ECONOMIC ASPECTS OF FOOT-AND-MOUTH DISEASE

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ABSTRACT

This paper first gives an overview of an economic study in 1989 concerning economic aspects of foot-and-mouth disease (FMD). In this study, the central issue was an economic evaluation of different strategies for prevention and control of FMD. From this study it was concluded that strategies without yearly routine vaccination were economically preferable compared to strategies with yearly routine vaccination. One of the major elements in the 1989 study were the costs of an FMD epidemic in the Netherlands. The results show that these costs depend strongly on the size of the epidemic, measured in numbers of farm affected and cleared and in the numbers of weeks an epidemic lasts, and on the assumed reactions of countries that import animal products from the Netherlands. In the discussion section of this paper, these assumptions are compared with the facts from the epidemic in the Netherlands in spring 2001.

1. INTRODUCTION

The FMD epidemics in the EU in 2001 focused the attention of farmers, farmers' representatives, veterinarians and policy makers to control and prevention of FMD. In the Netherlands, the epidemic in 2001 was the first epidemic occurring in the unvaccinated population after yearly routine vaccination was stopped in 1991. The initial difficulties to control the epidemic and the spread of FMD to different parts of the country showed the high susceptibility of the unprotected animal population. Consequently, the decision to stop vaccination in 1991 was heavily discussed. One rather broad idea in this discussion was that it were mainly short-term economic motives that led to the abolishment of yearly routine vaccination.

The abolishment of yearly routine vaccination starting in 1992 was an EU decision. The basis of this decision was formed by the strong will of EU member states to harmonise policies in order to realise the ideal of a free EU market. In the case of animal products especially differences in veterinary regulations between countries often served as trade barriers between EU countries. EU countries like Great Britain, Denmark and Greece did not apply routine vaccination against FMD. As they were free of FMD and non vaccinating, these countries had access to meat markets that require non vaccination and that pay a higher price for meat. Denmark for example utilized this position by exporting pig meat to Japan. The absolute refusal of these countries to start yearly vaccination, the idea that non vaccination results in the highest status for meat trade and the possibilities some other countries saw to get a share of the FMD free meat market were the main factors in the EU decision to stop yearly vaccination.

In 1989/1990 an economic evaluation of different strategies for prevention and control of FMD for the Netherlands was carried out (Berentsen *et al.*, 1992a, Berentsen et al, 1992b). A major finding of this research project was that abolishment of yearly routine vaccination would be economically profitable for the Netherlands. This conclusion was based on model calculations. Major aspects in these calculations were the costs of yearly routine vaccination, assumptions about the share of the FMD free meat market the Netherlands could get, the costs of an FMD epidemic and the frequency of epidemics. In the perspective of the FMD epidemic in the Netherlands in 2001, the method and the results of this research were often discussed.

The aim of this paper is to give an overview of the method applied and the results obtained in this 1989/1990 study. The discussion section will focus on the differences between the assumptions used in the 1989/1990 study and the reality of the 2001 epidemic.

2. MATERIAL AND METHODS

The modelling approach consisted of an epidemiological model and two economic models to simulate the spread of the disease and to determine the costs of an epidemic respectively and an integrating part in which all economic aspects of prevention and control of FMD are taken together and are recalculated as yearly costs per strategy. The strategies taken into consideration were:

I. Annual vaccination of the cattle population. In case of an epidemic:
   a. slaughter and destruction of animals on affected farms;
   b. slaughter and destruction of animals on affected farms plus ring vaccination.

II. No annual vaccination. In case of an epidemic:
   a. slaughter and destruction of animals on affected farms;
   b. slaughter and destruction of animals on affected and serious contact farms;
   c. slaughter and destruction of animals on affected farms plus ring vaccination.

The yearly vaccination included cattle only. A ring vaccination would start 3 weeks after the primary outbreak(s) and included all cattle and pigs within a radius of 25 km around the infected herd(s). A serious contact farm was considered a farm that had more than one contact with an affected farm in the period before the latter farm was found to be affected.

2.1 The epidemiological model

To simulate the spread of the disease, the state-transition approach was used (Miller, 1979). This approach consists of a Markov chain model, including two components: states and transitions. The Markov chain represents the process in which the number of elements at each state at a specific time is dependent on the number of elements at each state in the previous period of time and the transition probability between states (Carpenter, 1988a). In simulating an FMD epidemic, the cattle and pig farms are considered the modelling unit so all animals on one farm are estimated to be in the same state. The separate states in which the (animals on the) farms can be found are: susceptible, infectious, immune or removed.

