APPENDIX C

KEY PARAMETERS OF THE ECONOMIC MODEL

The economic model uses the results of the epidemiological model to estimate the direct, indirect and induced economic impact of a FMD outbreak. Because it is assumed that the outbreak is eliminated in a relatively short period of time (about three months, depending on the date of the initial diagnosis and the eradication strategy), all domestic effects are felt within one year while international trade restrictions continue for two years after elimination of the last outbreak. Since the epidemiological model estimates the number of affected herds, it is necessary to convert these figures into lost output. This is done by multiplying the number of depopulated herds by the average weekly output (milk or meat) for the South Valley and the number of weeks the premises remain empty.

An I/O model is used to calculate the total (direct, indirect and induced) effects on output generated by the direct impact. The I/O model used in this study (IMPLAN I/O system developed by M.I.G., Inc.) was originally developed by the USDA Forest Service in cooperation with FEMA and the Bureau of Land Management to assist the Forest Service in land and resource management planning. IMPLAN closely follows the accounting conventions used in the “I/O Study of the U.S. Economy” by the Bureau of Economic Analysis and the rectangular format recommended by the United Nations.

Since FMD is not considered to be a public health problem for humans, all costs arise exclusively from disruptions of the food-production system.

Economic losses due to a FMD outbreak are split into four categories: (1) the expenditures in extra resources used as a consequence of the disease, whether they are private (drugs, veterinary services, etc.) or public (quarantine enforcement, depopulation, C&D, etc.), (2) the direct effects of the disease on the production system (lost production, animal deaths, lower prices, etc.), (3) the indirect and induced effects of the disease on the entire economy (lost employment, disruption to other industries linked directly or indirectly to the dairy and livestock industries in the infected area, etc.), and (4) losses caused by trade restrictions.

The magnitude of the losses is expected to vary with the time of the year and the nature of the affected premises. Seasonality in milk production and feedlots is relatively small (less than 15%). Seasonal effects should be larger for cow-calf operations and stockers. However, due to lack of information on movements of beef cattle, it is not possible to estimate seasonality effects in cow-calf and stocker operations. Because the annual variation in the two most important sectors—milk production and feedlots— is relatively small, it is ignored and all production effects are calculated based on annual averages. Seasonality also affects the dissemination rate, because climatic conditions for airborne dispersion are more favorable in winter. However, the higher humidity and lower solar radiation during the winter, which favor airborne diffusion, are partially compensated for by the higher rainfall. Estimation of the magnitude of these effects is beyond the scope of this work. Consequently, seasonal differences in the dissemination rates are ignored.

The estimates of the direct costs of dealing with the outbreak (depopulation, quarantine enforcement, C&D costs, etc.) are based on APHIS (1991) and past experiences of C&D using market prices of December 1997. Since no medicines are used to fight FMD, it is assumed that producers do not spend any additional resources as a consequence of the outbreak. All eradication and C&D costs are born by the state and federal governments, with the exception of compensation for destroyed animals and products which is paid entirely by the federal government. Values for the latter are based on the average market price for similar products in California in December, 1997.

The total value of lost production is shared by producers and the federal and state governments. Producers lose the income from forfeited production during the time the premises remain depopulated, while the federal and state governments lose tax revenue due to the reduced output. The losses suffered by local governments are not included in the calculations.

The method of carcass disposal used can impose heavy costs on particular sectors of society. If the carcasses are buried, the soil above the trenches cannot be disturbed for a long period of time—about 25 years—and for all practical purposes, this land is lost for production. It is unclear whether dairies in which the destroyed animals are buried would still comply with county regulations for solid waste disposal, since manure cannot be incorporated into the soil above the trenches. If the carcasses are disposed of in landfills, a cost is imposed on the counties because of the accelerated filling of the landfill. Estimation of these costs requires a number of assumptions on the future use of the land, or future technologies for garbage disposal, which are beyond the scope of this study. Even though these costs are not included in the calculations, they could be significant and deserve further investigation.

The cost estimates do not include price effects on domestic supplies and demands. Assuming that the outbreak can be eradicated promptly—in less than six months—farmers are not expected to change their long term productions plans. The short term supply of beef will undoubtedly grow as exposed farms are depopulated, then fall until infected premises can return to production. Supply should return to normal levels as production recovers in the affected areas. If consumers recognize that FMD cattle can be safely consumed by humans, domestic consumption should initially rise in response to the fall in prices induced by the larger supply, and decrease when supply contracts as the herds are rebuilt. All these short term effects are extremely difficult to model. It is also expected that the net price effect after the markets return to equilibrium should be small as the initial larger supply is followed by a smaller output. Consequently, these short term adjustments are not considered in the model. Even though the net price effects are expected to be small, the distributional effects can be large because new suppliers can capture a share of the market during the quarantine period, and it may be difficult for producers in the state to return to their original production levels.

