Foot-and-mouth disease and export

an economic evaluation of preventive and control strategies for The Netherlands

P.B.M. Berentsen, A.A. Dijkhuizen and A.J. Oskam

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ABSTRACT

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An integrated approach has been developed to determine the economic consequences of alternative strategies to prevent and control Foot-and-Mouth Disease (FMD). This study contains a methodological part, with a critical evaluation of the relevant literature in this area. The approach is based on an epidemiological model developed earlier and an export model, developed specifically for this study. Both models are integrated in a complete model - suitable to run on a personal computer - to investigate the economic effects of alternative strategies for the Netherlands. Because many uncertain aspects play a role, a computer model makes it possible to compare the strategies under different conditions (i.e. sensitivity analysis).
Economic effects have been calculated for producers, consumers and the government. Total costs of an outbreak in the Netherlands vary between 100 million and 1.2 billion guilders, depending on where the outbreak occurs and on the strategy applied. The cost of an outbreak, however, forms only part of the relevant information. The frequency of primary outbreaks and the costs of vaccination (for some strategies) also influence the annual costs per strategy. Under normal conditions it is found to be profitable for the Netherlands to cease annual vaccination of the cattle herd. This strategy, however, is more risky and can lead - under very unfavourable conditions and in areas with a high herd density - to high costs. The export model that has been developed can be used for different countries and other infectious diseases. Only small changes in the model structure would be required and the model input should be adjusted to the particular problem.

CONTENTS

PREFACE

The research reported in this study took place during two successive periods: September 1988-August 1989 and December 1989-May 1990. In between, an interim report was discussed with several organizations and persons. Financial support was provided by the Foundation for the Investigation and Study of Foot-and-Mouth Disease and by the Veterinary Service. Moreover, the LEB-fund provided a grant to ease the publication of this report.

The authors are further indebted to the committee of experts, comprising dr. P.W. de Leeuw (National Animal Health Committee), drs. H.U.R. Nieuwenhuis (Veterinary Service) and dr. C. Terpstra (Central Veterinary Institute, Virology Department), who supervised the research. The research approach was decided upon in consultation with this committee and the results were discussed with its members in stages.

SUMMARY

This report states the methodology followed, and the results, of an economic evaluation of preventive and control strategies for Foot-and-Mouth Disease (FMD) in Dutch livestock farming.

The report begins with an overview of literature in this area. A number of research projects from various countries, which aimed at determining the optimal strategy for the prevention and control of FMD, or at determining the effects of an FMD outbreak under the strategy being applied, are discussed and provided with critical comments. Because many comments concern the economic methodology, the elements involved in a national-economic cost-benefit analysis are subsequently examined. In addition to the way in which the effect on producers, consumers and the government should be measured according to the economic theory, attention is also paid to the arguments for and against aggregation of these effects.

Three models have been used in order to determine the optimal strategy for the Netherlands.The simulation of outbreaks under different strategies and the calculation of the immediate control costs have been achieved with adapted versions of two models already developed for this purpose (Dijkhuizen, 1989). The calculation of the indirect costs of an outbreak, arising when importing countries temporarily close their borders to Dutch products, has been done with an 'export model' developed during this investigation. All three models, with their underlying principles, are discussed in the report.

For reasons of availability of the most recent input data, 1986 has been selected as a basic year for the calculations. The calculations show that an FMD outbreak can cost the Netherlands 170 million to 1.2 billion guilders, depending on where the outbreak occurs (in an region with low or high livestock density) and on the strategy applied. The costs of an outbreak under strategies without annual preventive vaccination are in general higher than under strategies with vaccination. On the other hand one has 1) an annual saving of roughly 25 million guilders on vaccination costs and 2) extra revenue because new markets can be supplied, where structurally higher prices are paid. By means of estimates for the most optimistic, the

most likely and the most pessimistic situation regarding the number of primary outbreaks per 10 years, the cost of an outbreak, the cost of annual vaccination and the extra revenue referred to above have been converted to the annual costs per strategy. In the most optimistic and the most likely situations, ceasing vaccination was found to be the most profitable option. In the most pessimistic situation, continuing vaccination is the better choice. In any case, an adequate control strategy remains necessary, which should be more than the slaughtering and destruction of animals on affected farms only.

The information used, the results and the conclusions are detailed in the report. Bearing in mind the recent decision in Brussels to stop the annual vaccination in the EC in 1992, the report gives a lot of information to get insight in the situation after 1992.

SAMENVATTING

Het onderhavige rapport bevat de gevolgde methodologie en de resultaten van een economische evaluatie van verschillende strategieën voor preventie en bestrijding van Mond en KlauwZeer (MKZ) in de nederlandse veehouderij.

Het rapport begint met een overzicht van de literatuur op dit gebied. Een aantal studies uit verschillende landen, die alle tot doel hadden het bepalen van de optimale strategie voor de preventie en bestrijding van MKZ, dan wel het bepalen van de economische effecten van een MKZ-uitbraak onder de toegepaste strategie, worden besproken en voorzien van kritische kanttekeningen. Omdat veel van de kritiek betrekking heeft op de gevolgde economische methodologie, is het volgende hoofdstuk van het rapport gewijd aan de verschillende elementen die een rol spelen in een economische kosten/baten analyse. Naast de wijze waarop economische effecten voor producenten, consumenten en overheid bepaald dienen te worden, is ook aandacht besteed aan argumenten voor en tegen het aggregeren van deze effecten.

Drie modellen, ondergebracht in één computerprogramma, zijn gebruikt om een aantal strategieën te evalueren voor Nederland. Het simuleren van uitbraken onder de verschillende strategieën en het berekenen van de directe bestrijdingskosten is gedaan met aangepaste versies van twee modellen die eerder voor dit doel ontwikkeld zijn (Dijkhuizen, 1989). Het berekenen van de indirecte kosten van een uitbraak, die ontstaan doordat importerende landen tijdelijk hun grenzen sluiten voor nederlandse producten, is gedaan met een 'exportmodel', dat ontwikkeld is gedurende dit onderzoek. Alle drie modellen, inclusief de onderliggende principes, worden besproken in het rapport.

Het jaar 1986 is gekozen als basis voor de berekeningen vanwege de beschikbaarheid van data. De berekeningen wijzen uit dat een MKZ-uitbraak Nederland 170 miljoen tot 1,2 miljard gulden kan kosten, afhankelijk van de plaats van de uitbraak (in een gebied met een lage dan wel een hoge veedichtheid) en van de toegepaste strategie. De kosten van een uitbraak onder strategieën zonder jaarlijkse vaccinatie blijken in de regel hoger te zijn dan van een uitbraak onder strategieën met jaarlijkse vaccinatie. Hier tegenover staat 1) een besparing van 25 miljoen per jaar op vaccinatiekosten en 2) extra opbrengsten doordat met name vlees afgezet kan worden op markten waarop structureel hogere prijzen worden betaald. Door middel van een schatting van de meest optimistische, de meest waarschijnlijke en de meest pessimistische situatie ten aanzien van het aantal primaire uitbraken per 10 jaar zijn de kosten van een uitbraak, de kosten van jaarlijkse vaccinatie en de extra opbrengsten van afzet op nieuwe markten omgerekend tot jaarlijkse kosten per strategie. In de meest optimistische en in de meest waarschijnlijke situatie blijkt het stoppen met vaccineren economisch gezien de beste keuze. In de meest pessimistische situatie verdient continueren van de jaarlijkse vaccinatie de voorkeur. In bijna elke situatie blijft een adequate bestrijdingsstrategie, die meer inhoudt dan alleen het afmaken en vernietigen van dieren op besmette bedrijven, noodzakelijk.

De gebruikte informatie, de gevolgde werkwijze en de resultaten en conclusies zijn uitgebreid beschreven in het rapport. Gezien in het licht van de recente besluitvorming in Brussel over het stoppen met de jaarlijkse vaccinatie tegen MKZ in 1992, biedt het rapport veel aanknopingspunten voor een beoordeling van de gevolgen van deze besluiten.

1 INTRODUCTION

Foot-and-Mouth Disease (FMD) is an extremely infectious virus disease which can occur in cloven-hoofed animals. Cattle and pigs are particularly susceptible (Carpenter and Thieme, 1979). In many countries successful attempts have been made to eradicate the disease, or at least to limit it to a minimum. There are basically two possible ways of doing this:

1. Regular preventive vaccination of susceptible animals, applied in the Netherlands since 1953 (Van Bekkum, 1987, p. 720). In practice, this amounts to the vaccination of cattle older than 4 months. Should an outbreak occur in spite of the preventive steps, it is brought under control, when the means used can consist of the slaughter and destruction of animals on affected farms, extra vaccination in an area around the affected farm, and transport bans.
2. The so-called 'stamping-out' approach, when no annual vaccination is applied, and often no ring vaccination either, after an outbreak. The intensive combatting of outbreaks, whereby sometimes animals at contact farms are also slaughtered and destroyed, is here considered sufficient to get the disease under control.

That both alternatives can achieve success is apparent from table 1.1, in which the number of primary and secondary outbreaks are recorded over 10 years in EC member states which do and do not apply preventive vaccination.

Whether or not to continue with preventive vaccination is a regular topic for discussion in many countries at present still vaccinating. Advocates of vaccination being discontinued argue the favourable results of other non-vaccinating countries, the recurring annual vaccination costs, and the possible new export potential if the country, by ceasing vaccination, is considered world-wide to be FMD-free. Those in opposition argue the much swifter spread of FMD in an unvaccinated population if a primary outbreak occurs, with all the related consequences, in particular for export.

Table 1.1: Number of primary and secondary outbreaks in the EC member states in the period 1977-1987

	no. of primary outbreaks	no. of secondary outbreaks
Countries that apply preventive vaccination:		
- Belgium	0	0
- France	2	38
- Italy	13	551
- Luxembourg	0	0
- The Netherlands	2	5
- Portugal	2	1182
- Spain	unknown	unknown
- West Germany	8	20
Countries that do not apply preventive vaccination:		
- Denmark	2	21
- Greece	3	7
- Ireland	0	0
- United Kingdom	2	0

Source: EC-Commission, 1989, Annexes, p.11

A comparison of the results of non-vaccinating countries with those of countries which do vaccinate is, they consider, only partially relevant, due to geographical differences (three of the non-vaccinating EC countries have a somewhat isolated location), differences in herd density, and the fact that some non-vaccinating countries benefit from the preventive vaccination applied by surrounding countries.

Some years ago, coordinated by the FAO, cost-benefit analyses were carried out by and for a number of Western European countries with regard to different strategies for the prevention and control of FMD. In the research for the Netherlands, the effect of an FMD outbreak on export was passed by, with a referral to the difficulty in quantifying (Dijkhuizen, 1989, p. 11). These consequences can be sizeable, particularly for such an export-oriented country as the Netherlands.

The formulation of the problem for the present research recorded in this report stems from the above-mentioned discussion between supporters and opponents of the abolition of vaccination. The formulation of the problem is summarized as follows:

Chi-Kwadraattoets op een verband tussen twee kenmerken (afhankelijkheid)

Voor mijn stageverslag moet ik onderzoek doen naar 2 dezelfde apparaten. (bepalen of ze van elkaar verschillen).

ik heb de volgende waarnemingen eruit gekregen:
Apparaat XE-1 -->
Positief: 80
Negatief: 229
Totaal: 309

Apparaat XE-2 -->
Positief: 124
Negatief: 398
Totaal: 522

Nu moet ik van mijn stagebegeleider een Chi-Kwadraat uitvoeren op deze waarnemingen (gezien het verschil in totale waarnemingen), maar ik heb geen idee wat hier allemaal bij berekend moet worden en wordt niet echt wijs uit al die formules (ik ben ook niet echt goed in wiskunde/statistiek)

wie kan mij helpen?!
bij voorbaat dank!!!

DaNumbah10
Student hbo - donderdag 17 juni 2004

Antwoord

Hier komt het volledige antwoord:

Uitgangspunt voor de chi-kwadraattoets op samenhang is je kruistabel:

	Apparaat		
Oordeel	XE-1	XE-2	totaal
Positief	80	124	204 (=24,55%)
Negatief	229	398	627 (=75,45%)
totaal	309	522	831

figuur 5.2 Beoordeling in relatie tot apparaat

Toets nu (met α=5%) of er tussen de variabelen apparaat en het oordeel een significante samenhang bestaat.

Oplossing

1 Hypothesen:

Altijd wordt als nulhypothese gekozen dat er geen verband is tussen de beide variabelen:

H_0 : Er bestaat in de populatie geen verband tussen de variabelen apparaat en oordeel (kenmerken onafhankelijk)

H_1 : Er is in de populatie wel een verband tussen de variabelen apparaat en oordeel

Onbetrouwbaarheid: $\alpha = 0{,}05$

What, from an economic and from the Dutch point of view, are the optimal strategies regarding the prevention and control of foot-and-mouth disease under a variety of conditions?

In order to be able to answer this question, a computer model[1] has been developed with which the economic effects of various strategies for the prevention and control of FMD can be compared. Attention is particularly paid to the quantifying of potential consequences for export. As regards the simulation of outbreaks and the calculation of the direct costs of an outbreak, Dijkhuizen's computer model has been used, which was designed as part of the above-mentioned FAO survey, together with the data then used.

In the seven remaining chapters of this report, it is explained how the research has been carried out and what the most significant results are. Chapter 2 contains an outline of earlier research in this field, in which attention is particularly paid to the research methodology applied and the principles employed. In chapter 3, it is attempted from the economic theory standpoint to indicate in what way a national-economic cost-benefit analysis should be carried out, and which elements should and should not be included. In chapter 4, delineation of the research is found. It is stated which elements have and have not been included in the analysis. In this chapter the principles essential to the form of the model are also included. The model itself is discussed in chapter 5. The data employed for the calculations are justified and explained in chapter 6. In chapter 7, the results follow. Finally, chapter 8 includes a discussion about some principles and the conclusions of the investigation.

In July 1990 the Ministerial Board of the EC decided to cease yearly vaccination from 1992, making the evaluation of control strategies in a non-vaccinated population highly important. The effects of this decision for the Netherlands can also be derived from the results in this study.

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[1]The model is written in English and programmed in Turbo Pascal. It is suitable to run on an IBM (-compatible) personal computer with the MS-DOS operating system and 640 kB. of random access memory. The program is available for purchase from the department of Farm Management (Price: Dfl. 250.- per copy).

2 AN OUTLINE OF EARLIER RESEARCH INTO ECONOMIC ASPECTS OF FMD OUTBREAKS

In various countries, and in various ways, research has in the past been aimed at economic aspects of FMD prevention and control strategies. Research in this field can be divided into three groups:

1. First of all there is research in which several strategies are evaluated to decide what the best strategy is, from an economic point of view, for the country in question (as regards whether annual vaccination should or should not take place, and as regards controlling an outbreak). To this group belong:
   - the research by Power and Harris (1973) for the UK;
   - the research by Lorenz (1986) for West Germany;
   - the research by Dijkhuizen, Smak, Terpstra and Van der Valk (1986) for the Netherlands.

   The last two surveys form part of a research project coordinated by the FAO, in which strategies for the prevention and control of FMD were evaluated by and for seven Western European countries.
2. The second group consists of research in which the economic effects of an FMD outbreak in a non-vaccinated population are ascertained. This concerns investigations by, among others, Johnston (1982) for Australia, and by Krystynak and Charlebois (1987) for Canada. These countries are FMD-free and do not vaccinate and are therefore allowed to export meat to countries such as the USA, Japan and South Korea. Because Australia and Canada export a large amount of meat, much attention has been paid in these surveys to the effects on export if an FMD outbreak takes place. In those circumstances the USA, Japan and South Korea close their borders to meat from the countries concerned for a minimum period of one year.
3. Finally, research has been carried out (by, among others, Thieme, 1985) about the optimal strategy for stamping out FMD in countries where the disease occurs endemically (South American countries and countries in the Middle East). As there are few similarities between those countries and the Netherlands, the research in question has not been considered further.

Below, the surveys in group 1 (for three Western European countries) are discussed first. Subsequently, the surveys in group 2 for Australia and Canada, as important meat exporters, are studied in more detail. In the discussion, the emphasis lies on the methodology followed.

2.1 Research for three Western European countries

The United Kingdom

In the study by Power and Harris (1973), the costs and benefits of the current strategy for the control of FMD (the Slaughter Policy) are compared with those of a vaccination policy. One of the reasons for starting this research was the large FMD epidemic (2364 outbreaks) in 1967/1968 in the UK, which caused the authorities to question the strategy which had been applied since 1892 (Power and Harris, 1973, p. 3). The strategies under consideration are as follows:

I. The Slaughter Policy (all measures apply to the situation that arises after an outbreak):
   - immediate slaughter of all susceptible animals on an affected farm;
   - location and slaughter of all animals which have been in contact with affected animals;
   - destruction of carcasses;
   - declaration of an 'affected region' (10 mile radius) and a 'controlled region' (usually a county), with stringent and less stringent restrictions respectively, regarding the transport of animals.

II. The Vaccination Strategy:
   - annual vaccination of cattle, sheep and goats more than three months old with a trivalent vaccine;
   - in the case of an outbreak the same strategy applies as in I. In addition, ring vaccination (5 mile radius) with a monovalent vaccine is implemented.

The basic situation with which both strategies are contrasted is the situation in which FMD occurs endemically in the UK (notably different to other, later, studies). The benefits of both strategies are assessed as the estimated loss for the UK if FMD becomes endemic. This loss consists of the reduction in milk and meat production, increased deaths, and reductions in fertility (Power and Harris, 1973, p. 10). Prices for 1967/1968 are employed here.

In these calculations, as in the calculations of the costs of the strategies, no account has been taken of export losses, nor of supply and demand reactions to the change in price. For the project period 1969-1985 a loss has been calculated for an endemic situation of 1.449 billion pounds sterling (based on 1967/1968 prices and discounted to 1968). This amount is the benefit per strategy.