In an FMD epidemic, the spread of the disease decreases during the epidemic by the introduction of transport bans and because farmers are more careful when visiting each other. The spread (the transition probability from susceptible to infectious) was therefore simulated in a dynamic way (Carpenter 1988b). According to Miller (1979), the probability of transition from susceptible to infectious (pi) in a particular week (j) is a function of the fraction of infectious farms in the previous week ($fi_{(j-1)}$) and the dissemination rate (dr);

$$pi_j = 1 - \exp[-dr_{(j-1)} \times fi_{(j-1)}]$$

Table 1. Percentages of farms protected per week after a ring vaccination and the numbers of risky contacts per affected herd per week.

	dissemination rate (nr. of farms)	percentage of cattle farms protected		percentage of pig farms protected
		vaccinated population	Non-vaccinated population	
week 1	4.5	85	0	0
week 2	2.7	85	0	0
week 3	2.2	85	0	0
week 4	1.7	85	0	0
week 5	1.2	85	50	50
week 6	0.8	95	80	80
week 7 and beyond	0.8	95	90	90

The dissemination rate represents the average number of farms to which the virus is transmitted by one affected farm, regardless of the state of the farm receiving the virus. (Whether the virus is expressed as disease symptoms depends on the state of each receiving farm.) The size of the dissemination rate depends on factors such as herd density, the transfer of animals between farms and the type of farm (many small or some large farms) in the area. The dissemination rate gradually decreases due to transport bans and to greater awareness among farmers (Miller, 1979). The fraction of herds being susceptible, immune or removed depends on the control strategy. Some of the input data used in the epidemiological model are given in Table 1.

2.2 The disease-control model

Given the simulated epidemic and the control strategy under consideration, the disease-control model calculates the direct costs for producers and government. These costs can be divided into: (1) costs of ring vaccination, and (2) costs of stamping out. The costs of ring vaccination depend on the number of farms in the vaccinated area and the vaccination costs per farm. For part of these costs, an EC-subsidy can be obtained. The costs of stamping out include:

- the value of the animals slaughtered and destroyed;
- costs of evaluation, transport, disinfection etc.;
- costs of idle production factors on farms where the herd has been removed;
- missed net cash flow in the industry;
- incidentals on cattle and pig farms.

Table 2. Input values used in the disease-control model.

Cost elements of vaccination:	
- Vaccine costs per dose (Dfl.1))	2.50
- Vaccination costs per animal, including vaccine (Dfl.)	
* first fifty cattle on the farm	5.80
* other cattle on the farm	5.35
* first fifty pigs on the farm	3.80
* other pigs on the farm	2.95
Cost elements of stamping out:	
- Costs per average cattle farm (Dfl.x1000)	
* removed animals 130	
* others (taxation, transport, disinfection, etc.)	15
- Costs per average pig farm (Dfl.x1000)	
* removed animals	100
* others (taxation, transport, disinfection, etc.)	17
- Costs idle production factors:	
* cattle farms (Dfl./cow/day)	8.10
* swine breeding farms (Dfl./sow/day)	2.70
* pig fattening farms (Dfl./hog/day)	0.33
- Incidentals on cattle and pig farms	
* % of losses removed animals	10
- Missed net cash flow industry and trade	
* per average removed cow (Dfl.)	1500
* per average removed pig (Dfl.)	350
- Annual discount factor (%)	5
Miscellaneous:	
- EC subsidy for ring vaccination	
* % of vaccine costs	100
* % of vaccination costs	50
- EC subsidy for stamping out	
* non-vaccinated population: % of cost repaid	50
* vaccinated population: all costs repaid up to the	
▪ minimum of either: number of outbreaks	20
▪ or: number of weeks	4

The first two items are losses for the government (farmers are compensated by the government for slaughtered and destroyed animals). The third, fourth and fifth part are losses for producers. The losses for the government are reduced because of an EC-subsidy on stamping out. The major input values are summarized in Table 2.

2.3 The export model

2.3.1 General aspects

The export model is product-oriented, i.e. the effects of export bans on producer and consumer income and on the government budget are calculated for each product separately. In calculating these effects, it is necessary to know the market structure for that product. The market structure is described by the number of markets to which the product is exported and by the following characteristics per market: the volume of export; the level of consumption; the price elasticity of demand; the transport costs per unit of product. For the domestic market, the import and the price of the product are also of importance.

Some countries (such as the USA, Japan and South Korea) do not accept meat from countries with an annual FMD-vaccination scheme. As a result, the price paid for meat on this so-called FMD-free market is about 10% higher than on other markets (Johnston, 1982). This was the reason to assume a change in market structure after ceasing the annual vaccination. So, for a correct evaluation of strategies it was necessary to define a market structure per product for situations both with and without annual vaccination.