The cost per hour for each type of worker in the C&D crews was obtained from Mace and Yoder (1997). Heavy machinery is used to remove the manure from the corrals, haul carcasses and materials to be burned, and dig trenches to burn or bury the carcasses. It is assumed that the same equipment is used in all premises except backyard operations, but the time requirement depends on the number of carcasses to be destroyed. Heavy equipment is used for three days in small dairies (500 head) and commercial hog operations (500 head), for six days in large dairies (2,000 head) and for nine days in feedlots (15,000 head). Condemned animals have to be fed until they are killed. It is assumed that feed stockpiled on the premises—also intended to be destroyed—is used for this purpose. The government compensates farmers for this feed.

The C&D crews for processing plants are composed of 13 coordinators, 50 operators of machinery and 80 ground cleaners. These crews work for 10 days on each plant. It is assumed that the C&D cost of milk processing plants and slaughterhouses is equal. The total cost of C&D at a processing facility is assumed to be $390,277, for both slaughterhouses and milk processing facilities.

The dairy industry

Direct losses in dairy production result from the depopulation of infected and contact herds during the quarantine period, which is 60 days after eradication of the last infected herd. The lost milk output is estimated as

$$LM = MP \times INF \times T / 365$$

where MP is the annual milk production in the South Valley, INF is the proportion of infected premises in the South Valley, and T is the number of days that the herds are out of commercial production divided by the number of days in one year. It is assumed that processing plants in the quarantine area have enough capacity to process all milk into fluid milk and cheese. Fluid milk is consumed in the region while cheese can be exported to other states and countries. It is also assumed that all dairies return to normal production one week after the quarantines are lifted. Even though this scenario is unlikely if the number of depopulated premises is large, the estimates provide a lower bound for the losses.

The total value of depopulated herds depends on their quality and composition. It is assumed that the herds are composed only of milking cows, which are valued at the average price for this type of animal in the South Valley. The value of calves and heifers is not included in the calculations because many dairies do not have them on the premises and for those that do, they represent a minor value compared to the cow herd. However, the value of destroyed calves and one year heifers is included in the estimation of the losses of the beef sector.

All contaminated materials in the dairies that cannot be disinfected must be destroyed. The most valuable items in this category are the stocks of hay and corn silage. Since dairies usually stock hay and silage for one year at the end of the harvest season, the volume to be destroyed depends on the timing of the outbreak. It is assumed that the stock is enough for six months of normal operations. It is also assumed that the dairies carry a stock of concentrates enough for one week of normal operation. The annual feeding requirements for an average cow in an average dairy in the South Valley were estimated in Butler and Ekboir (1995). These estimates were adjusted to the proper time intervals, six months for hay and one week for concentrates. The total value of the feed destroyed was obtained by multiplying the feedstock per cow by the number of animals on the premises.

It is assumed that C&D for a large dairy (2,000 milking cows) requires 10 days; for a small dairy (500 milking cows), five days. The cost of C&D and depopulation of a large dairy amounts to $3,098,279; for a small dairy, $819,217. The breakdown of the costs is:

	Large dairy	Small dairy
C&D	$ 136,740	$ 82,246
Destroyed feed	$ 561,538	$136,971
Destroyed animals	$2,400,000	$600,000
Total	$3,098,279	$819,217

The meat industry (beef and pork)

Losses in the meat industry arise from (1) depopulation of latent and infected premises, (2) destroyed materials, and (3) production lost in the period between depopulation and when reintroduced animals are ready for slaughter. It is assumed that exposed herds are slaughtered and diverted to human consumption. Even though all exports of beef from California would be halted, it is assumed that the markets in the quarantine area can absorb all the beef produced.

It is assumed that meat production falls in equal proportion to the number of slaughtered herds in the state's cattle and pork population. It is also assumed that all ranches return to production as soon as the quarantines are lifted, 60 days after depopulation of the last infected premise. This assumption is reasonable for all livestock premises except for cow-calf operations, which must first rebuild their stock of cows. If stockers are available outside the quarantine area, feedlots should be able to start selling finished cattle between 120 and 150 days after repopulation.