The costs of both strategies are divided into direct and consequential costs. The estimation of both types of cost is done with the help of the figures for the FMD epidemic of 1967/1968. Power and Harris define direct costs as the costs for public bodies and farms directly affected by the disease. The direct costs of the Slaughter Policy consist of the cost of:
- the valuation of the slaughtered cattle;
- the slaughter and destruction of cattle and the disinfection of farms;
- extra personnel for controls.

A clear definition of the consequential costs is not given. It is however stated that the consequential costs can be measured as the reduction of consumer surplus, or more directly, as the production loss for society as a result of the disease (Power and Harris, 1973, p. 8). The consequential costs of the Slaughter Policy consist of the cost of:
- loss of production factors. To measure this, the compensation paid to the farmers by the government has been used;
- the disturbance to the distributive sector, caused by transport bans. An estimated amount of the rise in consumer spending for meat has been used as an estimate for these costs.

The number of outbreaks under the slaughter policy is estimated on the basis of the number of outbreaks in the period 1901-1967, and amounts to 175 per year. The total discountable costs of the slaughter policy for the project period 1969-1985 amount to 35 million pounds sterling.

With regard to the vaccination strategy, the same costs are identified as with the slaughter policy. The direct costs are considerably higher, because they include vaccination costs. Due to an expected drop in the number of outbreaks under a vaccination strategy compared with a slaughter policy (primary outbreaks would drop by 50% and secondary ones by 90%), the consequential costs drop. For the sake of convenience it is assumed that the consequential costs in a vaccination strategy amount to 25% of the direct costs. The discounted total of the costs under the vaccination strategy amount to 60 million pounds sterling for the project period 1969-1985.

From the results (Power and Harris, 1973, p. 20), it emerges that the implementing of a (preventive and) control strategy against FMD generates an enormous net benefit. It also emerges that the slaughter policy is preferable to the vaccination strategy. Here, Power and Harris stress that the figures must only be seen as an indication, because they are heavily dependent on the assumptions at the basis of the calculations. Furthermore, the authors allege that the difference between slaughter policy and vaccination strategy would be much smaller if non-quantifiable effects were also taken into account. No elucidation of this allegation is provided.

This study is open to some criticism, which can be summarized in two points:

1. The arbitrary character of many of the assumptions. This applies, for instance, to the assumption regarding the drop in the number of outbreaks under vaccination. No foundation for this, or referral to other investigations, is provided. Likewise, there is no sensitivity analysis regarding these assumptions.
2. Methodological errors in the study. The aim of the study was to determine the net economic benefit for society of various strategies. For the determining of benefit, the authors take the output drop as a result of FMD becoming endemic (a very unrealistic situation), against 1967/1968 prices. For the determining of costs, the change in consumer surplus[1] is introduced to measure the national-economic effect. This in itself is inconsistent, but in addition, neither of the two methods is correct. In both cases, no change in producer surplus is provided; neither does the first case provide a change in consumer surplus. Because it is alleged that prices change, changes must also occur in producer and consumer surplus. It is not correct to claim that a production drop is equal to the sum of the change in producer and consumer surplus (as apparently is implicitly suggested in the calculation of the profit).

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[1] Also denoted as consumer profit and consumer advantage.

West Germany

The research by Lorenz (1986) is one of seven surveys carried out in 1986 which were coordinated by an FAO committee. The aim of all the surveys was to make a national cost-benefit analysis of various strategies for the prevention and control of FMD. The co-ordination had particular relevance to the factors which were to be included in the calculations, and to the methodology to be followed for the calculations, and had the aim of making it possible to compare the results of the survey for various countries. The seven countries taking part were West Germany, Finland, Ireland, the Netherlands, Spain, the UK and Switzerland. Of these surveys, only those for West Germany and the Netherlands will be discussed, because they are the most interesting as regards depth and methodology followed.

In the West German study the following two strategies are compared to each other:

I. Annual vaccination of cattle older than 4 months. In case of an outbreak, the slaughter and destruction of all susceptible animals on affected farms, and the applying of ring vaccination (10 km radius);
II. No annual vaccination. In the case of an outbreak, the slaughter and destruction of all susceptible animals on affected farms, and the applying of ring vaccination.

Strategy I is the strategy which has been employed in West Germany since 1967. To compare the strategies, the annual costs for a ten-year period under one strategy have been calculated. Because it is impossible to predict when an outbreak will occur, discounting has not been applied. Costs occurring to the same extent under both strategies have been ignored. An interesting result of this approach is that the costs resulting from an outbreak caused by an exotic virus (not familiar to Western Europe) are left aside. The fact of the matter is that neither a vaccinated (trivalent OCA vaccine) population nor a non-vaccinated population has any resistance to an exotic virus (Lorenz, 1986, p.5).

The number of primary outbreaks in 10 years caused by a virus familiar to Western Europe is, in the most likely situation, estimated at 3 in a vaccinated population and at 1 in a non-vaccinated situation. This estimation is based on a study by Strohmaier and Böhm (1984), which investigates the causes of primary outbreaks in West Germany in the period 1970 to 1984. The expected number of secondary outbreaks totals 4 under strategy I and 30 under strategy II. The costs of an outbreak are subdivided into direct costs and market losses. Direct costs concern the damage caused to farms because they are cleared, and the cost of ring vaccination. Market losses are created by export countries temporarily closing their borders to products from the region where the outbreak has occurred, if not to products from the whole of West Germany. It is supposed that there are two groups of countries, which react in different ways regarding the import of cattle, meat and dairy products from West Germany. The first group follows the 'EC scheme', which according to Lorenz means that no imports are permitted from the affected region (1.5 of the 31 West German districts) for three months. This reaction applies to all EC countries, and to 70% of the export of products to non EC countries. The remaining export countries refuse all West German export for a period of 6 months. The price drop on the domestic market resulting from the temporary surplus, which is of 20-40% (Lorenz, 1986, p. 15), multiplied by the market volume, forms the market loss for products for which there is no intervention system (livestock, cheese). For products for which there is intervention (dairy products), the extra costs of intervention have been included as costs for West Germany. Also included as costs for West Germany is the EC compensation for storage costs and decrease in value of a temporary meat surplus.

The outcome of the calculations is that in the most likely situation following strategy I would cost West Germany between 183 and 227 million German marks. Following strategy II would in the most likely situation cost West Germany between 47 and 61 million German marks (for comparison: the value of West German meat production amounted in 1986 to about 25 billion German marks).

When the study is divided into an epidemiological part and an economic part, it is noticeable that the epidemiological part is well founded. In particular, much attention is paid to the assumptions about the number of primary and secondary outbreaks. It is questionable, however, whether the extrapolation of the number of primary outbreaks in a vaccinated population to a non-vaccinated population (which Strohmaier and Böhm do) is a correct method. The economic part, and in particular the calculation of the market losses, can be heavily criticized, namely:

- The fact that consumer profit from lower prices is nowhere to be found. If it is intended that a national-economic cost-benefit analysis be made, the advantage to consumers must also be presented;
- The price drop from 20% to 40% for products for which there is no intervention system (livestock and cheese) is not supported at all. It is, furthermore, questionable whether cheese would be banned;

- The cost of extra intervention for dairy products is, just as the EC compensation for storage costs and loss in value, borne by all EC states. It is therefore incorrect to charge these costs entirely to West Germany;
- The duration of the reactions of export countries is not justified.

The Netherlands

In the Dutch research (Dijkhuizen, 1989), one of the series coordinated by the FAO, the assessment of export damage as a result of an FMD outbreak is not taken into account. Only the direct costs of an outbreak (such as the cost of the emptying and disinfecting of affected farms, the cost of ring vaccination and the production loss for farms, industry and trade) and the costs of annual vaccination are included in the evaluation of strategies. In the survey, the following 5 strategies are compared:

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

Strategy Ib is the strategy employed in the Netherlands since 1953.

Just as in the West German investigation, the average annual cost is assessed of pursuing a strategy for 10 years. The number of primary outbreaks per 10 years amounts, in the most likely situation, to 2 if annual vaccination occurs, and 1 if no annual vaccination occurs. These figures are based on a survey already mentioned, by Strohmaier and Böhm (1984). A special aspect of this survey is that the outbreaks under the different strategies are simulated with a Markov chain model. This, like the cost calculation, is included in a spreadsheet program on the PC. This approach makes it possible to simulate outbreaks in a simple manner, and to calculate costs in assorted circumstances (as regards herd density, effectiveness of control measures, etc.). In this way it is possible to quantify further the importance of uncertain assumptions.

In the most likely situation, the annual cost of pursuing strategy Ia and Ib amounts to about 25 million guilders. Pursuing strategy IIa costs about 16 million, and pursuing strategy IIb and IIc about 3 million per annum.

The major criticism as regards this study is that the cost-benefit analysis is incomplete, because the consequences of export limits bound to occur following an FMD outbreak are not quantified.

2.2 Research for Australia and Canada

Australia and Canada are countries which have for some time been free of FMD, and which do not apply annual vaccination. They can, therefore, export meat to countries (USA, Japan and South Korea) which have strict regulations regarding the FMD situation in the exporting country (FMD-free, no annual vaccination and no vaccinated animals present). The meat prices on this FMD-free market are structurally higher than on other meat markets (Anonymous, 1988, p. 39). The consequences of an FMD outbreak for Australia or Canada, because of the massive reactions on the FMD-free market, would be considerable. In both countries, it has been attempted to quantify the consequences of an FMD outbreak, under various circumstances, in order to ascertain the optimal control strategy.

Australia

Johnston (1982) calculates the economic consequences for Australia of a number of hypothetical FMD outbreaks under various control strategies. The situations included are:

1. A small outbreak which is instantly suppressed by the slaughter and destruction of 100,000 animals, or 0.03% of the national herd. The export of meat and wool is impossible for one year;
2. A larger outbreak, suppressed by the slaughter and destruction of 1/8 of the national livestock herd and by applying ring vaccination. The export of meat and wool is impossible for 2 years;
3. A sizeable outbreak , suppressed by the slaughter and destruction of 1/4 of the national livestock herd and by applying ring vaccination. The export of meat and wool is impossible for 3 years;

4. An outbreak suppressed, as in 2, by the slaughter and destruction of 1% of the national livestock herd and by the setting-up of a vaccination programme for 1/3 livestock lasting 3 years. The export of meat and wool is impossible for 6 years;
5. An outbreak which, as 3, is suppressed by the slaughter and destruction of 1% of the national livestock herd and by repeated vaccination of half the national livestock herd (4 years). Export is impossible for 7 years;
6. As 5, but vaccination for 5 years. Export is impossible for 8 years;
7. As 5, but with vaccination of 5/8 of the national livestock herd (6 years). Export is impossible for 9 years;
8. As 5, but with vaccination of 3/4 of the national livestock herd (7 years). Export is impossible for 10 years.

In order to be able to compare the economic consequences of the various situations, the costs and benefits over a period of 10 years are calculated and discounted as regards the basic situation in the different years. In the basic situation, export of meat and wool is not possible. An earlier survey (Longmire, Main and Reynolds, 1980) calculates that the cessation of the export of meat and wool would result in a production loss of 3 billion Australian dollars per year for producers (for comparison: the value of meat production in Australia amounted in 1986 to 9 billion Australian dollars). Here it is assumed that the producers would not adapt to the changed situation; in other words the supply would remain the same. In calculating the costs and profits in the various situations, the underlying principle is that if the export of meat and wool is not reintroduced after one year, the farmers adapt their supplies to the situation which has arisen. The adaption is determined with the aid of a linear programming model of the agricultural sector. This means that in all the situations except the first, the agricultural production changes. In the first situation, export recovers after one year, and the profit for year 2 to 10 consists of 3 billion Australian dollars.

The benefits calculated are the benefits for the agricultural sector. The costs for the control of an outbreak are the costs for the agricultural sector and the costs for the government (Johnston, 1982, p.67).

From the results (Johnston, 1982, p.10) it emerges that the difference between capitalized benefits and costs diminishes from one situation to the next. This is self-explanatory when an outbreak lasts longer under the same sort of control strategy (situations 1, 2 and 3 and situations 4, 5, 6, 7 and 8). The costs for control increase and the benefits decrease as time progresses. By a change from a control strategy without repeated vaccination to a strategy with repeated vaccination (such as for example the change from situation 2 to 4) the costs are found to decrease. The benefits decrease more, however, as a result of the longer time for which export is impossible. It follows from this that, for Australia, a control policy without routine vaccination is to be preferred, from an economic point of view, to a strategy with routine vaccination.

A number of points in this study are disputable:

- It is questionable whether the situations with and without routine vaccination can be compared. If, in a comparable outbreak (2 and 4, or 3 and 5) one reverts to a control policy with routine vaccination, the control takes 2 years longer. For this time extension no motivation or reference is given. The extension seems to have been arbitrarily decided.
- Although the impression is given that the survey is concerned with national-economic cost-benefit analysis (Johnson, 1982, p. 8) this is not the case. The difference in consumer income arising if the prices on the domestic market drop or rise are not presented, although it is a national-economic effect.

Canada

Krystynak and Charlebois (1987) have, with an econometric model of the agricultural sector of Canada, calculated how great the economic agricultural loss of two hypothetical FMD outbreaks would be for the agricultural sector of Canada. The calculations have been made for a period of 5 years, in which it is assumed that the outbreak occurs at the beginning of the period. The two alternatives are:

1. A less serious outbreak, resulting in an export ban on Canadian meat for a period of 1 year;
2. A serious outbreak, resulting in an export ban on Canadian meat for a period of 1.5 years.

The adaptions made to the Food and Agricultural Regional Model (FARM) were concerned with:

- the cessation of the Canadian export of cattle and meat for a period of 1 and 1.5 years respectively;

- the cessation of relating Canadian meat prices to those in the USA, so that the prices are only decided by supply and demand on the Canadian market.

The surplus on the domestic market arising after the outbreak is reduced by the model in the very short-term by a strong reduction of meat import and on a long-term basis by the drop in meat production.

The financial loss for the producers, ascertained by running the model with and without outbreaks, amounted to 2 billion Canadian dollars in the situation with the less serious outbreak, and 2.78 billion Canadian dollars in the serious outbreak (for comparison; the value of Canadian meat production in 1986 was 7 billion Canadian dollars). One important note must be made regarding this survey. In the model, the current price is taken as an indication for the future price. It is to this that the producers relate their production. This assumption is not realistic if it can be foreseen that the cause of a low price has a very temporary character. If the outbreak is only very short, as in the case of a less serious outbreak, and if it is known that an export ban will last a year, producers will not only relate production to a temporary low price. A more general question regarding this is whether the FARM model can be used for the calculation of rather extreme situations like an outbreak of FMD. Nevertheless, the use of such a model seems to be of some aid both as regards the formation of ideas and the calculation of the assessment of the consequences relating to FMD strategies.

3 A THEORETICAL BASIS FOR THE CALCULATION OF NATIONAL ECONOMIC EFFECTS

A cost-benefit analysis of a policy or of an event can be done at various levels. The two levels with which the sort of survey mentioned in the last two chapters is usually concerned are the sector and national levels. When a cost-benefit analysis is made for an (for example) agricultural sector, every attention is paid to the costs and benefits for the producers in the sector concerned. If the analysis is made on a national level, it concerns the costs and benefits for all producers, for all consumers and for the government or taxpayers. If, in the cost-benefit analysis, attention is only paid to the effects for producers and the government, and not to the consumer, as in the first four surveys from the previous chapter, an analysis is chosen, deliberately or unintentionally, at a level between sector level and national level. This procedure is legitimate, unless one is intending (as in some of the surveys discussed) to make an analysis at the national level.

In this chapter it is explained from neo-classical economic theory how the effects for producers, consumers and the government can be measured and if, and if so how, the effects can be summed.

3.1 Producers

Starting from the principle that farms strive for maximum profits on competitive markets, the supply curve is the same as the rising part of the marginal cost curve as shown in figure 3.1 (for a derivation see, among others, Just et al, 1982, pp. 48-52). The producer surplus is formed by the profit (area OABC, quantity times price) minus the variable costs (area OABD), and is therefore the hatched area DBC. This surplus can be considered as remuneration for the fixed inputs. If, by a chance occurrence (for instance an autonomous reduction of demand), the price drops from P1 to P2, the amount supplied will also drop. The amount that can be marked as loss for the producers with regard to the original situation is the reduction in profits minus the reduction in variable costs and therefore the decrease in producer surplus (area BCEF).

The slope of the supply curve is dependent on the period for which the curve is valid, and on the type of production. In the very long term, in all kinds of production, even strategic decisions (for example regarding the siting of farm buildings) are current, and the costs relating to that decision form part of the variable costs. The supply curve will in the long term be relatively smooth. In the very short term, when the production plan is determined and all investments have been made, a large proportion of the costs are fixed, and the supply curve will be relatively steep (Koester, 1981, p. 92). The course of the supply curve for periods somewhere in between the very long and very short term depends to a great extent on the type of production. In the case of production where growing processes play a part, as in agriculture, many decisions involving costs must be made before production (the growing process) begins. Because most growing processes in agriculture take some time, the supply curve is rather steep in the short and medium term.

