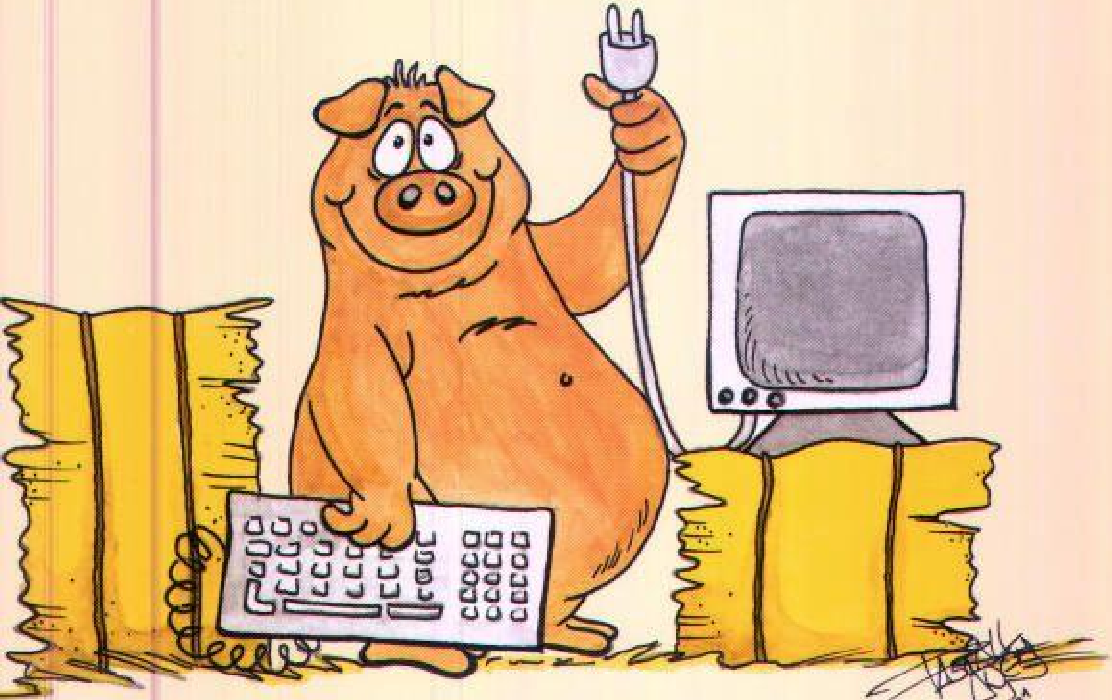
Economic welfare analysis of simulated control strategies for Classical Swine Fever epidemics



M.-J.J. Mangen

Stellingen – Theorems - Stellungsnahmen – Théorèmes

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1. Policy-making with respect to the control of contagious animal disease outbreaks should always consider all impacts on the most affected stakeholders. *(Dit proefschrift)*

2. As long as international agreements allow importing countries to ban live pigs and pork for an extra 6 months from countries that have used vaccination to control a Classical Swine Fever epidemic, an exporting country like the Netherlands should avoid this measure. *(Dit proefschrift)*

3. Decisions on strategies to control Classical Swine Fever epidemics should be made as a function of the pig densities in the infected areas. *(Dit proefschrift)*

4. During an epidemic of a contagious animal disease killing and rendering capacities should be prioritised for stamping-out infected premises and for preventive slaughter of suspected herds. *(Dit proefschrift)*

5. Scientists and decision-makers are better able to weigh the various control strategies for an epidemic if they have both epidemiological and economic models available. *(Dit proefschrift)*

6. Scientific truth, which I formerly thought of as fixed, as though it could be weighed and measured, is changeable. Add a fact, change the outlook, and you have a new truth. Truth is a constant variable. We seek it, we find it, our viewpoint changes, and the truth changes to meet it. *(William J. Mayo, 1861-1939)*

7. Et kann een keng Omelett maachen ouni d'Äer ze briechen. *(Luxemburgse spreekwoord)*

8. Rien de plus fort que la nature, rien de plus vulnérable. *(uit een Kalender)*

9. Im Ausland zu wohnen und zu arbeiten führt zu neuen Erfahrungen, und manche Alltagsgewohnheit des Gastlandes gibt Grund zum Staunen, zur Belustigung oder sogar zur Verärgerung. Fördert aber auch das Vergessen von weniger guten Eigenschaften des Heimatlandes, mit dem Ergebnis für Aussenstehende, dass zu Hause „immer" alles besser ist.

