.29	-.48	.58	0	.04	-.04
1988	7.43	-5.38	2.33	0	6.61	.67	.39	-.24	.99	0	.06	0
1989	4.96	-2.02	-1.17	.24	14.04	.67	1.08	.12	1.07	0	.05	.02
1990	8.26	6.72	2.78	.36	14.87	0	.47	.36	.91	0	.04	.04

*Retail weight basis

Table 3. Deviations from Benchmark Consumption for Selected Livestock Products Under Endemic, Vaccination and Eradication FMD Policies, 1976-90

	Endemic				Vaccination Policy				Eradication Policy			
Year	Beef (mil lbs)	Pork (mil lbs)	Chicken (mil lbs)	Fluid Milk (bil lbs)	Beef (mil lbs)	Pork (mil lbs)	Chicken (mil lbs)	Fluid Milk (bil lbs)	Beef (mil lbs)	Pork (mil lbs)	Chicken (mil lbs)	Fluid Milk (bil lbs)
1976	-1,952	-564	21	-.271	-1,952	-564	21	-.271	-100	-43	3	-.004
1977	-2,196	-28	87	-.291	-2,186	-27	87	-.290	-201	-32	11	-.013
1978	-316	234	15	-.380	-283	241	15	-.378	-136	-1	5	-.020
1979	-168	101	-11	-.464	-125	106	-12	-.460	-64	12	3	-.026
1980	479	-80	27	-.517	529	-77	26	-.511	22	0	0	-.028
1981	-528	-377	22	-.563	864	-59	-2	-.510	77	-8	-1	-.026
1982	-408	-76	83	-.511	895	42	0	-.446	96	-6	-2	-.020
1983	760	263	-33	-.429	815	17	-30	-.331	83	-2	-3	-.011
1984	535	54	-46	-.315	573	-39	-19	-.188	48	-2	-2	-.002
1985	674	-153	11	-.193	239	-56	-25	-.046	3	-3	-1	-.006
1986	-1,228	-463	0	-.126	-140	-16	-14	.066	-37	-1	0	.011
1987	-1,212	-20	105	-.052	-493	-3	-12	.131	-61	1	1	.012
1988	-393	298	-75	-.036	-720	1	9	.142	-64	2	1	.010
1989	-582	66	30	-.058	-778	3	15	.105	-48	1	2	.005
1990	-166	-200	-9	-.103	-645	26	26	.034	-23	1	1	-.001

The adjustment process in prices and production reflects both the delayed supply response by producers to initial price increases and the cyclical pattern of the disease. For example, when retail prices begin to moderate in the fifth year, the new disease epidemic in the sixth year generates a new, short wave of high prices which lasts for two years. And, the same process repeats again during the third major epidemic which occurs in the eleventh year. Prior to that epidemic peak in the disease pattern, prices are actually lower under the endemic situation than under the disease-free status. These lower prices reflect the increased supply of beef in response to price increases in previous years and a decreased infection rate. Over the 15-year period the net impact of the disease is for appreciably higher prices of beef and reduced supplies for consumption.

Impacts of the vaccination policy are also shown in Tables 2 and 3. To summarize, the overall net impact of the vaccination program is significant both in terms of prices and quantities as compared to the benchmark situation. And, compared to the endemic FMD situation, supplies (consumption) of livestock products are higher and prices lower.

Simulated impacts of the eradication alternative are also shown in Tables 2 and 3. The impact on prices and outputs of eradicating about one percent of animal herds is relatively modest.[10/] Although physical losses in terms of slaughtered animals occur only during the first year, the impact of these losses is extended over the entire 15 years. The initial price increases caused by the eradication program produce higher supplies of beef during the later years and consequently cause a subsequent reduction in price levels.

Because of projections for decreased consumption and higher prices for fluid milk even without FMD, the impacts of endemic FMD are absorbed with only minimal impacts on consumption and price levels.[11/] Projection of higher future consumption levels would, of course, intensify the impact of the disease on consumers.