The products concerned in this study were meat and breeding cattle. Because of the relative unimportance of breeding cattle compared to meat, only the market structures for meat are shown in Table 3 and 4 (for the data on breeding cattle see Berentsen *et al.*, 1990).

In calculating the indirect effects, it is necessary to know what reactions can be expected in importing countries in case of an FMD-epidemic in the Netherlands. Based on reactions during epidemics in Western Europe in the eighties, the following options were considered in the model: excluding imports of the product from the Netherlands or from the infected area only; relating the duration of the reaction to the first or to the last outbreak. The basic reactions considered in the study are described in Table 5.

Table 3. Market structure meat (1986) with yearly vaccination.

	EC				non-EC	
	Neth.	FRG, B.&L.	Fr.& It.	EC-rest	M.&S. America	Rest
consumption (tons/week)[1]	16731	114385	138288	53019	150000	447000
export Nl.(tons/week)[2]	-	10111	13978	2809	300	2556
part of national production (in %) of:						
- N. and W. Netherlands	17					
- E. Netherlands	37					
- S. Netherlands	46					
import Nl (tons/week)[3]	2962					
price elasticity of demand[4]	-0.5	-0.4	-0.2	-0.3	-0.4	-0.4
homogeneity	1	0.7	0.6	0.4	0.1	0.1
transport costs (Dfl.x 1000/ton)	0	0.20	0.40	0.30	0.70	0.60
maximum increase export (tons/week)	-	1011	1398	281	30	256
price (Dfl.x1000/ton)	4.92					
distortion costs (Dfl.x 1000/ton)	0.20					
storage costs (Dfl.x1000/ton/week)	0.03					

Table 4. Assumed market structure meat (1986) without yearly vaccination.

	EC				non-EC	
	Neth.	FRG, B.&L.	Fr.& It.	EC-rest	FMD-free	Rest
consumption (tons/week)	16731	114385	138288	53019	irrel.	447000
export Nl.(tons/week)	-	10111	13978	2809	1500	1356
part of national production (in %) of:						
- N. and W. Netherlands	17					
- E. Netherlands	37					
- S. Netherlands	46					
import Nl. (tons/week)	2962					
price elasticity of demand	-0.5	-0.4	-0.2	-0.3	irrel.	-0.4
homogeneity	1	0.7	0.6	0.4	0.1	0.1
transport costs (Dfl.x1000/ton)	0	0.20	0.40	0.30	0.70	0.60
maximum increase export (tons/week)	irrel.	1011	1398	281	150	136
price (Dfl.x1000/ton)	4.92					
distortion costs (Dfl.x 1000/ton)	0.20					
storage costs (Dfl.x1000/ton/week)	0.03					
price-premium (Dfl.x1000/ton)	0	0	0	0	0.49	0

2.3.2 Methodology

Three elements of the export model are basic in calculating the effects of export bans:

1. The reactions of producers to temporary changes in prices. As producers can foresee that an FMD-epidemic is only temporary, it was assumed that producers do not react to changes in prices of agricultural products due to an FMD-epidemic;

Table 5. Duration of export bans and the area involved.

	Ia and Ib	IIa and IIb	IIc
EC			
Germany, Belgium and Luxembourg	Until 4 weeks after the last outbreak, infected region	Same as Ia and Ib	Same as Ia and Ib
France and Italy	First 2 weeks the entire area of the Netherlands, after that like G, B and L.	Same as Ia and Ib	Same as Ia and Ib
Rest of the EC	Like G, B and L	Same as Ia and Ib	Same as Ia and Ib
Non-EC			
Central and South America	Until 52 weeks after the last outbreak, entire area of the Netherlands	-	-
FMD-free	-	Until 52 weeks after the last outbreak, entire area of the Netherlands	Until 104 weeks after the last outbreak, entire area of the Netherlands
Rest	Until 4 weeks after the last outbreak, entire area of the Netherlands	Same as Ia and Ib	Same as Ia and Ib

2. The way in which market prices and quantities react in the short term to changes in export markets. It is quite normal in models of international trade to consider markets as completely fluid: if a quantity change arises somewhere, it will be spread over the complete market. Such an assumption, however, was not very useful in our approach, because short-term reactions are not fluid at all. Therefore, the following assumptions were made:

a) There is a capacity limit for each export market, which is related to the usual volume of the export;
b) Increasing exports on a particular market can only be realized by means of a price reduction (derived from the export demand curve for this particular market);
c) The storage behaviour of participants in the market follows a rational expectations approach: producers store products when the expected future market price minus the storage costs are higher than the present market price.