10. Wanneer je beroepsmatig in een voor jou vreemde taal communiceert gebeurt het, vaker dan in je moedertaal, dat je niet correct begrepen wordt.

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Economic welfare analysis of simulated control strategies for Classical Swine Fever epidemics

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Economic welfare analysis of simulated control strategies for Classical Swine Fever epidemics

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Abstract

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A sector-level and trade market model and a generic, spatial, temporal and stochastic epidemiological model are used to simulate the epidemiological and economic effects of different measures to control classical swine fever (CSF) epidemics in different regions in the Netherlands. The control measures include the current EU legislation (stamping-out infected herds; tracing contact herds and installing quarantine zones), preventive slaughtering or an emergency vaccination strategy with delayed destruction and intra-community trade as additional control measures. In addition, the effects of supplementary animal welfare measures to interrupt piglet production during a CSF epidemic are analysed. Different trade scenarios are simulated: a partial trade ban for the quarantine zones only or a total export ban on all Dutch live pigs. Aggregating the welfare changes of the different stakeholders (pig producers, consumers and government) provides results on the net welfare effect for the Dutch economy.

Economic and epidemiological results suggest that measures to control CSF epidemics should be dependent on geographical circumstances. In a sparsely populated pig area, the measures defined by EU legislation are appropriate, whereas in a densely populated area additional control measures, e.g. emergency vaccination and/or preventive slaughter, are needed. The current political climate favours preventive slaughter for the Dutch situation. Furthermore, the option of supplementary animal welfare measures to interrupt piglet production during the epidemic is rejected on economic grounds. Results indicate that rendering capacities should be reserved for carcasses from infected and preventively slaughtered farms, and used to destroy pig carcasses slaughtered for animal welfare reasons only if capacity permits.

Keywords: Classical swine fever; contagious disease; epidemiological model; sector-level market and trade model; simulation; economic welfare analysis; densely and sparsely populated areas; supplementary animal welfare measures; the Netherlands.

Voorwoord

Na mijn afstuderen in Bonn wilde ik niets van een promotieonderzoek weten, drie tot vier jaar leek mij gewoon te lang. Ik haalde liever een tweede MSc-diploma in Nederland, dat was korter. Maar de enthousiaste verhalen van jullie, Marisol en Marie-Francoise, en mijn nieuwsgierigheid naar de wetenschap hebben mijn interesse gewekt. Een korte e-mail naar Wageningen en het was binnen 3 weken geregeld. Aalt en Alien, jullie wisten mij gauw te overtuigen dat een promotie onderzoek ook 2 jaar na het verlaten van de universitaire wereld nog kon, en dat het ook voor mij zou kunnen.