Despite the fact that FMD infects only cloven-footed animals it also produces economic repercussions in other related livestock sectors. For example, the strong interdependency in demand between the red meat and poultry sectors results in chicken consumption above the baseline level in response to price increases in the beef and pork sectors. This consequently leads to a strengthening of poultry prices.

Our simulation analysis assumes that FMD affects only the biological parameters and their dependent relationships. Historical market relationships embodied in the model are, therefore, assumed to remain unchanged. This means, among other things, that the presence of FMD does not impact in any significant way on the effective demand of consumers for meat. In reality, at least a temporary effect might be expected in, for example, a preference for poultry and fish over red meat.

BENEFIT-COST ANALYSIS OF FMD CONTROL POLICIES

In this section we combine within a social benefit-cost framework (1) our estimates of the benefits from alternative FMD control programs (mainly output from the preceding simulation analyses) and (2) our estimates of the costs of the alternative control programs. Benefits and costs accruing over the 15-year time period (1976-1990) are discounted to their current values.

Benefits of Control Programs

The benefits to society from having FMD or any other disease controlled can be considered as simply those adverse consequences avoided by controlling the disease. And, net benefits from control are then the differences between total net benefits accruing to a particular control program and the total costs incurred in implementing that program. Under certain control programs, such as vaccination, not all disease losses will be prevented. And, the size of the losses prevented (benefits realized) depends on the degree of disease control obtained. In our simulations the impacts of alternative control policies were computed by interpolation of actual data from other countries, especially France, England and Germany.

Benefits of FMD control are classified and enumerated below.

1. Direct benefits. These include the prevention of losses caused by (a) mortality, (b) delayed growth and/or reduced growth rates, (c) decreased milk production from mammary gland infections, (d) abortion and delayed conception and (e) reduction in length of productive life. The major economic consequences of these losses are expected to occur in the form of higher prices and reduced commodity supplies for consumers. And, it is these consequences which we have measured net of any changes in total production costs. The economic impact of FMD to some individual producers can, of course, be devastating while others profit from higher product prices.

2. Indirect (or consequential) benefits. These include the avoidance of (a) reduced agribusiness sales to, and purchases from the

livestock sector, (b) losses of wages and other incomes, (c) losses of export markets and (d) stress and pain accompanying control, particularly under an eradication or stamp-out program. Most of these indirect consequences are of a temporary nature and some are offset by other changes, e.g., the transfer of feed sales from the swine sector to the poultry sector. Our benefit-cost calculations are based on the inclusion of direct benefits only. Thus, to the extent that there are net indirect benefits associated with control programs, their benefit-cost ratios would be even higher than those calculated.

Valuation of Benefits

As indicated earlier, the physical impacts of the disease are entered into the livestock sector model by appropriate adjustments of selected equations. These physical adjustments are then translated into economic terms by the simulation model which measures the impacts on consumer prices and consumption over the 1976-90 period (Tables 2 and 3). Table 4 aggregates the costs of endemic FMD in terms of consumer expenditures for selected years and for the total period analyzed. The years selected represent epidemic peaks in the pattern of the disease spread. Thus the cost for these years is much greater than for those years when the disease morbidity is substantially lower. The present value of the total direct losses (computed as net absolute increases in consumer expenditures) for the period 1976-90 discounted at eight percent is $11.65 billion. This then is a direct benefit to consumers for having endemic FMD kept out of the United States. It does not include reductions in consumer choice, and it does not include loss of exports to foreign markets. FMD-free countries could, in the event of an epidemic of FMD, ban imports of

Table 4. Estimated Consumer Benefits from Preventing Endemic FMD in the United States, Selected Years and Total, 1976-90

Year	Benefit (Losses Avoided)
	$ million*
1976	2,884
1981	4,141
1986	2,377
Total for 1976-90	11,650

*Discounted at 8 percent annual rate

certain livestock and livestock products from the U.S. which in 1974 totalled over $490 million. And, most of the exported livestock commodities are commodities with low demand preference in the United States. Loss of export markets is, therefore, expected to impact heavily on livestock producers. In order to be on the conservative side in estimating benefits we have not included these and other indirect losses in computing the benefit-cost ratios for FMD control programs.