3. The calculations of the economic effects of changes in price and quantity. With regard to the economic effects for producers, consumers and national budget, only effects for the Netherlands were considered, as the study was focused on the Netherlands. Normal principles for the calculation of consumer surplus, producer surplus and budget effects were used (see Berentsen *et al.*, 1992a).

2.4 The integrating part

The integrating part starts by calculating:

- the national economic losses as a result of an epidemic;
- the costs of yearly routine vaccination (using input values for cost elements of vaccination as given in Table 2);
- the profit of selling products on the FMD-free market (for input values on amounts and price premium used see Table 4).

On the basis of expectations about the frequency of FMD epidemics (expressed in numbers per 10 years) in the most-optimistic, the most-likely and the most-pessimistic situation (see Table 8) (Strohmaier and Böhm, 1984; Scientific Veterinary Committee of the EC, 1988) the yearly costs per strategy were calculated. The relatively higher number of epidemics to be expected for the most-likely situation in case of routine vaccination is due to risk generated by the presence of vaccine and vaccine plants.

3. RESULTS

3.1 The basic situation

The highest number of secondary outbreaks occurred, as could be expected, in a non-vaccinated population with stamping out infected herds as the only control strategy (Table 6). Vaccination, however, is not necessarily the only remedy against a dramatic spread of the disease. The total number of outbreaks and the length of time in which they occur can also be considerably reduced by stamping out serious contact herds as well (strategy IIb).

Table 6. Simulated epidemic under different strategies.

	Vaccinated population		Non-vaccinated population		
	Ia	Ib	IIa	IIb	IIc
# of weeks with outbreaks	8	6	29	8	8
# of affected farms	33	27	688	58	240
# of cleared farms	33	27	688	138	240
% of region affected	8	8	19	8	8

Given these predicted numbers of outbreaks, the calculated direct and indirect costs under each of the strategies are summarized in Table 7. The direct costs are highly related to the length and extent of the epidemic. The indirect costs are by far the highest in the situation without yearly vaccination (as could be expected). This is mainly caused by the considerably longer reactions on the FMD-free markets.

The final comparison of strategies is done on a yearly base, taking into account the expected frequency of epidemics, the total costs per epidemic, the costs of yearly vaccination and the extra profits of export to FMD-free markets (Table 8).

In the case of the most-optimistic situation regarding the number of epidemics (0 within 10 years), routine vaccination is, of course, far from profitable. Routine vaccination costs about Dfl. 24 million per year, while in a non-vaccinated population profits occur due to the access to FMD-free markets. In the most-likely situation, strategies without yearly vaccination are also preferable. Pessimistic expectations about the frequency of epidemics, however, make a yearly vaccination the most-profitable option.

Table 7. Economic losses resulting from one epidemic (x 10^6 Dfl.).

	Vaccinated population		Non-vaccinated population		
	Ia	Ib	IIa	IIb	IIc
Direct costs:					
- value of removed animals	3.47	2.84	80.65	16.18	28.14
- disinfection costs	0.55	0.45	10.91	2.19	3.80
- costs of on-farm idle factors	0.40	0.33	12.02	2.41	4.19
- on-farm incidental costs	0.00	0.00	0.01	0.00	0.00
- losses for industry and trade	5.33	4.36	121.72	24.42	42.46
- costs of ring vaccination	0.00	8.78	0.00	0.00	11.09
Total direct costs	9.75	16.75	225.31	45.19	89.68
Indirect costs per product:					
- Meat:					
* no. of weeks market disruption	60	58	81	60	112
* producer losses	331.80	303.04	938.29	610.41	917.67
* consumers losses	-112.63	-103.44	-279.63	-185.51	-262.09
- Breeding cattle:					
* no. of weeks market disruption	34	32	55	34	34
* producer losses	19.88	18.71	32.21	19.88	19.88
* users losses	-15.33	-14.43	-24.80	-15.33	-15.33
Total indirect costs	223.71	203.88	666.07	429.45	660.13
EU-subsidy	2.43	9.46	45.78	9.18	24.67
Total costs per strategy	231.02	211.18	845.59	465.46	725.14

Table 8. Yearly costs per strategy and sensitivity analysis (x 10^6 Dfl.).