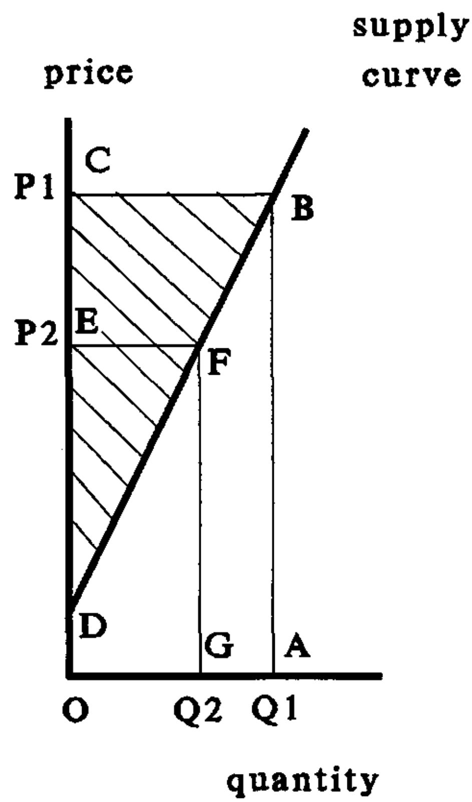

Figure 3.1: Supply curve and producers surplus

With stock raising, production is fixed in the short term. Once, for example, a herd of animals for slaughter has been fattened, they must be put on the market within a certain period. The influence of price fluctuations on marketing time is not large, because particularly marketing them with too high a final weight (some few weeks after the optimum marketing date) is penalized with considerable price reductions (see for a calculation Giesen et al, 1988, supplement 2). The supply curve for meat is therefore vertical in the short term. All costs have the character of fixed costs, i.e. they cannot be changed in the short term.

If, as the result of export bans resulting from a foot-and-mouth outbreak, the price of livestock drops, it is assumed, if in the short term, that the supply does not change through this; in other words the assumed supply curve for meat progresses vertically. For the time being it is assumed that the FMD outbreak can quickly be brought under control by taking adequate measures. (In the case of an endemic situation with long-term drops in price, supply reactions are indeed possible). There will likewise be no supply reactions in the long-term as a result of a short-lived FMD outbreak. This is the result of the assumption that the expected price, which effects planned production, will not be influenced by a short-lived market disturbance.

Because of the concept of the vertical supply curve, the loss for producers resulting from a price drop is determined by the difference in revenue. There is no cost difference, because all costs are assumed to be fixed. Any compensation paid by the government reduces the loss to producers by the amount of the compensation.

3.2 Consumers

By aggregating the demand curves of individual consumers a demand curve emerges for a product (figure 3.2). This curve expresses what proportion of a product will be purchased for a specific price. The slope of the demand curve is among other things dependent on the possibility of substitution by another product and on the extent to which the product has a luxury character.
The consumers pay the amount OABC (price times quantity) for a quantity Q1 (see fig. 3.2). The willingness to pay for the consumption of Q1 equals OABD; the area under the demand curve. This is the aggregate amount individual consumers would spend at maximum for the quantity Q1. The consumer surplus is the difference between the willingness to pay for the consumption of quantity Q1 and the amount paid for the consumption of this quantity. The consumer surplus is defined as the area under the demand curve and above the price line, area BCD (Just et al, 1982, p.72).

If, by some event (e.g. an autonomous price increase) the price of the product drops from P1 to P2, the quantity of demand increases from Q1 to Q2. The advantage of this change to the consumer is then recorded by the increase in the consumer surplus (area BCEF). If, as the result of an export ban following an outbreak, the supply of meat on the domestic market increases and consequently the price drops, the consumers profit with the change of the consumer surplus.

When measuring the effects for the consumer, it is usual to use the Hicks compensated demand curve as a basis. According to a 'normal' demand curve, the increase in the consumer demand resulting from a price drop consists of two components, a price effect and an income effect. The income effect concerns the increase of demand due to the real increase in the income of the consumer. Because the price of one product has dropped, the consumer can buy more with the same income. The Hicks compensated demand curve is corrected for this income effect. The Hicks compensated price elasticity of demand (the effect in % for 1% price increase) is calculated as follows:

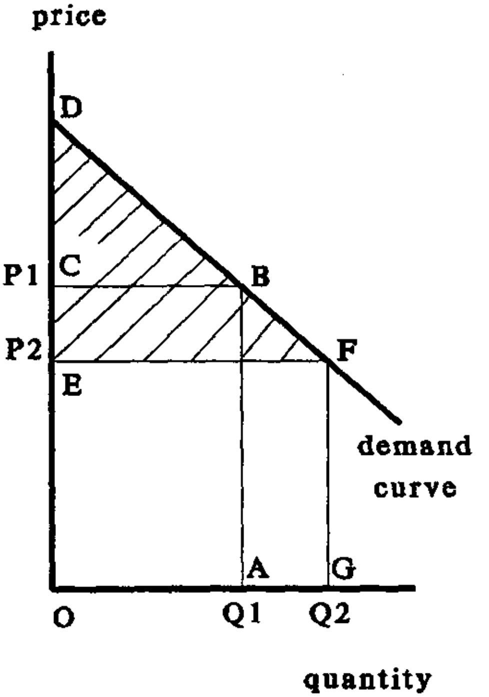

Figure 3.2: Demand curve and comsumers surplus

$$e_i^H = k_i . e_i^I + e_i^M$$

In which:
- e_i^H = Hicks compensated price elasticity of demand
- e_i^I = income elasticity of demand
- e_i^M = normal (Marshall) price elasticity of demand
- k_i = budget part of good i

This equation can be deduced from the so-called Slutsky-equation (Deaton and Muellbauer, 1980, p. 45). Because meat has both a non-fractional income elasticity and a budget part, the distinction between e_i^M and e_i^H is of some importance. Nevertheless, the uncertainty regarding the price elasticity is usually considerably greater than the difference between these two elasticities. For practical calculations it does not therefore matter whether one works from the normal, or the Hicks-compensated price elasticity.

3.3 Government

In the constellation of producers, consumers and government, the government must be seen as the administrator of the government budget. Depending on the definition of the problem, the government can be seen as a regional, a national, or a super-national government. The EC is an example of the latter. Because of the definition of the problem at the beginning of the present survey, the government is considered to be the national government.

Some examples of possible costs for the government as a result of an FMD outbreak are:
- compensation to producers whose animals have to be slaughtered and destroyed;
- cost of carrying out other steps to prevent further spread of FMD (setting up and checking transport bans, ring vaccination);
- an extra contribution to the EC budget for extra expenses for the intervention of meat.

3.4 Aggregation of benefits and costs

Within the theory of welfare economics there is some discussion about the aggregation of benefits and costs at a national level. Simple aggregation of these effects implies that benefits and costs of each group or individual can be compared. Adapting this includes a normative element. The example of a very poor and a very rich person, of whom the first can be assumed to benefit far more than the second from the same amount of extra income, illustrates the objection to this normative character.

Hennipman (1977, p.172) puts forward that an economist is free to apply interpersonal comparisons of benefits and costs providing that it is implicitly stated that the value judgment on which the comparison rests does not stem from economic science. Boadway and Bruce (1984, p.2) put forward that the comparison of different 'social states', in whatever way, is unavoidably a normative procedure. However they do not conclude from this that such a comparison should not be carried out by economists. If the value judgments receive general approval, they consider it legitimate to make comparisons in the light of those value judgments.

A basis is lacking for the use of value judgments resulting in the recognition of the importance of the income changes of the different parties. One possibility is to give the same weight to all effects. From an investigation concerning EC dairy policy in the years 1980-1987, it did, however, emerge that one guilder of producer income was considered about twice as powerful as one guilder of consumer income (Oskam, 1988, p. 48).

There are also arguments calling for the balancing of effects with the same weights. Balancing within the groups of producers and consumers, which are certainly not homogenous, unavoidable because of the calculation methods being employed, can be a reason also to balance the groups to national level. Furthermore, one can put forward that by a slight adjustment to the redistribution of income, the benefits and costs can be compensated.

The above leads to the decision to report the economic effects of different strategies for the prevention and control of FMD as separate effects on producer income, consumer income and government budget and on the balance of this, the national income. In this way more detailed information for the policy makers is also available, which can lead to a better weighing-up of alternatives (Just et al, 1982, p. 13).

4 OUTLINE OF THE RESEARCH AND MODELLING ASSUMPTIONS

A strict division between the delineation of the investigation and the modelling assumptions is difficult to make. A delineation can be an assumption for the model. In the following, all points falling under both categories are considered with the delineation of the investigation, and the implications for the model will also be given.

4.1 Outline of the research

4.1.1 Cost

The costs which will be considered in this research are divisible in costs for prevention and costs resulting from an outbreak.

The only preventive costs which play a role are the costs of the annual routine vaccination of cattle older than 4 months.

Costs with both a preventive and a control character are the apparatus costs. An apparatus is necessary in a co-ordinating and organisational capacity for annual vaccination and to co-ordinate and organise the control of an outbreak. It is assumed that the apparatus costs in situations with and without annual vaccination remain the same. The preventive part of the cost that disappears if vaccination is ceased can for the larger part be compensated by the rise in the apparatus costs for the control of an outbreak. This is because control of an outbreak in an unvaccinated population requires more effort than control of an outbreak in a vaccinated population. Because the apparatus costs are assumed to remain the same in the various alternatives, they are not considered further.

The costs resulting from an outbreak can be divided into direct and indirect costs. Direct costs are costs which immediately arise from an outbreak. This involves:

- costs for the control of an outbreak, i.e.:

  * costs of slaughter and destruction of animals on affected farms and for the disinfection of affected farms;
  * the loss of slaughtered animals;
  * cost of ring vaccination;
- production loss for the emptied farms and for processing firms, caused by the emptying of the emptied farms;
- loss for market and processing caused by transport bans.

Indirect costs are costs which arise as a result of reactions from other countries to an outbreak in the Netherlands. By reactions one understands here the temporary closure of borders to certain Dutch products, for the prevention of the spread of the virus. A possible consequence of export bans is that a surplus of certain Dutch products collects. The price drop which can result from this leads to a loss for producers and a profit for consumers. If the surplus concerns an intervention product, extra intervention is possible. In that case the EC costs of intervention rise and also the Dutch contribution to the EC budget. This increase also falls under the indirect costs of an outbreak.

By indirect costs, in short, the financial consequences are meant for producers, consumers and government of border closures by other countries.

4.1.2 Benefits

The benefits considered in this survey, and which can arise from following a particular strategy, are the extra profits for producers if these products can be put on an FMD-free market. The most significant demand on this market is from the US, Japan and South Korea. The most significant suppliers are Australia and New Zealand. On this market, about 2.1 million tons of meat were sold in 1986, which is equal to about 19% of the world market in meat (FAO, 1987a, pp. 54, 72 and 78). The meat prices on this market are structurally higher than on markets where meat is sold that comes from countries which cannot be considered as FMD-free (Anonymus, 1988, p.39), i.e. countries where FMD is endemic and countries which apply routine vaccination against FMD. If the Netherlands stop annual vaccination, there is a possibility that a proportion of the Dutch meat export can be transferred to the FMD-free market. The product of that quantity and the price difference are the benefits of following the strategies not including annual vaccination. Here it is assumed that the Netherlands are part of the FMD-free market. This means that the price does not change as a result of the relatively small supply from the Netherlands. If other EC countries stop vaccinating at the same time as the Netherlands, and all those countries put meat on the FMD-free market, it then depends on the supply increase on the FMD-free market whether the above assumption still applies. If the supply increase is substantial with regard to the amount already sold on the FMD-free market, the price on this market will go down.

4.1.3 Supply

In calculating the effects of an outbreak it is assumed that the supply of agricultural products, both on the domestic market and abroad, does not change. In most situations a change in price results in supply (and demand) changes. In the case of an outbreak of FMD the price change is very likely only to have a temporary effect; producers anticipate that prices will recover. Adaption to this price change, other than by extending the time of marketing of livestock, will not therefore occur. In this survey it is assumed that the supply remains constantly at the same level.

4.1.4 Strategies

In the survey, the following preventive and control strategies are compared:

I. Annual vaccination of the cattle population. In case of an outbreak:
   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 outbreak:
   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.

Regarding strategy IIb, it must be said that the feasibility is disputable. The opposition both from the producer and public opinion in general to the slaughter of animals on apparently healthy farms would probably be considerable. In order to assess whether the defence of such a method is worthwhile, the strategy will nevertheless be included in the model calculations.

The strategies to be evaluated are fixed in the computer model. This means that any new prevention and control method cannot be calculated without adjustment of the current model.

4.1.5 Products at issue in an outbreak of FMD

From the figures available concerning FMD outbreaks in Denmark (1982 and 1983), the Netherlands (1983 and 1984), Italy (1986 and 1987), and West Germany (1987 and 1988), the following can be concluded regarding the response from other countries:

Countries within the EC

Almost all reactions from countries within the EC concern the export of cattle, fresh meat and meat products. This always entails cattle, pigs, sheep and goats. The only exceptions found concern the ban by Greece and Denmark on the import of dairy products from the regions declared affected in the Netherlands during the FMD outbreaks in the provice of Flevoland and in the province of North Holland in 1984.

Countries outside the EC

The majority of these reactions also concerns cattle, fresh meat and meat products (in a limited way also poultry, poultry meat and poultry meat products). There are in addition the occasional reactions (from several countries) regarding a number of animal products such as dairy products, hides, fats, intestines, wool and hair, and regarding cattle and animal feed. Finally, Finland has once forbidden the import of fruit, and turnip and carrot plants (from Denmark), and Norway has once forbidden the import of plants with soil, potatoes, and vegetables with soil (from the Netherlands).

Dairy products

Of the products which have at any time been banned, dairy products are budget-wise the most important. Table 4.1 shows the export of dairy products to different destinations.

As regards the export figures for butter and skimmed milk powder, it must be mentioned that intervention products are concerned here, which are sold outside the EC with considerable export refund. Thus 90% of the butter export to group 2 consists of sales to the USSR (special sale arrangement) and 90% of the export of skimmed milk powder to group 2 consists of sales to Algeria.

Table 4.1: Export of dairy products in 1987 (x 1000 kg) with percentages in brackets[2].

	total export	group 1	group 2	group 3
Whole milk	2,171	990 (46)	672 (31)	509 (23)
Skimmed milk	5,269	5,071 (96)	198 (4)	0 (0)
Beverages made from or with milk	15,080	13,110 (87)	1,970 (13)	0 (0)
Butter	271,434	145,930 (54)	125,219 (46)	285 (0)
Butteroil	121,212	95,259 (79)	22,866 (19)	3,078 (2)
Cheese	382,662	370,629 (97)	11656 (3)	377 (0)
Condensed milk	409,045	320,002 (78)	86,140 (21)	2,903 (1)
Whole milk powder	250,000	200,210 (80)	45,170 (18)	4,809 (2)
Skimmed milk powder	154,000	97,356 (63)	50,679 (33)	5,965 (4)
Preserved whey	87,355	82,693 (95)	4,633 (5)	29 (0)
Prepared milk powder	66,031	58,713 (89)	6,590 (10)	728 (1)

Source: Commodity Board for Dairy Products, Annual Statistical Report 1987

Group 1: Remaining group (under which most EC member states)
Group 2: Greece, Denmark, Bulgaria, Norway, USSR, Algeria, South Africa
Group 3: Cyprus, Malaysia, Singapore, Nicaragua

The greater part of Dutch dairy export goes to countries in group 1 which, regarding a number of infectious animal diseases including FMD, demand that the milk from which the products is derived should not come from

[2] This table does not give the figures for casein. The sole Dutch producer keeps production and export figures secret.

farms affected, or recently affected. Because affected farms are emptied it is easy to meet this demand. Reactions from these countries regarding dairy products in the case of an outbreak of FMD can be disregarded.

A small part of Dutch dairy export goes to the countries of group 2, which demand that the milk should not originate from an affected region. An area with a radius of 10 km. round the affected farm appears to be accepted by many of these countries. Because this demand led to export restrictions after the outbreak in the Netherlands in 1983-1984, the Commodity Board for Dairy Products, after discussion with the parties concerned, drew up the 'Zuivelverordening 1984, Kanalisatie van melk afkomstig uit bepaalde gebieden' (this is the canalisation regulation). This regulation gives the chairman of this organisation the power to take steps for the channeling of milk from an area for which steps have been taken as set down in article 20d of the livestock law. By this, there is the possibility that buyers can be given the guarantee that the milk with which certain dairy products have been made does not originate from a certain region.

A very small proportion of dairy export goes to the countries of group 3, which demand that the land of origin must, for a certain period (usually one year), have been free of certain animal diseases. This demand naturally cannot be met during an outbreak. Annual vaccination is not seen as a problem by these countries.

With respect to the group divisions and the dairy products, it must still be mentioned that some countries from group 2 (e.g. Norway) do, with regard to the import of dairy products from the Netherlands after an FMD outbreak, make an exception for cheese. However, due to the manufacturing process for cheese, the chance of spreading the virus via the export of cheese is nil (Böhm, 1982, pp. 68-72).

From the above it is clear that, with the canalization regulation for dairy products, the loss from export limitations regarding dairy products is not very serious. The (slight) quantity of dairy products which are exported to countries in group 3 can according to the Commodity Board for Dairy Products be placed temporarily on other markets. This, added to the fact that, with major dairy companies (Coberco, Campina) and the Commodity Board for Dairy Products, one sees within the quota regulation hardly any expansion of marketing possibilities, makes it sensible to leave dairy products aside from consideration.

Other products

Because of the minor significance of the export of other products mentioned (hides, fats, etc.) which are in incidental cases refused, it is logical to exclude these products. Not only do these products represent a trifling export value compared to cattle and meat, but export bans are only occasionally applied to these products.

The products for which the consequences of export limitations are calculated are therefore meat, meat products and livestock.

4.2 Modelling Approaches

4.2.1 Division of the Netherlands into three regions

In order to be able to determine the difference in effect between outbreaks in regions with different herd densities, the Netherlands have been divided up in the model into three regions. These are:

1. North and West Netherlands, consisting of Groningen, Friesland, Drenthe, Flevoland, Utrecht, North Holland, South Holland and Zeeland (low herd density);
2. East Netherlands, consisting of Gelderland and Overijssel (average herd density);
3. South Netherlands, consisting of North Brabant and Limburg (high herd density).

With the input for the model it must be stated in which of the three regions the outbreak takes place.