Costs of Control Programs

Direct and indirect control costs include costs of (a) surveillance and related measures to prevent recurrence of the disease, (b) vaccine production, transportation, storage and application, (c) indemnification for depopulated animals and materials, (d) disposal of animals and materials, (e) maintenance of quarantines and (f) personnel and administrative costs.

Preventive Policy. The discounted direct cost of the preventive policy (current safeguard programs) for the 1976-90 period is estimated at $92 million. This estimate is based on actual expenditures by U.S. veterinary authorities on surveillance and other measures necessary to enforce the ban on certain livestock imports. The expenditures are made to keep other exotic diseases as well as FMD from entering the U.S. And, it would be difficult to separate surveillance and related costs of enforcing import restrictions on a disease-by-disease basis. Thus, we have charged the total amount to FMD preventive measures. There are other costs incurred by U.S. consumers (e.g., higher meat prices, inconvenience of baggage inspection, etc.) as a result of FMD related import restrictions. But other disease restrictions or other types of import quotas would probably become operative if FMD related restrictions were removed.

Eradication Policy. Costs of the eradication program are divided into two categories. The first category includes those costs incurred directly in administering and operating the eradication program. These include the costs of manning quarantines, diagnostic and laboratory investigations, valuation and indemnification, disposal of depopulated animals and materials and cleaning and disinfection of infected and exposed premises. Estimates of these program costs are based on actual field data gathered in the process of eradicating other diseases and on economic-engineering type analyses performed as part of this study. The cost of indemnity payments accounts for an estimated 60 percent of the total direct cost of the eradication program. And, the present value of the direct eradication program cost (discounted at eight percent) is estimated at $539 million.

The second category of costs evaluated here include those costs borne by consumers in the form of higher prices resulting from the reduction in meat supplies. The simulated effects of the eradication program are estimated to increase total expenditures by consumers for meat and dairy products by a net amount of $1,020 million over the disease-free (benchmark) situation. Thus, total costs of the eradication policy are estimated at $1,559 million.

Vaccination Policy. Unpublished data on costs of vaccine production, storage and administration were provided by New. His estimate of these costs is about $3.00 per animal.[12/]

Using these costs of vaccination we estimate the total discounted cost of a vaccination program to be $4,196 million. In contrast to the eradication program, the vaccination program does not involve major restrictions on movement of livestock and other products nor destruction of large numbers of animals. Consequently, related indirect costs are expected to be negligible.

In computing the benefits of a vaccination policy we deduct from the gross benefits the losses (higher net consumer expenditures) which are not avoided under the vaccination program. Our estimate of the present value of these continuing losses under a vaccination program is $2,719 million over the 1976-90 period. Subtracting this amount from the gross benefits of $11,650 million leaves $8,931 million. This amount then represents the net benefits over the 1976-90 period attributable to the vaccination program.

Evaluation of Alternative Control Policies

The expected present values of benefits and costs (discounted at eight percent) for each of the control alternatives considered are presented in Table 5. Net discounted benefits and benefit-cost ratios for each control policy are also shown. The current preventive policy employed by the U.S., when successful, yields a benefit-cost ratio of 127:1. And, rather clearly, the program can carry substantial costs via reduced imported supplies (and, thus higher prices) of livestock and livestock products and still yield a net benefit to consumers. The implicit assumption here is that in the absence of import controls and other preventive measures, FMD would, in fact, be introduced into the U.S. The probability of this happening is judged to be high enough to assume its occurrence.

Table 5. Evaluation of Control Policies in Terms of Benefit-Cost Ratios and Discounted Present Values, 1976-90*

Policy	Discounted Present Value DPV		Net Discounted Present Value (DPV of benefits less DPV of costs)	Benefit-Cost Ratio
	- - - - - - - -Million Dollars- - - - - - - -			
	Benefits	Costs		
Preventive Policy	11,650	92**	11,006	120.6
Eradication	11,650	1,559***	10,091	7.5
Vaccination	8,931	4,196	4,735	2.1

* A uniform eight percent annual discount rate has been applied to all estimates.