It is assumed that at the time of the outbreak feedlots have hay for half a year of normal operation, and a stock of other feed for a month. It is assumed that C&D of a feedlot (15,000 head) and a commercial hog operation (500 head) requires five days in both cases. The cost of C&D and depopulation of a feedlot amounts to $14,543,473 while for a commercial hog operation it adds up to $172,916. The breakdown of the costs is:

	Feedlot	Commercial hog Operation
C&D	$ 134,780	$ 92,916
Destroyed feed	$ 908,693	$ 25,000
Destroyed animals	$13,500,000	$ 55,000
Total	$14,543,473	$172,916

The C&D cost for a backyard operation is estimated at $32,443, since it only requires one day of cleaning by hand, equipment and supplies, and compensation for the destruction of one pig ($110).

Quarantine enforcement and trade losses

The quarantine cost is calculated on the basis that 300 checkpoints are established in the quarantine area. Two C&D crews, each with a site coordinator and five employees, work at every checkpoint. On average, each checkpoint uses 1,000 gallons of disinfectant per day. The quarantine is enforced for 120 days after depopulation of the last infected or exposed premise. The estimate does not include the cost due to the participation of law enforcement personnel.

Should the Asian markets close due to FMD, the U.S. would have to find alternative outlets for its meats. The obvious alternatives would be to expand the domestic market by reducing imports and/or to expand sales in the FMD-endemic segment or in FMD-free countries that accept the regionalization principle. California imports are mainly manufacture quality while exports to the Far East are both high quality cuts and manufacture beef. American exports to FMD-endemic markets, mainly Russia, are low quality cuts. The change of international beef flows would force a realignment of beef prices to clear the markets. The obvious changes would be an increase in the price of high quality beef in the FMD-free segment, due to the reduced supply, and a fall in the beef price in the U.S. and the FMD-endemic market. An econometric estimation of the price changes required to clear the markets is beyond the scope of this project. Ekboir et al. (1996a) developed a simple model to estimate changes in international beef markets caused by changes in trade patterns. According to that model, the price of U.S. beef exports of manufacture quality would fall by almost 50% if all American beef were sold in the FMD-endemic market. The reduction in the price of high quality cuts received by U.S. exporters should be larger because no other country demands a quality similar to Japan or Korea.

In an optimistic scenario, the markets lost in the FMD-free market would be easily replaced by other foreign markets or by an expansion of the domestic market, due to the lower price of beef. In such a case, the value of all U.S. beef exports would fall by 50% and the loss to the U.S. would be about $1.3 billion for each year that exports are excluded from the high price market.

Use of input-output model

This study estimates the total cost of a FMD outbreak with an I/O model, for several reasons:

- An I/O model estimates the outbreak's impact on the whole state economy, while a welfare analysis can only deal with a limited number of sectors. The gains from specifying more detailed responses in the markets included in the welfare analysis are offset by the loss of neglecting several important linkages.

• Estimation of supply and demand functions for the different types of livestock and dairy products involved in the study require substantial amount of data. In addition, beef supply functions must be derived from dynamic decision processes. Static specifications impose strong restrictions about the behavior of animal populations and farmers' expectations biasing the results.

• It is assumed that the outbreak is completely eradicated within a short period of time (about three months); the quarantines would remain for at least two months after depopulation of the last infected premise. Since implementation of changes in production plans in the livestock industry usually take longer than the eradication of the outbreak, it is expected that beef producers who are not infected will not change their production plans.

• The response of consumers to the outbreak cannot be determined in advance. Prices should initially fall due to increased supply from the slaughter and marketing of exposed (not infected) animals, and should rise as herds are rebuilt after the lifting of the quarantine. On the other hand, it is not known how consumers will react to a FMD outbreak, even though it is known not to affect humans.

In summary, it is assumed that the indirect and induced impacts on other sectors of the economy are more important that the price effects in the livestock and dairy sectors.

The basis of an I/O model is a matrix that describes commodity flows through the economy, moving from producers to intermediate and final consumers. This matrix is a descriptive framework for showing the relationship between industries and sectors, and between inputs and outputs. Figure C1 represents a basic I/O transaction (or gross flows) matrix.

Figure C1

	To	Purchasing sectors					Local final demand			Exports	Total gross output
From \/	>	1	. . .	j	. . .	n	Households	Private investment	Government		
Producing sectors	1	X_{11}	. . .	X_{1j}	. . .	X_{1n}	C_1	I_1	G_1	E_1	X_1
	.	.		.		.	.	.	.	.	.
	.	.		.		.	.	.	.	.	.
	.	.		.		.	.	.	.	.	.
	i	X_{i1}	. . .	X_{ij}	. . .	X_{in}	C_i	I_i	G_i	E_i	X_i
	.	.		.		.	.	.	.	.	.
	.	.		.		.	.	.	.	.	.
	.	.		.		.	.	.	.	.	.
	n	X_{n1}	. . .	X_{nj}	. . .	X_{nn}	C_n	I_n	G_n	E_n	X_n
Labor		L_1	. . .	L_j	. . .	L_n	L_C	L_I	L_G	L_E	L
Other value added		V_1	. . .	V_j	. . .	V_n	V_C	V_I	V_G	V_E	V
Imports		M_1	. . .	M_j	. . .	M_n	M_C	M_I	M_G	--	M
Total gross outlay		X_1	. . .	X_j	. . .	X_n	C	I	G	E	X