4.2.2 Reactions to an FMD outbreak

Regarding the procedure of the EC partners, the Permanent Veterinary Committee (PVC) and the EC Commission in the case of an FMD outbreak in a member state, the following has become clear regarding outbreaks in Denmark, the Netherlands, Italy and West Germany. If there is an FMD outbreak in a member state, this member state at least takes steps conforming to the EC principles to prevent spread. The EC Commission and the other member states are informed of the outbreak and the steps taken. At the same time, other member states can take steps on an individual basis (export bans for certain products). If these steps, in the view of the first member state, are too draconic, or if the steps taken by the first member state are insufficient in the view of one or more other member states, then it can be requested that a meeting of the PVC be called as soon as possible to discuss the situation and the measures. If all are satisfied with the measures taken, the situation and the measures are discussed at the next regular PVC meeting. At the PVC meeting it is attempted to draw up advice regarding a resolution applying to the stating of a rule by the Commission regarding the FMD outbreak. If there is no agreement reached on the advice, the resolution is put, with no advice, to the Commission, who puts it to the Council for the taking of a decision. If an agreement is reached regarding the resolution, the Commission, without consulting the Council, passes the resolution. In the resolution, a minimal of the following is determined:

- A ban for the member state with FMD on the export of certain products from a certain part of the country to other member states;
- The conditions under which the ban will be lifted;
- The obligation for other member states to withdraw import measures already made.

The above implies that it can occur that a country has two provisional, differing reactions. In the model the reaction(s) of each market with respect to each product must be specified. Per reaction (export ban) the following must be stated:

- Does the export ban apply to the relevant product from the whole of the Netherlands, or only from the region of the Netherlands declared affected;
- Is the duration of the border closure related to the first (primary) outbreak or to the latest (secondary) outbreak. If provisionally only one reaction takes place, the duration will always be related to the latest outbreak. If two reactions take place, it is possible that the first reaction lasts a fixed number of weeks (related to the first outbreak). The duration of the second reaction will then be related to the latest outbreak;
- Is the reaction 100% certain or not. It has been made possible in the model to work with uncertain reactions. If all reactions regarding a single product are stated, then, if there are uncertain reactions, the

likelihood of these arising per combination of uncertain reactions must be stated.

4.2.3 Intervention

The model has included the possibility of applying EC intervention in a situation in which a surplus of a product exists on the domestic market. Regarding meat, there are two potential possibilities for intervention during an outbreak:

- There can be regular intervention. Regular intervention is only possible for beef (which comes from a region declared unaffected) and is enforced if a number of conditions (namely regarding meat prices in member states) are met. For the model it must be stated whether regular intervention is or is not applied during the outbreak period;
- If an outbreak is of long duration, a special EC intervention regulation can be brought in for meat from the region declared affected. During a long outbreak in Italy in 1986-1987 such a regulation was brought in. In the model, the possibility has been included to take account of such a regulation. For this it must be stated:
  * How many weeks after the first outbreak the regulation is brought in;
  * Whether or not a maximum has been set regarding the amount of products to be intervened. If that is so, the amount must be stated;
  * Whether this form of intervention is limited to a certain period. If this is so, it must be stated whether the end of this period is related to the date of the first outbreak (an absolute period) or to the date of the latest outbreak (a relative period). Also, it must be stated how long the period lasts.

For each form of intervention, the intervention price must be given.

5 Model Description

The model developed for this research consists of four parts (see the flow chart in Figure 5.1):
- the epidemiological model;
- the disease control model;
- the export model;
- the integrating part.

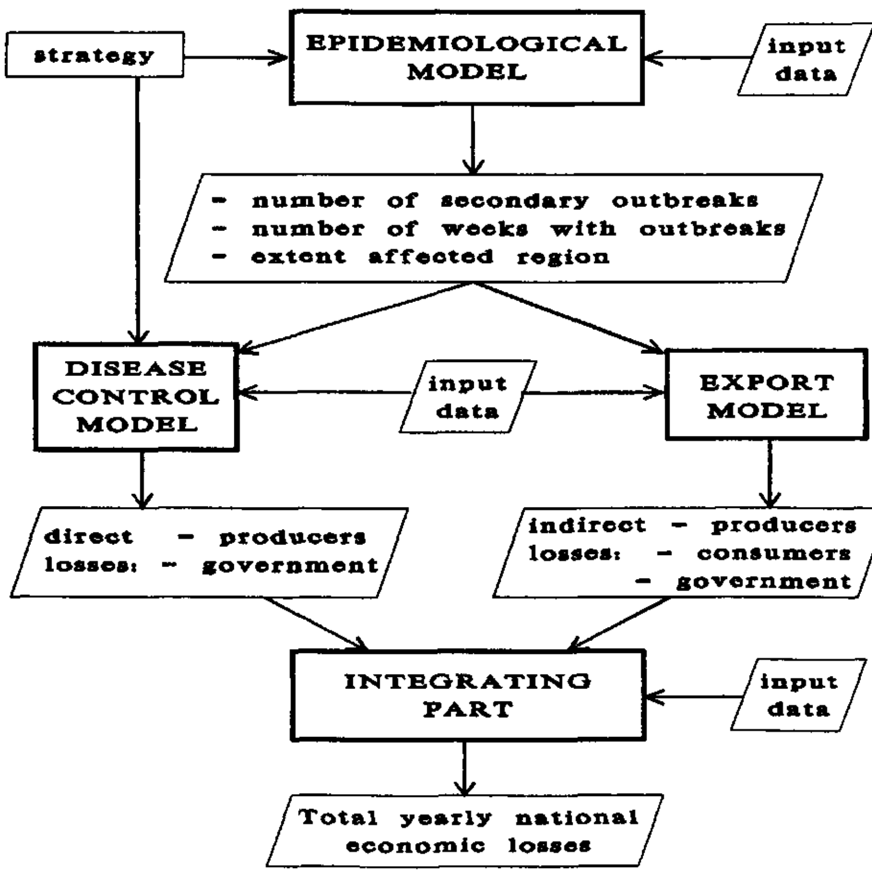

Figure 5.1: An overview of the model

For each of the strategies under consideration the annual costs of following that specific strategy are calculated using the three models and the integrating part:

- In the epidemiological model one primary outbreak is simulated, using the control strategy under consideration and taking into account disease specific input values and demographic data. Both in this model and in the export model the time unit used is one week. Relevant output to be used for further - economic - calculations concerns the number of secondary outbreaks that follow a primary outbreak, the number of weeks with outbreaks, and the part of the region that is regarded as affected.
- Subsequently, the two economic models are being started: (1) the disease control model, that calculates the direct losses for producers and government, and (2) the export model, calculating the indirect losses for producers, consumers and government. The disease control model asks for additional input data on the costs of ring vaccination, the costs of stamping out and the costs of idle production factors for farmers and industry. For the export model a specification is required of (a) the products affected by trade embargoes, (b) the markets to which these products are delivered, and (c) the actual reactions on these markets.
- Finally, the integrating part is used to quantify the yearly national economic losses of following the specific strategy, combining the direct and indirect financial losses. For these calculations additional input is required on: (1) the number of primary outbreaks to be expected per 10 years, (2) the costs of yearly routine vaccination, and (3) the price premium for the products under consideration of getting access to FMD-free markets.

After this calculation cycle has been made for all strategies, results of the strategies can be compared. The base against which the results must be interpreted is the situation in which no costs are made for the prevention of FMD and in which outbreaks of FMD do not occur. On this basis, there is by assumption no export of products to any FMD-free market.

In the rest of this chapter, the epidemiological model, the disease control model, the export model, and the integrating part will be discussed in succession.

5.1 The epidemiological model

To simulate the spread of the disease, the state transition approach is used (Miller, 1979; for an explanation see also Dijkhuizen, 1989, p.1). 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 of the previous period of time and the transition probability between states (Carpenter, 1988a, p. 170).

To simulate an FMD outbreak, the elements are formed by the cattle and pig farms. The separate states in which the (animals on the) farms are found, and the transitions between the states, are illustrated in table 5.1.

Table 5.1: The separate states and transitions in the epidemiological model.

From: / To:	susceptible	infectious	immune	removed
susceptible	remaining susceptible	infection	effective vaccination	'contact' slaughter
infectious	-[1]	-	-	'outbreak' slaughter
immune	-	-	remaining immune	-
removed	restocking	-	-	remaining removed

[1] - indicates an unimportant or impossible pathway.

In the first type of Markov chain model, the transition probability is fixed. This means that an autonomous process takes place, in which during the process there is no exterior influence possible (Carpenter, 1988a, p.170). This assumption is unrealistic if it applies to an FMD outbreak. In an FMD outbreak, the spread decreases during the outbreak by the introduction of transport bans because farmers are more careful when visiting other farms. The spread (the transition probability from susceptible to infectious) is therefore simulated in a dynamic way (Carpenter 1988b, pp. 160-163). 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);

$$pi_j = 1 - e^{-dr_{(j-1)} \times fi_{(j-1)}}$$

The dissemination rate represents the average number of farms to which the virus is spread by one affected farm, whatever the status of those farms. Whether the virus also strikes depends on the status of each farm. The size of the dissemination rate depends on factors such as herd density, the transfer of animals 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 care by the farmers (Miller, 1979, p.62).

The preventive and control strategies work in different ways in the spread of FMD. Preventive vaccination reduces the fraction of susceptible farms, so that with any control strategy fewer farms will become affected in the case of an outbreak than in a non-vaccinated population.

The slaughter and removal of all animals on affected farms means from a model point of view that farms affected in a particular week will be emptied in the next week (the transition probability therefore equals 1).

The application of effective ring vaccination means that the farms outside the ring are protected from the spread of the virus. These farms go in two steps (phased transition from the group of farms) from the state 'susceptible' to the state 'immune'. The farms outside the ring are not immune in the real sense of the word, but they are considered immune by the model because they are protected by the ring vaccination.

The slaughter and destruction on serious contact farms is represented in the model by the assumption that a specified proportion of the potential outbreaks per week do not occur, because a number of susceptible farms, that could possibly be affected because of risky contacts, have been emptied. This means that the probability of going from susceptible to affected becomes smaller and that the probability of going from susceptible to emptied gets a value greater than nil (for all strategies other than strategy IIb this chance is nil).

After an outbreak has been simulated in a region, the last item to be determined in the epidemiological model is which percentage of the region concerned must be considered to be affected each week. When the first outbreak occurs, it is assumed in the model that a circular area with a radius of 25 km. round the first outbreak should be considered to be affected. To determine the affected region, two approaches can in principle be used. The region affected can be related to the number of outbreaks occurring, or to the period of time for which the total outbreaks last. For the time being the latter possibility has been chosen for the model. It is assumed that, as long as an outbreak lasts, the affected region increases every five weeks by half of the region affected in week 1.

5.2 The disease control model

Given the simulated outbreak and the control strategy under consideration, the disease control model calculates the direct costs for producers and government.

Depending on the control strategy, the direct costs of an outbreak can consist of:
- cost of ring vaccination;
- cost of stamping out.

The costs of ring vaccination are the product of the number of farms in the ring vaccination area and the vaccination costs per farm. The vaccination costs per farm are partly fixed and for the other part dependent on the number of animals to be vaccinated on the farm. The costs are reduced because the EC subsidizes a ring vaccination.

The costs of stamping out consist of:
1. the value of the slaughtered and destroyed animals;
2. the cost of evaluation, transport, disinfection, etc.;
3. the loss of income during the time affected farms are empty;
4. loss of income in trade and industry;
5. incidental costs on cattle and pig farms.

The first two cost items concern a fixed amount per farm. These are costs for the government because farmers are compensated by the government for slaughtered animals. The costs for the government are reduced because of an EC subsidy on stamping out.

The last three cost items are losses for producers.

5.3 The export model

The export model is product-oriented. This means that the effects of export bans for producers, consumers and government are calculated per single product. After the effects have been calculated for all products, they are summed.

To calculate the effects, it must be stated per product that is affected by export bans after an outbreak whether it is possible to put that product on an FMD-free market if annual vaccination is ceased. In that case, the market structure of the product is dependent on the strategy followed. Then it must be stated whether the reactions of the FMD-free market to an outbreak are different depending whether, during control, ring vaccination has or has not been applied. There are indications that some countries of the FMD-free market close their borders to certain products for a longer time for certain products when ring vaccination has been applied for the control of an outbreak.

Next, the following must be entered per product:

1. per marketing structure, specifications which describe the marketing structure;
2. per marketing structure (and possibly per control method if annual vaccination does not occur) the reactions of export markets to an FMD outbreak;
3. any intervention possibilities.

The specifications describing a marking structure consist of:

- the number of export markets specified;
- the price per single product on the domestic market;
- the sale (volume) per export market;
- the import (volume) on the domestic market;
- the price elasticity of demand per market;
- the consumption (volume) per market;

- the transport costs per single product per market;
- any price premium on an FMD-free market;

With these data, the reactions, the intervention possibilities and the data describing the outbreak, the economic effects of export bans are calculated. The precise method of calculation is described extensively in the appendix.

5.4 The integrating part

In the integrating part the annual costs of following a strategy for a period of 10 years are determined.

For this purpose the following costs and benefits are calculated:
- the national economic losses as a result of one primary outbreak. This is the sum of direct and indirect costs;
- the benefits per year of any supply to an FMD-free market in a period without outbreaks. These benefits are the product of the amount of product that is supplied to the FMD-free market and the price premium;
- the costs of annual vaccination. These costs are the product of the number of cattle farms that are vaccinated and the costs per average farm. The costs per farm are partly set and for the rest dependent on the number of animals to be vaccinated on the farm.

The total outbreak costs over a period of 10 years are the product of expected number of primary outbreaks per 10 years and the sum of direct and indirect costs per outbreak. The average annual costs are the sum of average outbreak costs per year (total outbreak costs/10) and annual vaccination costs minus any benefits per year due to the export of goods to an FMD-free market.

6 Input data

In this chapter, the input data are explained for the calculations for which the results are stated in chapter 7. For reasons of availability and uniformity 1986 has been chosen as basis year for all data. The same division as that used in chapter 5 can also be used here. The input data can be split into input data for;

- the epidemiological model;
- the disease control model;
- the export model;
- the integrating part.

6.1 Input data for the epidemiological model

The input data for the epidemiological model consist of a description of:

- the regions;
- the spread of the disease;
- the control strategies.

Data which describe the three regions

Table 6.1: Demographical data per region and for the total country.

	north and west	east	south	total
Total area of the region (x 1000km^2)	21	9	7.3	37.3
Number of farms (x 1000):				
- cattle farms	39.4	17	13.6	70
- pig farms	3.9	12.6	18.5	35
Number of animals (x 1 mln.):				
- dairy cows	0.9	0.85	0.5	2.25
- other cattle	1.1	1.05	0.7	2.85
- sows	0.2	0.55	0.8	1.55
- piglets	0.5	1.7	2.5	4.7
- fattening pigs	0.8	2.6	3.8	7.2

Source: CBS Agricultural Countings 1986 and LEI Agricultural Data 1987

For reasons of a more accurate simulation of an FMD-outbreak the Netherlands is split up in three regions with different animal density. The northern and western part consists of the provinces Groningen, Friesland, Drente, Flevoland, Utrecht, North Holland, South Holland and Zeeland, the eastern part consists of the provinces Gelderland and Overijssel, and the southern part consists of the provinces North Brabant and Limburg. Table 6.1 gives a summary of the input data per region.

Data which express the spread of the disease

The data expressing the spread of the disease, and those describing the control strategies, originate from the investigation by Dijkhuizen et al. (1986, appendix 1).

If a primary outbreak has occurred, the following factors are of importance for the spread of the disease:
- the number of susceptible farms in the basic situation;
- the dissemination rate.

The percentage of susceptible farms in a vaccinated and in an unvaccinated population does not depend on the region. It is assumed that in an unvaccinated population 100% of the pig farms and 100% of the cattle farms are susceptible. If routine vaccination is applied, it is only applied to cattle older than 4 months. In a vaccinated population it is therefore assumed that 100% of the pig farms and 15% of the cattle farms are susceptible.

The dissemination rate (the average number of farms to which the virus is spread by one affected farm) decreases during the time that an outbreak lasts, because of transport bans and because producers are more careful regarding visiting other farms. The dissemination rate also depends on the density of farms in the region where the outbreak occurs. Regarding the spread of the virus by air it is logical to linearlink spread and density of farms. Regarding spread by contacts between producers, the nature of the link between spread and farm density is probably less than linear. This leads to the following estimations as regards the dissemination rates for the different regions (see also Table 6.2):

- in the region with average herd density (region 2) the dissemination rates used in the research by Dijkhuizen et al. (1986) are assumed valid;
- in the region with low herd density (about 1/3 lower than in the average region) the dissemination rates are 1/6 lower than in region 2;
- in the region with high herd density (about 1/3 higher than in the average region) the dissemination rates are 1/6 higher than in region 2.

Table 6.2. The dissemination rate per region and per week.

	region 1	region 2	region 3
week 1	3.8	4.5	5.3
week 2	2.3	2.7	3.2
week 3	1.8	2.2	2.6
week 4	1.4	1.7	1.9
week 5	1.0	1.2	1.4
week 6 and further	0.7	0.8	0.9

-- *Data which express the working of the control strategies*

For each control strategy it applies that:
- a farm that is struck by the primary outbreak is emptied after 10 days;
- farms that suffer from secondary outbreaks are emptied within a week;
- re-stocking of farms takes place after 8 weeks.

Most strategies contain additional measures to avoid spread of the disease. Below is stated, per control strategy, what the additional measures are and what any effect of the strategy is on the number of affected farms (see page 23 for a description of the strategies).

I. Vaccinated population:
   a. no additional measures;
   b. ring vaccination as an additional measure. The vaccination starts in week 3. The radius of the ring is 25 km. To get an effective vaccination, pig farms are revaccinated after two weeks. The percentages of cattle and pig farms that are assumed to be protected in the weeks following the vaccination are given in table 6.3;

II. Non-vaccinated population:
  a. no additional measures;
  b. removing herds on contact farms as an additional measure. Following this measure it is assumed that the number of risky contacts per affected farm, and as a result of that the number of secondary outbreaks, will diminish by 50%. The assumed number of risky contacts per affected farm per week are given in table 6.3;
  c. as Ib. Under this strategy pig farms and cattle farms are revaccinated after two weeks.