** This amount does not include the social cost of having FMD related product import restrictions in the U.S. The latter is probably a significant amount only in the case of fresh and frozen beef products.

*** For eradication efforts in which a lower number of animals would have to be slaughtered (say 0.1 percent of the susceptible U.S. livestock population as in the 1914 outbreak) the net discounted benefits and the benefit-cost ratio would be considerably higher.

The other two control alternatives considered assume that FMD is already present in the country. Both the eradication and vaccination control programs yield favorable benefit-cost ratios indicating their economic preferability to endemic FMD. The comparatively low benefit-cost ratio for vaccination, 2.1, suggests, however, that additional R and D investments would be desirable in order to improve the efficiency of FMD vaccination technology and, thereby, to reduce the unit costs of FMD vaccination. In the event that a vaccination program needs to be implemented in the U.S., it would be comforting to have, on the shelf, a vaccination strategy with a higher benefit-cost ratio than is currently available.

Though subject to possible errors in estimation, the research results cited in this report should provide decision makers with much improved perspective regarding the expected order and magnitude of measurable costs and benefits of the alternative FMD control strategies considered. And, both their conceptual and their empirical bases are much preferable to the gross "rules of thumb" which have been used to justify animal disease control programs in the past.

FOOTNOTES

1/ The authors are indebted to Dr. Hunt McCauley and Dr. John New, College of Veterinary Medicine, University of Minnesota for their major contributions in the planning and conduct of this study. Without their technical inputs and continuing assistance, the study could not have been conducted.

2/ The Darien Gap area is a 250-mile link in the Pan American Highway System connecting North and South America. At the present, the Highway is terminated at Tocumen, Panama and Rio Leon, Colombia.

3/ This is so because of the inelastic demand and supply of most livestock products. The shift in supply to the right, brought about by disease control, depresses prices and incomes in the farm sector resulting in lower prices to consumers, ceteris paribus.

4/ A statement which gives detailed description of the model can be obtained either from the authors or from the Commodity Economic Division, Economic Research Service, USDA.

5/ We acknowledge the very major professional input of Dr. Lloyd Teigen of ERS in adapting the ERS livestock model to the FMD problem situation and to the University of Minnesota computer system. Ann Mylander also provided a key input in running the model.

6/ The major modifications made in the existing ERS livestock model in order to simulate the impacts of FMD were on those equations relating to pig crop, calf crop, slaughter volumes, breeding herd inventories, milk production, etc.

7/A specification of exogenous variables including their historical values and those forecast to 1990 are availab from the authors on request.

8/Baseline projections to 1990 do, for example, show major increases in beef and pork consumption (47 and 59 percent respectively) and a 19 percent decline in the consumption of fluid milk. But it is less the absolute value of these baseline projections and more the deviations in alternative scenarios with which we are concerned.

9/We chose 70 percent as the infection rate occurring in all susceptible animals during the initial 12 to 18 months of the epidemic during which time no FMD control procedures were implemented and the disease was permitted to become endemic. The effects of choosing lower or higher infection rates can be easily simulated.

10/Actually, since an eradication program is normally concentrated in only one or two regions of the country, its impact on product supplies and prices is concentrated, with greater intensity, on a local or regional basis. Since our model of the livestock industry does not permit regional partitioning, these impact estimates are necessarily presented on a national basis.

11/ The actual adjustments in milk production are, however, quite complex as production per cow increases over time and cullings are mainly from the animals most seriously affected by FMD.

12/ The major cost item is veterinary fees which account for more than 50 percent of the total cost per administered dose of vaccine. The $3.00 figure is relatively high when compared to vaccination costs in other countries. Power and Harris, in their study of FMD in Great Britain, estimated the 1967 cost of vaccinating cattle to be about 22.5 pence (or 40 cents at current exchange rates). German reports estimated the 1973 cost per head at about $1.40. Several key factors underlining the APHIS/USDA estimates probably account for the high costs of vaccination. For example, labor costs are considerably higher in the U.S. than they were in Eruope at the time the above estimates were made. Transportation and distribution costs are higher in the U.S. since the area covered by the vaccination program is large compared to Europe.

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