Row *i* in the table shows the sales of industry *i* to all other industries (intermediate demand) and to consumption, private investment, government spending and exports (which are the components of final demand). Intermediate demand plus final demand measures total gross output (or sales) of industry *i*. Conversely, column *j* shows the purchases of industry *j* from all other industries (intermediate inputs), from primary inputs (labor, capital, etc.) which are value added entries taking the form of wages, profit, rent, interest and taxes, and from imports.

By making certain assumptions about the economic system, and in particular about the sectoral production functions, the I/O accounts of Figure C1 can be transformed into an analytical model (Richardson, 1972). For simplicity of exposition, assume that there are only three sectors, that there is only one final demand (Y) and only one source of value added (V). Summing across each row and rearranging, results in

$$X_i - X_{i1} - X_{i2} - X_{i3} = Y_i \qquad (1)$$

If the amount of industry 1's output purchased by each of the purchasing industries is a stable function of the latter's output, equation (1) may be written

$$X_i - a_{i1} X_i - a_{i2} X_i - a_{i3} X_i = Y_i \qquad \text{for all i} \qquad (2)$$

where

a_{i1} = write equation!!!

The a's are called *direct input coefficients,* and in a *n* sector model they represent the direct requirements of the output of any sector *i* per unit of output of any other purchasing sector *j*. The crucial assumptions for equation (2) to hold are: (1) there are no joint products, since each commodity is supplied by a single industry and via one method of production, (2) all production functions are linear, implying constant returns to scale and no substitution between inputs, (3) additivity, i.e., the total effect of production is the sum of the separate effects, which rules out external economies and diseconomies, (4) the system is in equilibrium at given prices, and, (5) in static versions of the I/O model, there are no capacity constraints, so that the supply of each good is perfectly elastic.

As was pointed out before, the total effect of an external shock to the production system can be separated into direct and indirect effects. To estimate all direct and indirect effects it is useful to express the system in matrix notation. Equation (2) becomes now

$$X\text{-}AX = Y \qquad (3)$$

where X and Y are column vectors of gross output and final demand respectively, and A is an *nxn* matrix of direct input coefficients, a_{ij}. Equation (3) may be rewritten as

$$(I\text{-}A)\ X = Y$$

where I is the identity matrix. Under the condition that (I-A) has an inverse (in practical terms, this condition is met if the Y vector contains at least one non-zero element), gross output can be expressed as a function of final demand

$$X = (I-A)^{-1} Y = B Y$$

The matrix B is called the Leontief inverse. Its elements are called the interdependency coefficients and represent the direct and indirect requirements of sector *i* per unit of final demand for the output of sector *j*.

Repercussion of exogenous changes on total income and employment can be estimated via the concept of the multiplier. The income multiplier (as originally developed by Keynes) indicated the total growth in income induced by an autonomous shift in demand, once all direct and indirect effects were accounted for. I/O models allow estimation of different types of multipliers depending on whether the interest is in output, income or employment.

Output multiplier

The output multiplier for industry *i* simply measures the sum of direct and indirect requirements from all sectors needed to deliver one additional dollar of output of *i* to final demand. It is derived by summing the entries in the column under the industry *i* in the Leontief inverse matrix table.

Income multiplier (type I)

It is defined as the ratio of the direct plus the indirect income change to the direct income change resulting from a unit increase in the final demand for any given sector.

Income multiplier (type II)

It is defined as the ratio of the direct, indirect and induced income change to the direct income change resulting from a unit increase in final demand. The basic assumption used in the calculation of this multiplier is that the relationship between changes in final demand and changes in household expenditure is linear. Because of this linear relationship, the economic impact is overestimated.

Income multiplier (type III)

The type III multiplier compares direct, indirect and induced effects to the direct effects generated by a change in final demand. To minimize the overestimation caused by the linear consumption function used in the type II multiplier, the induced effects are based on the changes in employment and population.

In spite of their limitations, I/O models have been widely used for economic research and planning. Thorough reviews of this technique can be found in Miller and Blair (1985) and Richardson (1972).