The percentage of pig farms, protected after a ring vaccination is the same both in a vaccinated and in a non-vaccinated population. This is the implication of the assumption that pigs never get a routine vaccination.

Table 6.3: Percentages of farms protected per week after a ring vaccination and the numbers of risky contacts per affected herd per week.

	percentage of cattle farms protected		percentage of pig farms protected	number of risky contacts per affected farm
	vaccinated population	non-vacc. population		
week 1	-	-	-	3
week 2	-	-	-	3
week 3	-	-	-	1
week 4	-	-	-	1
week 5	85	50	50	1
week 6	95	80	80	1
week 7 and further	95	90	90	1

6.2 Input data for the disease control model

All data needed here refer to the costs of different control programs. The data summarized in table 6.4 concern cost elements of (ring)vaccination, cost elements of stamping out, and information about EC subsidy on different control programmes. All data in table 6.4 originate from the research project carried out by Dijkhuizen, Smak, Terpstra and Van der Valk and mentioned in chapter 2 (page 12-13).

Table 6.4: Input values used in the disease control model

Cost elements of vaccination:	
- Vaccine costs per dose (Dfl.)	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

Source: Dijkhuizen, 1989, p.6.

6.3 Input data for the export model

As indicated in paragraph 4.1.5, the consequences for meat and for livestock of export restrictions are calculated.

Because it cannot be expected that reactions regarding different types of meat (beef, pork, veal, mutton, goat meat and meat products) will differ, all types of meat have been brought under one group.

The category of livestock consists of cattle for slaughter and cattle for breeding. When live cattle for slaughter can temporarily no longer be exported due to export restrictions, slaughter will often take place in the Netherlands. The meat can then be exported or stored. The problem then arising for the export model handling is that the export of live cattle changes to the export of meat. Because shifts between products in the model are not possible and because the demand for cattle for slaughter strongly depends on the demand for meat, it has been decided to convert live cattle for slaughter to meat. Therefore the category live cattle only includes cattle for breeding. In this way the problem of the shift from cattle for slaughter to meat is resolved. Below, the input data will be discussed per product.

6.3.1 Meat

The data to be entered are data which describe the markets, reactions and intervention.

Market data

For meat it is assumed that if the Netherlands cease their annual vaccination against FMD they can be allowed into the FMD-free market. This means that the data must be entered for two market structures. The data for the market structure if annual vaccination is applied are given in table 6.5.

The share of the each region in the Dutch meat production is determined as follows. The average meat production per beef head is determined by the total Dutch beef production (including export animals for slaughter) divided by the number of cattle. In the same way the meat production is also determined per veal calf, per pig and per sheep/goat. Multiplying these average weights by the number of animals in each category per region (see table 6.1) and finding the sum of all categories gives the meat production per region. By dividing the meat production per region by the total meat production the share per region is determined.

Table 6.5: 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					

1) Sources: EC Statistical Yearbook 1986 and FAO Production Yearbook 1986
2) Sources: EC Statistical Yearbook 1986, EXMIS-data (LEI), PVV Annual Statistical Report 1986 and Agricultural Data 1988
3) Sources: EC Statistical Yearbook 1986 and Agricultural Data 1988
4) Source: Caspari et al. (1980, p.124)

The expression homogeneity is explained extensively in appendix A. The values taken are rough estimations based on geographical information about the market and on the composition of the product exported.

The domestic price is determined by dividing the production value of meat by the produced amount (Agricultural Data 1988, pp.180, 184)

The distortion costs resemble the costs that arise as a result of measures to ban imports of product from the region that is considered to be affected. Exports to markets that take this measure can still be continued but the part of the exports to these markets that originated from the affected region has to be exported from another region. This means that the export pattern gets distorted. The costs of this shift of export are a rough estimation.

To estimate the store costs of meat, the costs which the EC charges for the storage of intervened meat have been used (Sixteenth Financial Report EOGFL, 1987, p.82).

In table 6.6. the data are shown for the market structure if annual vaccination no longer takes place.

Table 6.6: 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

Sources: see Table 6.5.

Comparison of table 6.6 with table 6.5 indicates that the division of export between EC and non-EC countries has not changed. What has changed is the division of export on the non-EC market. It is assumed that the Netherlands can eventually put 1-2% of beef export and 10 to 15% of pork export on the FMD-free market (verbal information Coveco). It is also assumed that the meat price on the FMD-free market is 10% higher than on the other markets. The price premium amounts accordingly to 490 guilders/ton.

Reaction data

In tables 6.7 and 6.8 the reactions of the export countries are shown to an FMD outbreak in the Netherlands.

Table 6.7 shows the reactions if annual vaccination in the Netherlands is continued.

Table 6.7: Export ban after an FMD outbreak with respect to meat in the situation with yearly vaccination.

	EC			non-EC	
Strategy	FRG, B & L	Fr.&It.	rest EC	M&S.America	rest
Ia en Ib	till 4 weeks after last outbreak, infected region	first 2 weeks entire area of the Neth., after that as FRG,B&L	like FRG, Be.& Lu.	till 52 weeks after the last outbreak entire area of the Neth.	till 4 weeks after last outbreak, entire area of the Neth.

The reactions in this situation have been based on the reactions to the outbreak which occurred in the Netherlands in 1983-1984 in Eastern Flevoland and in North Holland. The reaction within the EC, that meat was refused from the region declared affected until 4 weeks after the last outbreak is considered the norm by most member states. In 1983 France and Italy decided to refuse all meat from the Netherlands in the short period (2 weeks) before the member states agreed about measures in the Permanent Veterinary Committee. After that, these countries conformed to the community viewpoint. The Central and South American countries, largely under pressure from the U.S., refused imports of meat from the whole of the Netherlands until a year after the last outbreak took place.

The remainder, consisting largely of African countries, refused the import of meat from the whole of the Netherlands until 4 weeks after the last outbreak.

In table 6.7 and 6.8 non-vaccinating EC countries (such as the UK and Denmark) do not form a separate group, although they may react differently to an outbreak in the Netherlands. At the moment there is no necessity to see non-vaccinating EC countries as a separate group because the export of meat (and breeding cattle) to these countries is almost zero. After 1992 all EC-members will be non-vaccinating countries.

Table 6.8. shows the reactions of export countries regarding meat, in which it is assumed that the Netherlands no longer practices annual vaccination.

Table 6.8 Export ban after an FMD outbreak with respect to meat in a situation without annual vaccination in the Netherlands.

	EC			non-EC	
Strategy	FRG, B & L	Fr.&It.	rest EC	FMD-free	rest
IIa en IIb	till 4 weeks after last outbreak, infected region	first 2 weeks entire area of the Neth., after that as FRG,B&L	as FRG, B & L	till 52 weeks after the last outbreak entire area of the Neth.	till 4 weeks after last outbreak, entire area of the Neth.
IIc	ditto	ditto	ditto	till 104 weeks after last outbreak, entire area of the Neth.	ditto

Countries within the EC are not allowed to extend their reaction under the present EC-legislation as far as meat is concerned. Some countries could be willing to do so if they themselves also cease annual vaccination. The reactions on the FMD-free market are determined from the earlier described investigations by Johnston (1982) and by Krystynak and Charlebois (1987). The duration of the reaction depends on the application of a ring vaccination to control the outbreak. The reaction lasts a year longer than when no ring vaccination is used. Other reactions do not change.

Intervention data

In the basic situation it is assumed that, during the outbreaks, no intervention of meat takes place in any form. To determine the effect of intervention measures, some calculations will later be made in which intervention is possible.

6.3.2 Cattle for breeding

Compared to the export of meat, the export of cattle for breeding is of minor importance (value of export cattle for breeding in 1986: 35 million, value of export of meat (incl. live cattle for slaughter) in 1986: ca. 7.5. billion, PVV Annual Statistical Report 1986). Within the category of cattle for breeding, consisting of cattle and pigs, the export of pigs for breeding is slight compared to the export of cattle for breeding. Because of the only very slight significance of the export of pigs for breeding it has been decided only to include cattle in the category animals for breeding.

For animals for breeding, market data and reaction data must be entered into the model. Intervention for live cattle is not possible.

Market data

For animals for breeding it is assumed that, if vaccination is ceased, none can be placed on an FMD-free market. These markets are placed so far away, and the Netherlands have in the field of animals for breeding so little new to offer on these markets, that putting them on this market will remain limited to incidental occasions. Table 6.9 shows the market data for animals for breeding.

The production share of the different regions is taken as the same as the ratio between the number of cattle per region and the total number of cattle in the Netherlands.

The net retainment costs are the calculated costs minus any benefits made by retaining an animal for a period of one week.

Table 6.9: Assumed market structure cattle for breeding (1986) in a situation with and without yearly vaccination.

	EC		non-EC	
	Neth.	rest	Africa	Middle East
demand (nrs./week)	10000	20000	10000	5000
export Nl.(nrs./week)	-	58	155	61
part of national production (in %) of:				
- N. and W. Netherlands	40			
- E. Netherlands	37			
- S. Netherlands	23			
import Nl. (nr./week)	23			
price elasticity of demand	-1.0	-1.0	-1.0	-1.0
homogeneity	1.0	0.1	0	0
transport costs (Dfl.x1000/animal)	0	0.3	0.6	0.6
maximum increase export (nrs./week)	-	6	16	6
price (Dfl.x1000/animal)	2.13			
distortion costs (Dfl.x 1000/animal)	0.20			
retainment costs (Dfl.x1000/animal/week)	0.02			

Sources: PVV Annual Statistical Report 1986, Agricultural Data 1988 and verbal information transport companies.

For the data for cattle for breeding the EC has been considered to be one unit. The reason for this is that the larger part of the export to countries within the EC goes to Greece, Portugal and Spain (about 95%). Due to the only slight export to other EC countries the inclusion of separate groups is not necessary.

Reaction data

If the Netherlands cease vaccination, the reactions are the same for all strategies. This is the result of not defining a different market structure (with an FMD-free market) for the situation without annual vaccination. The reactions in the situation with and without annual vaccination are indicated in table 6.10.

Table 6.10: Export ban with respect to cattle for breeding following an FMD outbreak in a situation with annual vaccination (strat.Ia and Ib) and without annual vaccination in the Netherlands (strat. IIa, IIb and IIc).

		non-EC	
Strategy	EC	Africa	Middle East
Ia, Ib, IIa IIb and IIc	till 12 weeks after last outbreak, affected region	till 26 weeks after last outbreak, whole country	as Africa

In table 6.10 it is assumed that EC countries follow EC legislation. Non-EC countries are assumed to follow guide lines established by the Office International des Epizooties (OIE).

6.4. Input data for the integrating part

The data to be fed in here concern the number of primary outbreaks per 10 years.

The expected number of outbreaks per 10 years depends on the preventive strategy followed. From investigation in West Germany (Strohmaier and Böhm, 1984) about the cause of primary FMD outbreaks in the period 1970 to 1984, it emerges that of the 28 defined primary outbreaks:

- 16 were caused by vaccination with insufficient inactivated virus;
- 4 were caused by the escape of virus from vaccine production plants;
- 2 were caused by the feeding of food remains to pigs;
- 5 had unknown causes.

From an analysis of the causes of primary FMD outbreaks in EC member states by a sub-group of the Scientific Veterinary Committee of the EC (1988) it emerges that of the 34 investigated primary outbreaks in the period 1977-1987:

- 13 can almost certainly be put down to the use of insufficient inactivated virus or to escapes of virus from laboratories;

- 8 were almost certainly caused by infection sources outside the EC (meat import, airborne transmission);
- 13 were due to unknown causes.

On the basis of these figures and the investigation by Dijkhuizen et al. (1986, appendix 1), an expectation has been made of the number of primary outbreaks per 10 years in the most optimistic, the most likely and the most pessimistic situation (table 6.11).

Table 6.11: Expected number of primary outbreaks per 10 years

	vaccinated population	non-vaccinated population
most optimistic situation	0	0
most likely situation	2	1
most pessimistic situation	4	4

It might be observed that all primary outbreaks are generated at separate moments. Therefore, the most pessimistic situation implies that under strategy IIc (ring vaccination) the FMD-free non-EC market is closed for nearly the complete period of ten years.

7 Results

In this chapter, the results will first be discussed of calculations from the input data as stated in chapter 6 (basic situation). Subsequently, the results of a number of alternative calculations will be discussed.

7.1 The basic situation

The results of outbreak simulations with the epidemiological model for the three regions are given in table 7.1, 7.2, and 7.3.

Table 7.1: Simulated outbreaks in region 2 under different strategies.

Strategy	number of weeks with outbreaks	number of affected farms	number of cleared farms	percentage of region affected
I Vaccinated population:				
a stamping out affected herds	8	33	33	22 - 33
b as Ia plus ring vaccination	6	27	27	22 - 33
II Non-vaccinated population:				
a stamping out affected herds	29	688	688	22 - 76
b stamping out aff.+ cont.herds	8	58	138	22 - 33
c as IIa plus ring vaccination	8	240	240	22 - 33

Outbreaks, without exception, last the longest if no routine vaccination takes place and if, to control the outbreak, only the affected farms are cleared. From the tables it is clear that applying ring vaccination, especially in regions with a higher animal density, reduces the duration of an outbreak. With regard to the outbreak in region 3 under strategy IIa, it must be remarked in this context that this outbreak is not over after 30 weeks. With the present epidemiological model, more than 30 weeks cannot be simulated. This means that the results of the economic calculations for this strategy in this region give too positive a picture.

Table 7.2: Simulated outbreaks in region 1 under different strategies

Strategy	number of weeks with outbreaks	number of affected farms	number of cleared farms	percentage of region affected
I Vaccinated population:				
a stamping out affected herds	3	5	5	9
b as Ia plus ring vaccination	3	5	5	9
II Non-vaccinated population:				
a stamping out affected herds	18	245	245	9 - 23
b stamping out aff.+ cont.herds	7	36	92	9 - 14
c as IIa plus ring vaccination	7	127	127	9 - 14

Table 7.3: Simulated outbreaks in region 3 under different strategies.

Strategy	number of weeks with outbreaks	number of affected farms	number of cleared farms	percentage of region affected
I Vaccinated population:				
a stamping out affected herds	13	133	133	27 - 54
b as Ia plus ring vaccination	7	84	84	27 - 40
II Non-vaccinated population:				
a stamping out affected herds	>30	>2055	>2055	27 - 94
b stamping out aff.+ cont.herds	10	98	222	27 - 40
c as IIa plus ring vaccination	8	434	434	27 - 40

The results of the economic calculations are shown in two types of tables. The tables of the first type (table 7.4, 7.7, and 7.10) show the economic losses which occur due to a primary outbreak followed by the simulated number of secondary outbreaks. These losses are divided into direct and indirect costs. Direct costs of an outbreak refer to the costs which are made for the control of the outbreak. The total of the direct costs is shown without and with the EC subsidy. Indirect costs refer to the losses for producers and advantages for consumers which are due to the reactions of export countries to an FMD outbreak in the Netherlands. These indirect costs are given per product. The total indirect costs are given with

and without the change of consumer surplus for meat. The total of direct and indirect costs is given in three ways:
- exclusive EC subsidy and inclusive change of consumer surplus meat;
- inclusive EC subsidy and inclusive change of consumer surplus meat;
- inclusive EC subsidy and exclusive change of consumer surplus meat.

The last two totals are used for further calculation of costs per strategy per year. By multiplying the total costs per outbreak with the expected number of primary outbreaks per 10 years, dividing this by 10 and finally correcting for costs of annual vaccination (strategy Ia and Ib) or for extra benefits on the FMD-free market (strategy IIa, b and c), the costs per strategy per year are obtained. These costs are given including change of consumer surplus (table 7.5, 7.8 and 7.11) and excluding change of consumer surplus (table 7.6, 7.9 and 7.12). As stated earlier, the costs per strategy must be interpreted against the background of the hypothetical nil situation which is that:
- no annual vaccination takes place;
- no export to an FMD-free market takes place;
- no outbreaks of FMD occur.

Table 7.4 shows the losses if, under the different strategies, an outbreak occurs in region 2 (Overijssel and Gelderland).

Taking the tables 7.4 and 7.1 together makes clear that the direct costs are closely connected to the duration and the extent of the outbreak. With the indirect costs, it is noticeable that the losses under the strategies with annual vaccination are much smaller than the strategies without annual vaccination. The cause of this is that in the situation without annual vaccination, meat is put on the FMD-free market. The long-term reaction of that market to an FMD outbreak in the Netherlands involves five times as much meat (1500 as opposed to 300 tons per week) as the only long-term reaction (from Central and South America) in the situation with annual vaccination. If an outbreak occurs under strategy IIc, the reaction of the FMD-free market also lasts longer. Because strategy IIc means that a ring vaccination is applied, the FMD-free market namely refuses meat from the Netherlands for two years after the last secondary outbreak. From the total costs it emerges clearly that the losses due to an FMD outbreak in a vaccinated population are far smaller than when an outbreak occurs in a non-vaccinated population.

Table 7.4: Economic losses resulting from an outbreak in region 2 (x mln. Dfl.)