	Vaccinated population		Non-vaccinated population		
	Ia	Ib	IIa	IIb	IIc
Most optimistic situation:					
- no. of epidemics / 10 year	0	0	0	0	0
- total costs per year	24.5	24.5	-38.2	-38.2	-38.2
Most likely situation:					
- no. of epidemics / 10 year	2	2	1	1	1
- total costs per year	70.7	66.8	46.3	8.3	34.3
Most pessimistic situation:					
- no. of epidemics / 10 year	4	4	4	4	4
- total costs per year	116.9	109.0	300.0	148.0	251.8
Sensitivity analysis:					
- epidemic in a low farm density area	59.0	59.1	18.7	4.8	28.6
- epidemic in a high farm density area	87.8	72.7	81.0	12.4	38.4
- 2 epidemics / 10 years	70.7	66.8	130.9	54.9	106.8
- no export to an FMD-free market	70.7	66.8	62.4	26.0	28.9
- half the export and price premium on the FMD-free market	70.7	66.8	59.9	23.1	35.8

3.2 Sensitivity analysis

Sensitivity analysis was done for the most-likely situation (Table 8). A 40% lower herd density (as is the case in the northern and western part of the Netherlands) reduced the yearly costs, whereas a 30% higher farm density (which counts for the south of the Netherlands) increased the yearly costs. In both cases, the strategies without yearly vaccination remained favourable. In an area with low farm density, the control strategy of stamping out only affected herds became more profitable.

It appeared that the expected frequency of epidemics is an important variable. For a frequency of two epidemics per 10 years only strategy IIb could compete with the strategies that include yearly vaccination. Regarding the importance of getting access to FMD-free markets, it appeared that strategies without yearly vaccination remained in favour even if no access to FMD-free markets is obtained.

4. DISCUSSION

From the results of the 1989/1990 study, it was concluded that strategies without yearly vaccination could very well compete with vaccination strategies. However, much depends on the validity of the epidemiological model and on the assumptions used in the economic models. Since the first epidemic after ceasing yearly vaccination took place in 2001, assumptions and results can be compared with reality. The simulated strategy closest to the strategy applied during the recent epidemic is strategy IIb.

During the 2001, epidemic 26 farms were confirmed to be infected with FMD. The first outbreak was confirmed on March 21 and the last outbreak on April 22, so the epidemic lasted about four and a half weeks. A comparison with the result of the 1989/1990 study shows that the number of farms affected as well as the duration of the epidemic is about half of that of the simulated epidemic using strategy IIb. However, due to a number of reasons comparison is difficult. First of all the starting situation was not an unprepared situation as was assumed in the study. Due to the vast FMD-epidemic in Great Britain with the first outbreak confirmed on February 20, Dutch farmers were more cautious, which should have a decreasing effect on the size of the epidemic. The same effect could be expected from the 72 hours stand still that was applied after the first outbreak in the Netherlands was confirmed. Finally, the control strategy with clearing farms in an area with a radius of 1 kilometre and later on 2 kilometres around an infected farm, combined with emergency vaccination and clearance of a bigger area later on was much stricter than strategy IIb in which about one and a half non-infected farms were cleared per infected farm. This should have a decreasing effect on the size of the epidemic also.

Looking at the 2001 epidemic from an economic point of view national economic costs will probably be higher than Dfl. 465 mln. being the simulated losses of an epidemic under strategy IIb. This is due to a number of reasons. Firstly, the direct costs will be high because of the great number of farms that were cleared. In total, 2763 farms were cleared. This number includes households with only a few animals, but nevertheless the number of removed animals is much higher than expected under strategy IIb. Estimates of the Ministry of Agriculture show costs of Dfl. 500 mln. for compensating, vaccinating and removing animals, 40% of which will probably be paid by the EU (Ministry of Agriculture, 2001). Taken into account also losses for industry and trade, total direct costs could be Dfl. 700-800 mln which is some 20 times the amount calculated in 1998/1990 study. Although the duration of the 2001 epidemic was shorter than simulated, also indirect costs will probably be higher. Because of initial suspicion of FMD on farms in different parts of the Netherlands and because of spread of FMD to two different areas in the Netherlands, export of animal products from the Netherlands as a whole and later on from a major part of the Netherlands was forbidden. This is more severe than was expected in the simulations where only a smaller infected region was considered closed for our important export countries like Germany, France and Italy. Moreover, the export ban did not only concern meat and live animals, but also dairy products. Finally, losses appear in other sectors that were not taken into account in the 1989/1990 study. As the major part of the outbreaks took place in a touristic area, especially tourism suffered losses during the period with outbreaks. Due to movement restrictions, many tourists cancelled their plans. However, determination of these kinds of losses is difficult. Looking from a national economic point of view it is important to consider that tourists may have spent their money in a different part of the Netherlands or that they may have postponed their holiday plans until later. So determination of these losses should be done on a national and at least on a yearly base.

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