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Marie-José

Contents

Chapter 1

Introduction

1.1 Background

1.1.1 Classical swine fever

Classical swine fever virus (CSFV) is a highly infectious virus. Natural hosts of CSFV are domestic pigs and wild boar. The virus is relatively stable in moist excretions and fresh meat products, including ham and salami type sausages. However, it is readily inactivated by heat, detergents, lipid solvents, proteases and common disinfectants (Moennig, 2000). The diagnosis of classical swine fever (CSF, syn. Hog cholera, European swine fever) based on clinical signs is often difficult as symptoms may vary considerably, depending on the age and/or breed of the affected animals and on the viral strain (Dahle and Liess, 1992; Depner et al., 1996; Terpstra, 1997). Usually young animals are affected more severely than older animals. Mortality rates may reach 90% in young pigs. Under natural conditions the most frequent route by which the CSFV enters its host is oronasal with an incubation period of 7-10 days. Acute and chronic courses of CSF are known. All courses of the infection have in common that the animals are viraemic at least as long as they show clinical signs. Death occurs 2-3 weeks after infection (acute course) or after up to three months (chronic course). The outcome of transplacental infection of foetuses depends largely on the time of gestation and may result in abortions, stillbirths, mummification, malformations or the birth of weak or persistently viraemic piglets (carrier piglets). Although carrier piglets may be clinically normal at birth, they invariably die from CSF. Survival periods of 11 months after birth have been observed (Moennig, 2000).

1.1.2 World situation

CSF is a serious, economically damaging disease of swine that can spread in epizootic form and can also establish enzootic infections in pig populations. It is classified as an OIE List A disease, i.e. every suspected case has to be investigated and once it is confirmed, the outbreak has to be notified. Although most countries with significant pig production have statutory control measures for the disease, the efficacy of these measures varies in accordance with the structure of the sector (contacts, density), the national economy as well as the state of development of veterinary and laboratory infrastructure. Though effective vaccines exist, they do not on their own bring about disease eradication. Any use of vaccine has consequences for the disease status of the country or region (Edwards et al., 2000). The OIE defines the requirements for CSF-free status as follows:

a) Absence of CSF for at least two years in a vaccinated pig population

b) Absence of CSF for one year after slaughter of the last affected animal following a stamping-out campaign with vaccination
c) Absence of CSF for six months after slaughter of the last affected animal following a stamping-out campaign without vaccination.

At the beginning of the 21st century, CSF is still endemic in many parts of the globe. Successful eradication has been achieved in many countries including North America, Australasia, and parts of Northern Europe, and many such countries have successfully maintained freedom in the absence of vaccination resulting in a totally susceptible swine population. By contrast, in most of Africa the situation is uncertain, but the disease is not reported as a problem except in Madagascar (Edwards et al., 2000).

1.1.3 European Union

1.1.3.1 History

When Denmark, Ireland and the UK joined the then EEC, the Community took the national laws of those 3 countries on imports into account, in particular the import ban (a trade barrier) from countries with CSF outbreaks. The new member countries had at that time already eradicated the CSF virus and also ceased vaccination. However, a primary objective of the European Union (EU) was and is to establish free movement of people, capital, services and goods between the Member States. In order to dismantle these barriers to trade the Community decided in 1980 to eradicate CSF from the whole of its territory by applying a common policy of slaughter and gradual abolition of systematic vaccination for the purpose of prevention. The programme involved Community financial aid and was introduced in 1980 together with legislation on the control of the disease. The programme was reviewed in 1985 and since then, the strategy of the non-vaccination policy – eradication of disease and elimination of infection – has been applied. Table 1.1 summarises the number of outbreaks inside the EU over time. The vaccination was stopped in all Member States in the early 1990's (Westergaard, 1991). Despite this, sporadic outbreaks in the domestic pig population have occurred in parts of Europe in recent years. CSF is still endemic in the wild boar population in certain parts in Europe. Epidemiological field investigations confirmed by genetic typing have shown that 59% of the primary outbreaks in German domestic pig herds in the 1990's were due to direct or indirect contact with infected wild boar or wild boar meat (Fritzmeier et al., 2000).

Table 1.1 CSF infected herds from 1960 until 2000 in the EU as well as the date of cessation of vaccination for the different member countries. Data were taken from Laevens (1998) and from Handistatus II of the OIE (2001).