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	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
- in case of a ring vaccination					
* costs of vaccine	0.00	5.27	0.00	0.00	6.31
* vaccination costs	0.00	3.51	0.00	0.00	4.78
Total direct costs	9.75	16.75	225.31	45.19	89.68
EC subsidy	2.43	9.46	45.78	9.18	24.67
Direct costs minus EC subsidy	7.31	7.29	179.53	36.01	65.01
Indirect costs per product:					
- Meat:					
* no. of weeks market disruption	60	58	81	60	112
* producers losses	331.80	303.04	938.29	610.41	917.67
of which decline of export returns	264.14	242.24	754.60	509.16	785.56
* consumers losses	-112.63	-103.44	-279.63	-185.51	-262.09
- Breeding cattle:					
* no.of weeks market disruption	34	32	55	34	34
* producers losses	19.88	18.71	32.21	19.88	19.88
of which decline of export returns	19.57	18.42	31.66	19.57	19.57
* 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
Ditto excl. consumer surplus meat	336.34	307.32	945.70	614.96	922.22
Total costs (direct plus indirect)	233.46	220.64	891.37	474.64	749.81
Total costs per strat.(incl. EC subsidy)	231.02	211.18	845.59	465.46	725.14
Ditto excluding consumer surplus	343.66	314.61	1125.23	650.97	987.23

If the losses per outbreak are expressed on a yearly base and supplemented with annual costs for preventive vaccination and the annual extra profit for export to the FMD-free market respectively, the costs emerge per strategy per year as shown in table 7.5 and 7.6.

Table 7.5: Costs per strategy per year incl. consumer surplus if outbreaks occur in region 2 (x mln. Dfl.)

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most optimistic situation:					
- no. of primary outbreaks / 10 year	0	0	0	0	0
- total costs per year	24.53	24.53	-38.22	-38.22	-38.22
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year	70.73	66.76	46.34	8.33	34.29
Most pessimistic situation:					
- no. of primary outbreaks / 10 year	4	4	4	4	4
- total costs per year	116.94	109.00	300.02	147.96	251.84

Table 7.6: Costs per strategy per year excl. consumer surplus if outbreaks occur in region 2 (x mln.Dfl.)

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most optimistic situation:					
- no. of primary outbreaks / 10 year	0	0	0	0	0
- total costs per year	24.53	24.53	-38.22	-38.22	-38.22
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year	93.26	87.45	74.30	26.88	60.50
Most pessimistic situation:					
- no. of primary outbreaks / 10 year	4	4	4	4	4
- total costs per year	161.99	150.37	411.87	222.17	356.67

From tables 7.5 and 7.6 it is clear how much annual vaccination costs, and how great the extra profit per year is if the FMD-free market is used. If no outbreak occurs (most favourable situation) then the costs under strategies Ia and Ib are 24.53 million guilders. These are the vaccination costs. Under strategies IIa, IIb and IIc, the costs amount to -38.22 million guilders. These are the extra profits provided by using the FMD-free market.

In table 7.7 till 7.12 results are presented if outbreaks occur in region 1 and 3 respectively.

By comparing the losses as the result of an outbreak in the different regions (table 7.4, 7.7 and 7.10) it emerges that the losses increase as the herd density increases. This is largely the result of the fact that the outbreaks last longer with higher herd density (see table 7.1, 7.2, and 7.3).

For all regions, it is so that the costs per strategy per year in the most optimistic and the most likely situations are lower in the case of no annual vaccination being applied (see table 7.5, 7.6, 7.8, 7.9, 7.11 and 7.12). The only exception to this is made by annual costs for the most likely situation in region 3 under strategy IIa. In the most pessimistic situation the opposite applies. In that situation, the annual costs are in all cases lower when annual vaccination is carried out.

If one is considering the manner in which an outbreak is controlled, it then emerges that in the regions with the higher herd density (regions 2 and 3) the results are better when more is done than merely slaughtering and destroying animals on affected farms. If annual vaccination is used, the best results are obtained when after an outbreak, ring vaccination is applied. In region 1 the results with or without ring vaccination are roughly the same (table 7.8 and 7.9). If no annual vaccination is applied, then in all cases, the slaughter and destruction of animals on affected and serious contact farms (strategy IIb) gives the best result. For regions 2 and 3 the second best result is obtained by applying control strategy IIc. In a non-vaccinated population strategy IIb always scores better than IIc, because the long-term reaction of some export countries to ring vaccination (whereby the losses as the result of an outbreak rise sharply) are not present in strategy IIb. That this effect is severe emerges from the fact that in the event of an outbreak in region 1, even strategy IIa is more favourable than strategy IIc (table 7.8).

Table 7.7: Economic losses resulting from an outbreak in region 1 (x mln. Dfl.).

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Direct costs:					
- value of removed animals	0.59	0.59	31.19	11.71	16.17
- disinfection costs	0.08	0.08	3.72	1.40	1.93
- costs of on-farm idle factors	0.05	0.05	2.47	0.93	1.28
- on-farm incidental costs	0.00	0.00	0.00	0.00	0.00
- losses for industry and trade	0.57	0.57	23.02	8.65	11.93
- in case of a ring vaccination					
* costs of vaccine	0.00	1.03	0.00	0.00	1.50
* vaccination costs	0.00	0.92	0.00	0.00	1.53
Total direct costs	1.29	3.24	60.41	22.68	34.35
EC-subsidy	0.67	2.16	17.45	6.55	11.31
Direct costs minus EC-subsidy	0.62	1.08	42.95	16.13	23.03
Indirect costs per product:					
- Meat:					
* no.of weeks market disruption	55	55	70	59	111
* producers losses	258.06	258.06	750.73	590.60	897.85
of which decline of export returns	209.90	209.90	625.96	497.33	773.73
* consumers losses	-90.14	-90.14	-230.26	-180.89	-257.46
- Breeding cattle:					
* no.of weeks market disruption	29	29	44	33	33
* producers losses	16.94	16.94	25.72	19.28	19.28
of which decline of export returns	16.69	16.69	25.32	18.99	18.99
* users losses	-13.08	-13.08	-19.84	-14.88	-14.88
Total indirect costs per strat.	171.78	171.78	526.34	414.11	644.79
Ditto excl. consumer surplus meat	261.92	261.92	756.60	595.00	902.25
Total costs (direct plus indirect)	173.07	175.02	586.75	436.79	679.13
Total costs (incl. EC subsidy)	172.40	172.86	569.30	430.24	667.82
Ditto excl. consumer surplus meat	262.34	263.00	799.56	611.13	925.28

Table 7.8: Costs per strategy per year including consumer surplus if outbreaks take place in region 1 (x mln. Dfl.).

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most optimistic situation:					
- no. of primary outbreaks / 10 year	0	0	0	0	0
- total costs per year	24.53	24.53	-38.22	-38.22	-38.22
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year	59.01	59.10	18.71	4.80	28.56
Most pessimistic situation:					
- no. of primary outbreaks / 10 year	4	4	4	4	4
- total costs per year	93.49	93.67	189.50	133.87	228.91

Table 7.9: Costs per strategy per year excluding consumer surplus if outbreaks take place in region 1 (x mln. Dfl.).

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most optimistic situation:					
- no. of primary outbreaks / 10 year	0	0	0	0	0
- total costs per year	24.53	24.53	-38.22	-38.22	-38.22
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year	77.00	77.13	41.74	22.90	54.31
Most pessimistic situation:					
- no. of primary outbreaks / 10 year	4	4	4	4	4
- total costs per year	129.47	129.73	281.60	206.23	331.90

Table 7.10: Economic losses resulting from an outbreak in region 3 (x mln. Dfl.)

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Direct costs:					
- value of removed animals	13.70	8.65	231.62	25.02	48.92
- disinfection costs	2.23	1.41	33.19	3.59	7.01
- costs of on-farm idle factors	1.42	0.90	26.64	2.88	5.63
- on-farm incidental costs	0.00	0.00	0.02	0.00	0.00
- losses for industry and trade	20.47	12.93	314.74	34.00	66.47
- in case of a ring vaccination					
* costs of vaccine	0.00	8.43	0.00	0.00	9.23
* vaccination costs	0.00	5.04	0.00	0.00	6.04
Total direct costs	37.83	37.36	606.22	65.49	143.30
EC-subsidy	2.40	13.34	132.41	14.30	40.22
Direct costs minus EC-subsidy	35.43	24.02	473.82	51.19	103.09
Indirect costs per product:					
- Meat:					
* no.of weeks market disruption	65	59	82	62	112
* producers losses	411.21	320.29	1044.46	644.79	920.91
of which decline of export returns	319.09	253.16	797.73	532.84	785.56
* consumers losses	-135.77	-108.01	-333.90	-194.77	-262.09
- Breeding cattle:					
* no.of weeks market disruption	39	33	56	36	34
* producers losses	22.80	19.29	32.78	21.04	19.87
of which decline of export returns	22.45	18.99	32.23	20.72	19.57
* users losses	-17.59	-14.88	-25.25	-16.23	-15.33
Total indirect costs per strat.	280.66	216.69	718.09	454.83	663.36
Ditto excl. consumer surplus meat	416.43	324.70	1052.00	649.60	925.45
Total costs (direct plus indirect)	318.48	254.05	1324.31	520.32	806.67
Total costs per strat.(incl.EC-sub)	316.09	240.70	1191.90	506.02	766.45
Ditto excl. consumer surplus	451.86	348.71	1525.80	700.79	1028.54

Table 7.11: Costs per strategy per year incl. consumer surplus if outbreaks occur in region 3 (x mln.Dfl.)

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most optimistic situation:					
- no. of primary outbreaks / 10 year	0	0	0	0	0
- total costs per year	24.53	24.53	-38.22	-38.22	-38.22
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year	87.75	72.67	80.97	12.38	38.43
Most pessimistic situation:					
- no. of primary outbreaks / 10 year	4	4	4	4	4
- total costs per year	150.96	120.81	438.54	164.19	268.36

Table 7.12: Costs per strategy per year excl. consumer surplus if outbreaks occur in region 3 (x mln. Dfl.)

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most optimistic situation:					
- no. of primary outbreaks / 10 year	0	0	0	0	0
- total costs per year	24.53	24.53	-38.22	-38.22	-38.22
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year	114.90	94.27	114.36	31.86	64.63
Most pessimistic situation:					
- no. of primary outbreaks / 10 year	4	4	4	4	4
- total costs per year	205.27	164.01	572.10	242.10	373.19

For the above conclusions regarding the economic results, it does not matter whether one looks at the results including or excluding consumer surplus. If one leaves the consumer surplus aside, it is the result level that changes and not the ranking of the strategies.

7.2 Some alternative calculations

The alternative calculations, for which the results are presented here, are mostly concerned with calculations with the export model.

To avoid too many tables, all alternative calculations will be carried out for region 2. Region 2 is selected because that region is the most representative for the Netherlands as a whole.

A different frequency of primary outbreaks

One of the assumptions underlying the calculations for the basic situation concerns the decline in frequency of primary outbreaks in the most likely situation if vaccination is ceased. To get an impression about the impact of that assumption, a new calculation is made in which it is assumed that the number of primary outbreaks in the most likely situation will be the same both in a vaccinated and in a non-vaccinated population.

Table 7.13: Costs per strategy per year if outbreaks occur in region 2 (x mln. Dfl.)

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	2	2	2
- total costs per year (incl. cons. sp.)	70.73	66.76	130.90	54.88	106.80
- total costs per year (excl. cons. sp.)	93.26	87.45	186.82	91.98	159.22

Looking at the results in table 7.13, it is obvious that the frequency of primary outbreaks is an important variable. If a number of 2 primary outbreaks per 10 years in a non-vaccinated population is a realistic assumption, only the strategy with stamping out contact herds can compete with vaccination strategies.

A less effective strategy IIb

With regard to strategy IIb it is assumed that 50% of the risky contacts, and, as a result of that, 50% of the potential secondary outbreaks per contact are avoided by stamping out serious contact herds. An alternative calculation is carried out, assuming 20% of the risky contacts are avoided. Results are presented in table 7.14.

Table 7.14: Costs per strategy per year if outbreaks occur in region 2 and if only 20% of secondary outbreaks are prevented by stamping out contact herds (x mln. Dfl.)

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year (incl. cons. sp.)	70.73	66.76	46.34	24.86	34.29
- total costs per year (excl. cons. sp.)	93.26	87.45	74.30	46.55	60.50

Strategy IIb remains the better option in a non-vaccinated population, but the reduced effectiveness has a considerable impact on the yearly costs as shown in table 7.14.

Different export to and premium on the FMD-free market

Great uncertainty exists about the assumptions concerning export to the FMD-free market. To see what the impact of these assumptions is, two calculations are carried out. In the first one it is assumed that no export to the FMD-free market will take place, whatever strategy is used. In the second calculation it is assumed that only half the amount of meat can be exported to the FMD-free market and that only half the price premiumcan be realized (new situation; amount: 750 ton/week, price premium: 250 Dfl/ton). The latter could be the case if more countries get access to the FMD-free market.

Table 7.15: Costs per strategy per year in the most likely situation if outbreaks occur in region 2 (x mln. Dfl.) with no, respectively less possibility to export to FMD-free markets.

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
no. of primary outbreaks / 10 year	2	2	1	1	1
- results including consumer surplus:					
* total costs per year when no supply to FMD-free markets exists	70.73	66.76	62.39	25.97	28.87
* total costs per year with half the supply and half the price premium	70.73	66.76	59.88	23.09	35.82
- results excluding consumer surplus:					
* total costs per year when no supply to FMD-free markets exists	93.26	87.45	83.24	37.24	40.14
* total costs per year with half the supply and half the price premium	93.26	87.45	83.18	36.92	53.08

The results in table 7.15 show that the yearly costs of non-vaccinating strategies rise for most strategies if no access to FMD-free markets occurs or if a smaller amount can be brought on this market against a lower price. However, non-vaccinating strategies remain favourable as far as annual costs are concerned.

The results also demonstrate that the benefits from getting access to FMD-free markets in the basic situation are for a significant part outweighed by the higher costs of an outbreak. The higher costs are caused by the fact that a considerable amount of meat cannot be brought on the FMD-free market for a long period if an outbreak occurs. Especially when strategy IIc (with a ring vaccination) is used, this leads to high costs because the period of non-delivery on the FMD free market is two years. Table 7.15 shows that following strategy IIc it is preferable to have no access to FMD-free markets.

These remarks all hold for the most likely situation. For the most pessimistic situation (4 primary outbreaks per 10 year) counts that yearly costs are much lower if no access to the FMD-free market exists. In that situation and as far as yearly costs are concerned, strategy IIb and IIc can even compete with the vaccination strategies.

No EC subsidy on control costs

A third uncertain factor is the EC subsidy on disease control costs. Therefore a calculation has been made assuming that no EC subsidy on control costs exists.

Table 7.16: Costs per strategy per year in the most likely situation if outbreaks occur in region 2 (x mln. Dfl.) with no EC subsidy on control costs.

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year (incl.cnsm.surplus)	71.22	68.65	50.92	9.24	36.76
- total costs per year (excl.cnsm.surplus)	93.75	89.34	78.88	27.80	62.97

As could be expected looking at the level of the subsidy in table 7.4, ceasing the subsidy on control costs does not shift the level of yearly costs dramatically (see table 7.16). The ranking of strategies does not change.

All EC countries change their reactions

In the basic situation it is assumed that the unanimous reaction of all EC-countries is to avoid import of meat and breeding cattle originating from the affected region. For meat this reaction lasts till four weeks after the last secondary outbreak and for breeding cattle till twelve weeks after the last outbreak. This reaction may change if annual vaccination against FMD for the whole of the EC is ceased. If that is the case, countries have more to fear from an outbreak because costs of an outbreak in a non-vaccinated population are always higher than those of an outbreak in a vaccinated population. The result of this could be that the unanimous reaction of all EC-countries will be more severe after vaccination is ceased. To gauge what the effects of changed reactions could be, a calculation is done for which it is assumed that for strategies IIa, IIb and IIc the unanimous reaction of all EC-countries is:

- for 8 weeks after the last second outbreak no import of meat originating from the affected region;
- for 104 weeks after the last outbreak no import of breeding cattle originating from the affected region.

The other reactions are assumed to remain the same.

Table 7.17: Costs per strategy per year in the most likely situation if outbreaks occur in region 2 (x mln. Dfl.) with longer lasting reactions of EC-countries.

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year (incl.cnsm.surplus)	70.73	66.76	46.97	8.60	34.57
- total costs per year (excl.cnsm.surplus)	93.26	87.45	74.94	27.15	60.78

Looking at the results in table 7.17 it can be seen that a change of the period for which reactions of EC countries last, if an outbreak takes place in a non-vaccinated population, appears to have little influence on the results. The only outbreak costs that change are the producer losses. These losses increase slightly because a small part of the export of meat and breeding cattle has to change from origin for a longer period.

From this alternative calculation it becomes clear that a reaction concerning the export from the affected region leads to relatively low costs.

All reactions last one week longer

To get an impression about the change in the indirect costs if an outbreak lasts one week longer, a calculation is made using the assumption that all reactions last one week longer. For countries that show two successive reactions (such as Italy and France) it is assumed that only the last reaction lasts one week longer as would be the case if an outbreak lasted one week longer. The results of the calculations are shown in table 7.18 (to be compared with the lower part of table 7.4).

Table 7.18: Indirect costs resulting from an outbreak in region 2 (x mln. Dfl.) if all reactions last one week longer.

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Indirect costs per product:					
- Meat:					
* no.of weeks market disruption	61	59	82	61	113
* producers losses	346.22	317.38	954.29	625.65	932.90
of which decline of export returns	275.12	253.16	766.43	521.00	797.40
* consumers losses	-117.26	-108.01	-284.26	-190.14	-266.71
- Breeding cattle:					
* no.of weeks market disruption	35	33	56	35	35
* producers losses	20.46	19.29	32.80	20.46	20.46
of which decline of export returns	20.14	18.99	32.23	20.14	20.14
* users losses	-15.78	-14.88	-25.25	-15.78	-15.78
Total indirect costs per strategy	233.64	213.78	677.58	440.19	670.87
Increase compared to table 7.4	7.93	9.9	11.51	10.74	10.74

The indirect costs, and thereby also the total costs, increase by 10 to 12 million (including consumer surplus). The fact that there is not much difference here between the figures under the different strategies is because in all cases the sanctions regarding the total export are lengthened by one week. Because, under the strategies without annual vaccination, a heavier sanction applies for a larger part of the exported meat, the increases under these strategies are greater.

Intervention of meat originating from the affected region

An EC measure that could be taken to relieve the national economic losses as a result of an outbreak is the intervention of meat originating from the affected region. To see what the effect of such a measure could be, a calculation is made using the assumption that intervention of meat originating from the affected region is possible for a period of three weeks, starting one week after the primary outbreak. The intervention price is set at Dfl. 4.70 per kg. and it is assumed that the meat taken into intervention has no residual value. The effect of this measure on outbreak costs is shown in table 7.19.

Table 7.19: Indirect costs resulting from an outbreak in region 2 (x mln. Dfl.) if intervention of meat from the affected region is possible.

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Indirect costs per product:					
- Meat:					
* no.of weeks market disruption	60	58	81	60	112
* producers losses	205.30	178.89	763.61	455.01	762.26
of which decline of export returns	172.90	151.49	641.69	398.94	675.34
* consumers losses	-61.57	-52.84	-211.67	-120.03	-196.60
* loss of government budget	7.28	7.28	7.28	7.28	7.28
- Breeding cattle:					
* no.of weeks market disruption	34	32	55	34	34
* producers losses	19.88	18.71	32.21	19.88	19.88
of which decline of export returns	19.57	18.42	31.66	19.57	19.57
* consumers losses	-15.33	-14.43	-24.80	-15.33	-15.33
Total indirect costs per strategy	155.57	137.61	566.64	346.81	577.49

Looking at the results (and comparing them with the results in the lower part of table 7.7), it can be seen from the loss of government budget that intervention takes place for all strategies to the same extent. The loss of government budget arises because a contribution has to be paid by every EC-member to cover the extra expenses on intervention. It is logical that the size of intervention is the same for all strategies because for the first four weeks the meat exporters face the same reactions irrespective of the strategy.

It is obvious that intervention of meat originating from the affected region has a considerable effect on indirect costs. Indirect costs are decreased by 66 mln. (strategy Ib) to 100 mln. (strategy IIa). Although the advantage of intervention is greater if indirect costs in the situation without intervention are higher, the ranking of strategies with regard to yearly costs remains the same for all situations (see table 7.20).

Table 7.20: Costs per strategy per year in the most likely situation if outbreaks occur in region 2 (x mln. Dfl.) and if intervention of meat originating from the affected area is possible.

	VACC. POPULATION		NON-VACC. POPULATION		
Strategy:	Ia	Ib	IIa	IIb	IIc
Most likely situation:					
- no. of primary outbreaks / 10 year	2	2	1	1	1
- total costs per year	57.10	53.51	36.40	0.06	26.03
- total costs per year	69.42	64.08	57.56	12.07	45.69

8 Discussion and Conclusions

In this research project the central issue was to quantify the economic effects for the Netherlands of alternative strategies for the control of Foot-and-Mouth Disease (FMD). Attention has particularly been paid to the consequences of alternative strategies for the export of meat, meat products and cattle. Because the input data for the calculations contain many uncertainties, it was decided to develop a computer model, in which these input data can easily be modified. A flexible tool has therefore been made available to support policy makers in their decision-making process considering whether or not to cease annual vaccination against FMD. The model has been designed in such a way that in principle the export consequences of other diseases can also be calculated.

The 'export model' follows on from the earlier developed FMD model by Dijkhuizen et al (1986). Although much discussion is possible about, in particular, the epidemiological input values, this model and its input value have been used for the present investigation. This has been done to avoid a repetition of the discussions carried out in the past and to obtain an epidemiological basis about which, at least between the researchers then involved, there was a consensus of opinion. Altogether this does not mean that adaptation is ruled out on grounds of new perspectives; in the present model, too, one can switch to other points of departure. Furthermore, additional epidemiological assumptions were necessary because the Netherlands has been divided into three regions with different herd density. These regions are:

1 North and West Netherlands, consisting of the provinces of Groningen, Friesland, Drente, Flevoland, Utrecht, North Holland, South Holland and Zeeland (low density);
2 East Netherlands, consisting of the provinces of Gelderland and Overijssel (normal density);
3 South Netherlands, consisting of the provinces of North Brabant and Limburg (high density).

The extent to which the disease spreads depends to some extent on the herd density. Regarding this relationship, illustrated by the so-called Dissemination Rate (the number of farms to which the virus is spread by one affected farm), extra assumptions had to be made.

There is also an element of uncertainty in the reactions of importing countries to an FMD outbreak in the Netherlands. Particularly if the whole EC stops annual vaccination in 1992, a new situation is created in which it is difficult to estimate how the reaction pattern will be to an FMD outbreak in the Netherlands. Extra calculations with alternative reactions give more insight into the economic consequences of the following of strategies without annual vaccination.

In the investigation, assumptions had to be made regarding the extent of the realizable 'price premium' in the case of export to the so-called FMD-free market. Although in this field the advice has been asked of specialists, the assumptions used remain very uncertain considering the hypothetical character of the situation. The calculated advantages which can be obtained with a strategy without vaccination are dependent on these - uncertain - assumptions.

Another point worthy of further attention is the effect of intervention measures for meat. If an FMD outbreak occurs while regular intervention is being applied, then it is sure to have a favourable effect on the costs of an outbreak (in spite of the fact that intervention remains limited to certain types of meat). The investigation of the other intervention possibility, that is a special arrangement for intervention of meat from the affected region during an outbreak, can make it clear what the effects can be of efforts on the part of the EC to put such a regulation into force.

From the results of the situations calculated, as stated in chapter 7, the following conclusions can be drawn:

1 Given the current annual preventive vaccination, the control strategy applied in the Netherlands ('clearing of affected farms and application of ring vaccination') leads in most cases to the least cost if an outbreak occurs. Only with an outbreak in an region with low herd density (such as in region 1) does the exclusion of ring vaccination lead to a slightly better result.

2 If preventive vaccination is not applied, the costs of an outbreak rise (i.e. one primary followed by several secondary outbreaks) steeply. In the situation with annual vaccination, the costs of an outbreak vary namely from 172 million guilders of an outbreak in region 1 (about 2% of annual export value of cattle and meat) to 316 million guilders of an outbreak in region 3 (about 4%). In the situation without annual

vaccination, the costs vary from 430 million guilders of an outbreak in region 1 (around about 5.5%) to around 1.2 billion guilders of an outbreak in region 3 (about 15%). Of the strategies without annual vaccination, following strategy IIb leads in all cases to the lowest costs of an outbreak (see page 23 for an explanation of strategies). In region 1 strategy IIa comes in second place, and in the regions 2 and 3 strategy IIc is the second best.

3 The indirect costs of an FMD outbreak are many times greater than the direct costs. There is, however, a distinct connection between both types of costs; if an outbreak is of long duration and there are many farms involved (therefore large direct costs), then the effects for export are also more considerable. This relationship is not valid in all situations or under all strategies. The expected extent of the costs of an outbreak are strongly influenced by the assumptions and the information which is used in the 'export model'.

4 The indirect costs consist largely of costs connected with the export of meat and meat products and animals for slaughter. Here it is assumed that the export of live animals for slaughter can easily be replaced by the export of meat. Effects on other products are - compared to the effects for meat, meat products and animals for slaughter - slight or of no significance.

5 The permanent annual costs (separate from the number of outbreaks per 10 years) reverse, and become benefits, if the annual preventive vaccination is ceased. This is caused by the vaccination costs no longer applying and benefits exist because part of the export is put on the FMD-free market for a higher price. That higher price is however only achieved in periods in which no outbreak of FMD has occurred for some time. If the export is aimed at the FMD-free market and an outbreak occurs, the costs therefore rise sharply.

6 In the most optimistic and the most likely situations regarding the number of primary outbreaks in 10 years, the strategies without annual vaccination lead in almost every case to lower annual costs than with preventive vaccination (except strategy IIa for an outbreak in region 3). Strategy IIb gives the best results, followed by strategy IIa if the outbreak occurs in region 1 and by strategy IIc if the outbreak occurs in region 2 or 3. If the most pessimistic situation exists regarding the number of primary outbreaks, then the best results are achieved with

the current strategy (Ib). One can thus draw the conclusion that with an annual vaccination of cattle, the financial risk is clearly reduced. The extent of this risk is strongly dependent on the frequency of primary outbreaks under a strategy without annual vaccination. In the most pessimistic situation, this number is assumed to be the same as the number of primary outbreaks with annual vaccination (i.e. 4 per 10 years).

7 In a non-vaccinated population, control strategy IIb ('stamping out affected and serious contact herds') is attractive from an economic point of view. The advantage obtained by this alternative offers more than enough play to reimburse the loss to these cleared farms in a realistic way. Even if strategy IIb is less effective (i.e. a lower percentage of potential secondary outbreaks being avoided), it remains the favourable option. The question is to what extent public opinion allows the implementation of such a strategy.

8 The range in which the yearly costs lie gives an indication about the extra yearly losses if a bad strategy is chosen. The difference in the annual costs per strategy amounts in the most likely situation from 54 (outbreak in region 1) to 75 million guilders (outbreak in region 3) per year. In the most pessimistic situation the differences between the annual costs per strategy are many times greater.

9 Although the extent of the annual costs of following a strategy are clearly influenced by whether one does or does not consider the effects for the domestic consumers of meat and meat products, the ranking of strategies as stated in conclusion 6 does not change.

10 An alternative calculation shows that the ranking of strategies in the most likely situation does change if a number of 2 primary outbreaks per 10 years is assumed for both the situations with and without yearly vaccination. The alteration of this important variable for region 2 shows that only strategy IIb is a favourable alternative. If strategy IIb would be less effective, however, (i.e. only 20% of the potential secondary outbreaks being avoided) then strategies with yearly vaccination are favourable. The yearly costs of strategy IIa and IIc are far more higher than the yearly costs of strategies with annual vaccination.

11 Obtaining admission to the FMD-free market does not appear to be a deciding variable as far as the ranking of strategies is concerned.

Alternative calculations for region 2 with the assumption that no meat, respectively half the amount of meat (with half the price premium), can be brought on the market, show that the ranking of strategies in the most likely situation remains the same. This is an important conclusion because the assumptions about the possibilities on the FMD-free market are not very solid.

12 Alternative calculations show that ceasing the EC subsidy on stamping out does not change the yearly costs much, nor does it change the ranking of strategies. The same applies to a change of the period for which the common reactions of the EC-countries last. As long as the reactions remain limited to product originating from the affected region, an extension of the reactions does relatively little harm.

13 The length of the period an outbreak lasts is of importance for the extent of the indirect costs. Alternative calculations show that for every week longer an outbreak lasts, the indirect costs rise by about Dfl. 10 mln., irrespective of the strategy applied.

14 Intervention of meat originating from the affected region can have a significant impact on the indirect costs of an outbreak. An alternative calculation for region 2 shows that if intervention of meat originating from the affected region is possible for a period of 3 weeks at the beginning of an outbreak (with an intervention price of Dfl. 4.70 per kg.), the outbreak costs go down by 66 to 100 mln. guilders. However, if such a measure were taken, it implies that it also can be taken if other EC-members suffer from an outbreak. This means that the contribution by the Netherlands to the EC would rise considerably more than what is calculated in this alternative. Therefore this calculation gives probably too positive a picture of intervention. The intervention mechanism spreads risk among member countries.

15 The results of this research project provide a number of indications (see above) that an optimal control strategy in the case of an outbreak depends on the herd density in the region concerned. Further investigation regarding the strategy to be followed in the control of FMD with relation to the region where the outbreak occurs is to be recommended. Particularly the information in the epidemiological field, regarding the relation between herd density and dissimination rate and also more generally regarding the spread of the disease, should be strengthened and extended.

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Appendix Structure and contents of the export model

In the export model the national economic losses due to export bans are calculated per produce according to flow charts 1 and 2. The abbreviations used in the flow charts are described in the list preceding flow chart 1.

LIST OF ABBREVIATIONS:

PMIN	The price level below which producers store their produce.
SSPRDWK	Suspect production per week (production that originates from the region considered as affected by the EC).
NRMPRDWK	Normal production per week (production that originates from the non-affected part of the country).
QNSWEEK	Quantity of product per week during an outbreak that cannot be exported because of closed borders.
PRODLOSS	Loss of producers income.
CLOSMAR	The weekly set of markets that are closed for the product originating from the entire area of the country which suffers from an FMD outbreak.
HLFOPMAR	The set of half open markets per week (markets that refuse produce originating from the affected region).
REOPMAR	The set of actually open markets per week including the home market (markets that do not refuse any product whatever the origin may be).
OPENMAR	The sum of REOPMAR and HLFOPMAR.
DISTFAC	A factor resembling the costs per unit of product of changing the origin (from affected to non-affected area) of product that is exported.
STOCKSSP	The stock of product originating from the affected region. STOCKSSP at the beginning of a week is the sum of STOCKSSP at the end of the week before and the suspect production in the particular week.
STOCKNRM	The stock of product originating from the non-affected area. STOCKNRM at the beginning of a week is the sum of STOCKNRM at the end of the week before and the normal production in the particular week.
AEDEMPR	The aggregate price elasticity of demand.
SPREAD	The diversion of additional supply to markets in such a way that the price decrease on each market is the same.
EXSUPP	Extra supply on a market above normal supply.

QSUPEXTR	Maximum amount of product that can be exported additionally to a market given the capacity of the export channel.
EXPORT	Export of product to markets in a situation without FMD
QUANTINT	Amount of product that is intervened in the particular week.
PINTERV	Intervention price.
QUINTERV	Amount of product that can be intervened in case the amount is limited.

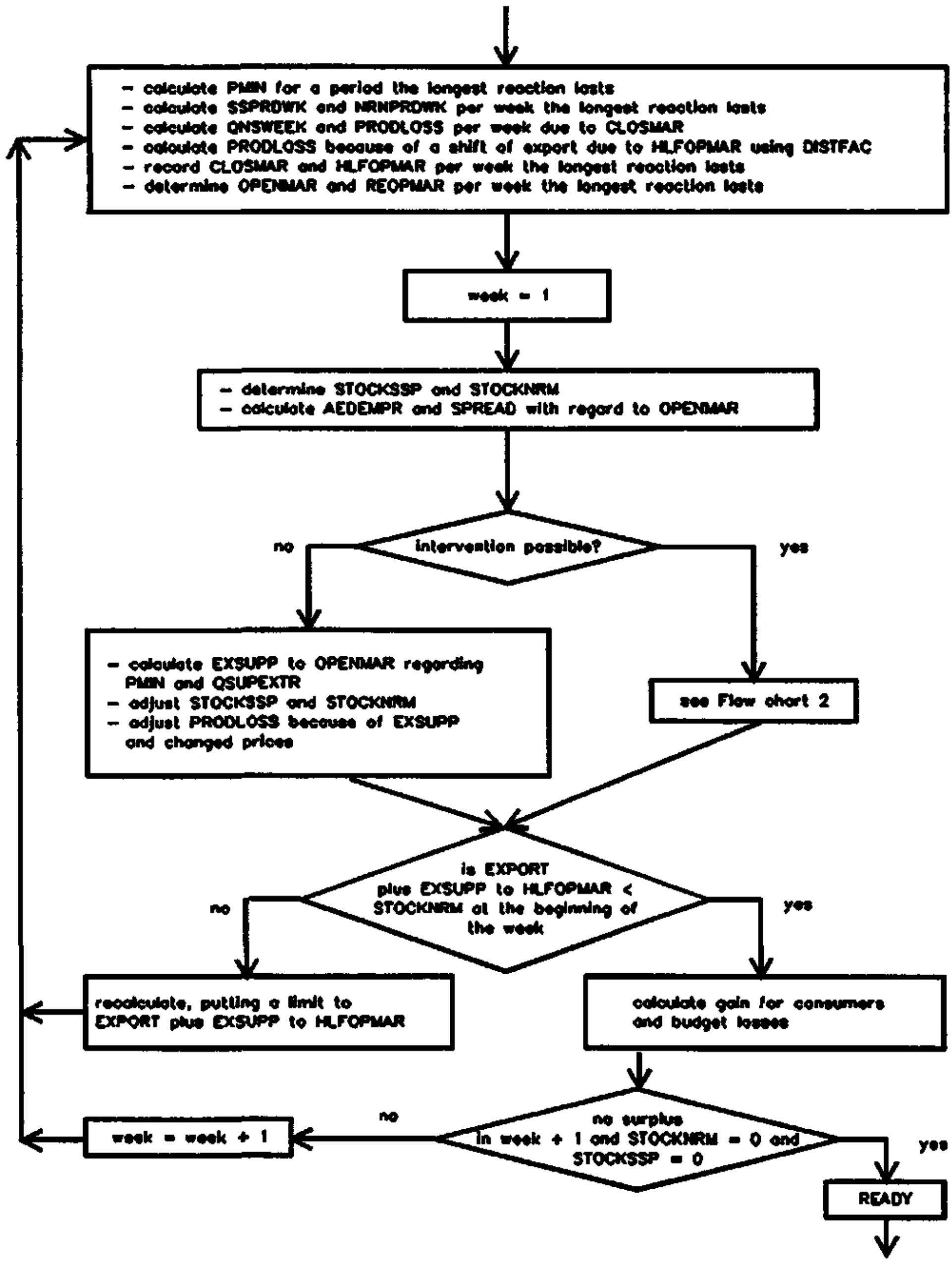
As can be seen from flow chart 1 the model starts by determining a minimum price for each week the longest reaction lasts. Below this price level producers start to store their produce. The determination of the minimum price is done by a so-called realistic price expectation model. This submodel represents the expectations of the producers about the price. The submodel is based on the following expectations:
- Markets outside the EC will remain closed for a longer period for the product concerned that originates from the country where an outbreak of FMD takes place;
- Markets within the EC will remain open (eventually after a very short period of closure) for produce not originating from the affected region.

Taking into account these expectations a new equilibrium is determined. The price belonging to that equilibrium, minus the costs of storing a unit of product during one week, is the minimum price below which producers start to store their produce.

According to the share that each region has in the production of the product concerned and to the percentage of each region that is considered to be affected, the suspect production and the normal production per week are calculated. This is done for a period as long as the longest outbreak lasts.

Subsequently the quantity of produce that cannot be exported due to markets closing to produce originating from the country with FMD, is calculated per week. Also the loss for producers of not selling this amount of product, being the product of the quantity and price plus transport costs, is calculated.

As most markets (e.g. the EC markets) refuse product originating from the affected region another loss for producers arises. Because of the assumption that exported produce originates from all over the country (related to the share of each region in the national production), a proportion of the export originates from the affected region. Because of this a proportion of the export to countries that refuse produce from the affected region has to change in origin. This leads to extra costs, which are the product of the amount of export



Flow chart 1: **The calculation process of national economic losses due to export bans.**

required to change in origin and a factor resembling the costs of the change of one unit of product.

A last step in the first part of the export model is the composing of sets of markets for each week the longest reaction lasts. Per week a set is made of:
- markets that are closed for all produce originating from the country hit by FMD;
- markets that are closed only for produce originating from the affected region;
- markets that are not closed for the produce concerned at all.

The last set includes the home market.

In the second part of the model, a number of steps are taken for each week with a surplus of produce, to get rid of the surplus. First the stocks of suspect and normal produce at the beginning of the week are calculated, taking into account the stocks at the end of the week before and the production of suspect and normal produce in the particular week.

Secondly, the aggregate price elasticity of demand is calculated, as is the diversion of extra export to different markets (that are not closed for produce originating from the entire area of the country). The diversion is calculated in such a way that the price decrease on each market is the same. In the part following, a deduction of the formula for the aggregate price elasticity of demand and the formula for the diversion of extra export is given.

DEDUCTION OF THE AGGREGATE PRICE ELASTICITY OF DEMAND

Below, the aggregate price elasticity of demand for product originating from country NL is deduced. Country NL exports product to country A and B. First a list with the explanation of the variables is given.

E_{p_A} : price elasticity of demand for country A

dQ_A : change of consumption in country A

P_A : price product in country A

dP_A : change of price

Q_A : consumption product in country A

EXP_{NL}^{A} : export of product from country NL to country A

$E_{P_A}^{NL}$: price elasticity of demand for NL product in country A

P_{NL} : price product in country NL

T_A : transport costs per unit from country NL to country A

$E_{P_{NL_A}}^{NL}$: demand price elasticity for NL product from country A and related to NL prices

$SUPP_{NL}^{tot}$: total supply of product originating from country NL

I_{NL} : import of product for country NL

$E_{P_{NL_{tot}}}^{NL}$: total price elasticity of demand for NL product and related to NL prices

For country B the same variables are used as for country A. For this purpose index A is changed into index B.

Starting with the price elasticity of total demand in country A:

$$E_{P_A} = \frac{dQ_A \cdot P_A}{dP_A \cdot Q_A} \tag{1}$$

Multiply left and right by $\dfrac{Q_A}{EXP_{NL}^{A}}$ gives the price elasticity of demand for imported product originating from country NL.

$$\frac{Q_A}{EXP_{NL}^{A}} \cdot E_{P_A} = \frac{dQ_A \cdot P_A}{dP_A \cdot EXP_{NL}^{A}} = E_{P_A}^{NL} \tag{2}$$

The price per unit of product in country A equals the price in country NL plus the trade and transport costs per unit of product. A price drop in country A equals the price drop in country NL.

$$P_A = P_{NL} + T_A \quad and \quad dP_{NL} = dP_A \tag{3}$$

Substituting (3) in (2):

$$E_{P_A}^{NL} = \frac{dQ_A . P_{NL}}{dP_A . EXP_{NL}^A} + \frac{dQ_A . T_A}{dP_A . EXP_{NL}^A} \tag{4}$$

Now we are interested in the first element of the right hand part of (4). This is the price elasticity of demand for NL product and related to NL prices for country A

$$E_{P_{NL_A}}^{NL} = \frac{dQ_A . P_{NL}}{dP_A . EXP_{NL}^A} = E_{P_A}^{NL} - \frac{dQ_A . T_A}{dP_A . EXP_{NL}^A} \tag{5}$$

Rewriting the right hand side of (5) gives:

$$E_{P_{NL_A}}^{NL} = \frac{Q_A}{EXP_{NL}^A} . E_{P_A} - \frac{Q_A}{EXP_{NL}^A} . E_{P_A} . \frac{T_A}{P_A} \tag{6}$$

or

$$E_{P_{NL_A}}^{NL} = \frac{Q_A}{EXP_{NL}^A} . E_{P_A} . \left(1 - \frac{T_A}{P_A}\right) \tag{7}$$

All elements in the right hand part of equation (7) are known, so the price elasticity of demand for the NL product and related to NL prices for country A can be calculated. A similar equation can be deduced to determine the demand price elasticity for other countries to which export takes place.

The total price elasticity of demand for the NL product and related to NL prices equals the weighed average of the demand price elasticities of the markets concerned. The weighing factors are formed by the share of each market in the total supply of product produced by country NL, i.e. the open markets. For three participating countries NL, A and B the total demand price elasticity can be derived as follows.

By definition and without stock changes the total supply of country NL equals domestic consumption minus imports plus exports.

$$SUPP_{NL}^{tot} = (Q_{NL} - I_{NL}) + EXP_{NL}^{A} + EXP_{NL}^{B} \tag{8}$$

Using the weighing factors, total price elasticity of demand equals

$$E_{P_{NL_{tot}}}^{NL} = \frac{Q_{NL}-I_{NL}}{SUPP_{NL}^{tot}} \cdot E_{P_{NL}}^{NL} + \frac{EXP_{NL}^{A}}{SUPP_{NL}^{tot}} \cdot E_{P_{NL_A}}^{NL} + \frac{EXP_{NL}^{B}}{SUPP_{NL}^{tot}} \cdot E_{P_{NL_B}}^{NL} \tag{9}$$

Substitution of (7) and a similar equation for country B in (9) and defining price elasticity of demand for NL product in country NL as

$$E_{P_{NL}}^{NL} = \frac{Q_{NL}}{Q_{NL}-I_{NL}} \cdot E_{P_{NL}} \tag{10}$$

gives the final equation for the calculation of the total price elasticity of demand:

$$\begin{aligned} E_{P_{NL_{tot}}}^{NL} = {} & \frac{Q_{NL}}{SUPP_{NL}^{tot}} \cdot E_{P_{NL}} + \frac{Q_A}{SUPP_{NL}^{tot}} \cdot \left(1 - \frac{T_A}{P_A}\right) \cdot E_{P_A} \\ & + \frac{Q_B}{SUPP_{NL}^{tot}} \cdot \left(1 - \frac{T_B}{P_B}\right) \cdot E_{P_B} \end{aligned} \tag{11}$$

DEDUCTION OF AN EQUATION FOR THE DIVERSION OF EXTRA EXPORT

When some markets are closed, it is first assumed that all other markets experience identical price changes:

$$dP_{NL} = dP_A = dP_B \tag{12}$$

Rewriting (12) gives:

$$\frac{dQ_{NL}.P_{NL}}{E_{p_{NL}}.Q_{NL}} = \frac{dQ_A.P_A}{E_{p_A}.Q_A} = \frac{dQ_B.P_B}{E_{p_B}.Q_B} \tag{13}$$

From (13) follows:

$$dQ_A = \frac{E_{p_A}.Q_A.P_{NL}}{E_{p_{NL}}.Q_{NL}.P_A}.dQ_{NL} \quad and \quad dQ_B = \frac{E_{p_B}.Q_B.P_{NL}}{E_{p_{NL}}.Q_{NL}.P_B}.dQ_{NL} \tag{14}$$

As total change of supply equals the sum of the parts

$$dQ_{tot} = dQ_{NL} + dQ_A + dQ_B \tag{15}$$

the total change of supply amounts

$$dQ_{tot} = \left(1 + \frac{E_{p_A}.Q_A.P_{NL}}{E_{p_{NL}}.Q_{NL}.P_A} + \frac{E_{p_B}.Q_B.P_{NL}}{E_{p_{NL}}.Q_{NL}.P_B}\right).dQ_{NL} \tag{16}$$

As all variables in the right hand part between brackets are known, the ratio of the extra supply per market is given.

HOMOGENEITY OF MARKETS AND REPRESENTATIVITY OF PRODUCTS

It was assumed above that markets are perfectly homogeneous and that only one homogeneous product is sold.

By the homogeneity of a market one means the extent and speed of price adjustment on the market after supply of the product on that market has been changed. If a change of supply leads immediately to an identical price change on all submarkets then this market can be considered fully homogeneous. The other extreme situation exists if a change of supply leads to a very local change of price only, while the price on most submarkets does not react. The homogeneity of a market is influenced by the distances between submarkets, the extent to which information between submarkets is transferred, infrastuctural and geographical conditions, etcetera.

If a fully homogeneous product is sold, the price elasticity of demand for product originating from another country can be derived from the normal price elasticity of demand, as has been done above. This can change if the particular product is the sum of a number of (not fully substitutable) subproducts. If the ratio of subproducts forming the product that is imported differs from the ratio of the total supply (so if the product is not representative), then the price elasticity of demand for product originating from another country cannot be calculated in the way done above. The absolute value of the price elasticity of demand is reduced when exports are less representative on a particular export market (say market A). Therefore homogeneity of a market and homogeneity and representativity of a product are similar entities.

To take into account the homogeneity of a market and the homogeneity and representativity of a product, a homogeneity factor must be given per product and per export market. This factor can vary between 0 (no homogeneity and representativity) and 1 (perfect homogeneity and representativity). If the homogeneity factor is 1, the calculation of the total price elasticity of demand is done as described above. If the factor is 0, the price elasticity of demand for imported product is assumed to be equal to the price elasticity of demand of market A. If the factor is between 1 and 0 the price elasticity of demand for imported product is a linear interpolation between the two extremes. With h_A being the homogeneity factor for market A, equation (7) becomes:

$$E^{NL}_{P_{NL_A}} = \left(1 - h_A + h_A \cdot \frac{Q_A}{EXP^A_{NL}}\right) \cdot E_{P_A} \cdot \left(1 - \frac{T_A}{P_A}\right) \tag{17}$$

This implies the assumption that market A acts as if it is a market with perfect homogeneity but with a changed (lower) price elasticity of demand:

$$E_{P_A} \quad \textit{is replaced by} \quad \left((1 - h_A) \cdot \frac{EXP^A_{NL}}{Q_A} + h_A\right) \cdot E_{P_A}$$

This changed price elasticity of demand is used in all further equations.

Now the explanation of flow chart 1 is continued.

After the aggregate price elasticity of demand and the diversion of extra supply have been calculated, the diversion of extra supply and calculation of the financial consequences for producers takes place as follows.

If intervention of product is not possible the diversion of extra supply and the calculation of financial consequences is done as is illustrated by the example in figure A.1.

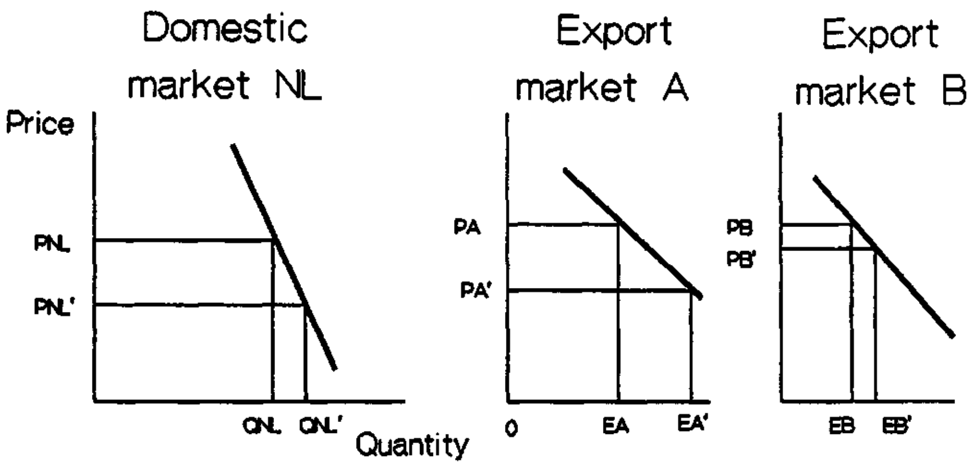
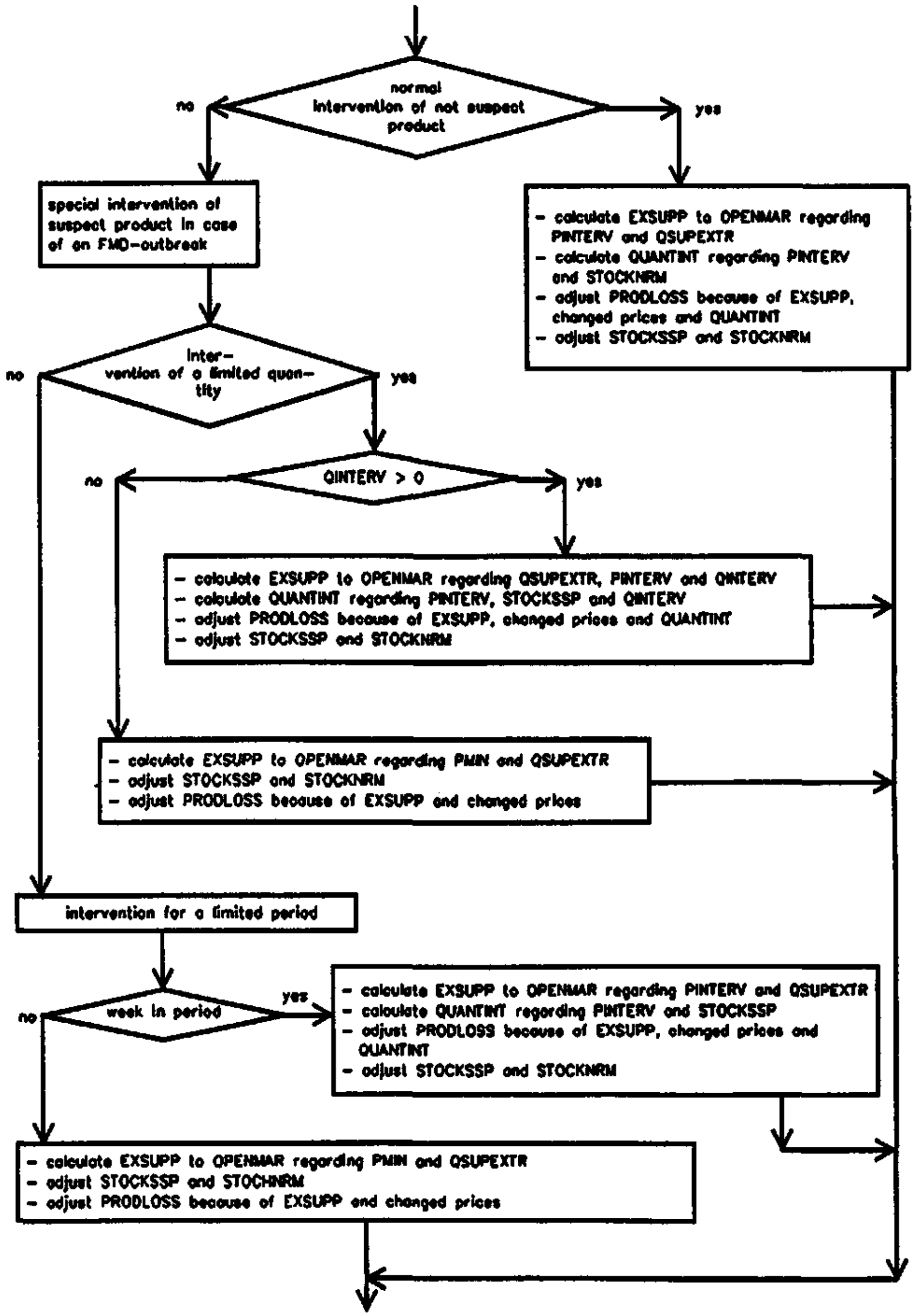


Figure A.1: Example of the way a surplus is diverted to open markets NL, A and C

This figure shows the situation on three open markets before and after additional produce is brought on these markets. The variables referring to the situation afterwards are marked with a apostrophe. To dispose of the surplus, extra supply takes place on each market that is still open and in a ratio as calculated according to equation (16). The price drop on market B (PB-PB') is smaller than on market NL and A. This is caused by the capacity of the export channel to market B. This capacity (EB') limits the extra export. For market A, the capacity of the export channel does not limit the extra export. The amount brought on markets NL and A is limited by either the calculated minimum price or by the size of the surplus. If the minimum price limits the amount of extra supply, the rest of the surplus is added to the stock and will be available the following week.

From the prices and quantities before and after the extra amount is supplied, the financial consequences for the producers can be calculated. The costs of storage are included in these financial consequences. The effects of changed prices for producers and consumers are calculated according to the principles discussed in chapter 3.



Flow chart 2: **The part of the export model that is used if a form of intervention takes place.**

If intervention of produce is possible, a similar procedure as described above takes place (see flow chart 2). In the weeks intervention is possible, the minimum price is formed by the intervention price. Because this procedure is very much like the procedure described above, it will not be explained further.

After the diversion of the surplus has taken place, a check is done to ensure that the total export to countries that only accept produce if it does not originate from the affected region, is not bigger than the stock of normal produce was at the beginning of the week. If the export is bigger than the normal stock, a new series of calculations takes place with limits on the maximum export. If the amount of export tallies with the stock, the gain for consumers (a result of lower prices) and the budget loss (a result of eventual intervention measures) are calculated.

If a surplus for week + 1 exists or the stocks still exist, a new series of calculations is started for week + 1. If neither of both conditions is satisfied, the losses due to export bans as far as this produce is concerned are determined.