	Country or country group							
Year	NL	D	B	F	I	South[a]	North[b]	EU
1960	1519	404	109	392	900	-	0	3324
1961	1729	2823	215	735	525	-	0	6027
1962	512	2366	1705	1350	407	-	7	6347
1963	974	1553	679	662	838	-	2	4708
1964	782	769	508	722	770	-	0	3551
1965	1117	341	337	123	439	-	0	2357
1966	473	1908	184	44	310	-	0	2919
1967	333	517	283	32	455	-	0	1620
1968	283	142	317	132	99	-	0	973
1969	144	139	402	161	38	-	0	884
1970	917	343	510	132	3	-	2	1907
1971	338	396	93	15	17	-	1	860
1972	164	961	40	84	14	-	0	1263
1973	904	3936	90	62	51	-	0	5043
1974	162	1226	85	119	11	-	0	1603
1975	38	200	3	97	3	-	0	341
1976	42	68	0	47	5	-	0	162
1977	11	202	1	17	48	-	0	279
1978	3	349	0	39	62	-	0	453
1979	0	87	0	28	7	-	0	122
1980	0	18	7	19	0	-	0[b]	44
1981	11	4	37	6	5	20	8	91
1982	65	19	102	8	34	4	1	233
1983	161	535	26	13[c]	48	2	1	786
1984	176	1041	9	19	13	3	0	1261
1985	36	351	67	2	25	1	0	482
1986	1[c]	46	80	20	28	0	10	185
1987	1	41	83	5	13	0	2	145
1988	0	3	2[c]	15	12	0[a]	0	32
1989	0	64[c]	8	0	11	0	0	83
1990	2	118	113	4	15[c]	0	0	252
1991	0	6	0	1	15	0	0	22
1992	5	13	0	1	20	0	0	39
1993	0	105	7	1	12	0	0	125
1994	0	117	48	0	25	0	0	190
1995	0	54	0	0	42	0	2	98
1996	0	4	0	0	49	0	2	55
1997	424	44	8	0	55	78	0	609
1998	5	11	0	0	18	21	0	55
1999	0	415	0	0	9	0	0	424
2000	0	174	0	0	3	0	16	193

a) Column "South" summarises Greece (since 1973) as well as Spain (since 1986) and Portugal (since 1986). The date of cessation of vaccination was 1 January 1988 for Greece, 1 July 1988 for Spain and 1 July 1989 for Portugal.

b) Column "North" summarises Luxembourg (from the beginning), Denmark, Ireland and United Kingdom (since 1973) as well as Austria, Finland and Sweden (since 1995). All of those countries stopped vaccination before 1980.

c) Preventive vaccination was stopped during the indicated year.

1.1.3.2 Currently applied EU CSF legislation

The current European-wide CSF legislation assumes that in the case of an epidemic, quarantine zones[1] around an outbreak are based on geographical and epidemiological principles, and take no account of national boundaries between the Member States. Following a limited outbreak, a protection zone is established of a minimum of 3 km radius around the disease focus and a further surveillance zone for a minimum 7 km beyond that (i.e. 3-10 km from the disease focus). Within these quarantine zones the measures include a census of pig holdings, official veterinary inspections, and movement controls on pigs. In the case of a more extensive outbreak, and subject to approval by the Standing Veterinary Committee of the EU, the control measures are extended as a safeguard to include a buffer zone around the quarantine zone. Where multiple disease episodes have occurred in a region, it may be appropriate to merge adjacent quarantine zones to achieve control over a wider area. This regionalisation (again based on geography and epidemiology, rather than national territories) is used for the following: to apply strict controls to a quarantine area within the EU in order to control and eradicate the disease; to prevent spread of disease from the quarantine area; and to permit free movement of pigs and pig products outside the quarantine area. Stamping-out of infected herds and imposing quarantine zones is, in short, the current applied EU legislation. Preventive slaughter on neighbouring farms may be applied as an additional control measure. Preventive vaccination is prohibited in the EU and emergency vaccination during an epidemic is allowed under certain strict restrictions (see directive 80/217/CEE, article 14). Emergency vaccination might have a serious impact on the national economy through exports bans of live pigs and pig meat and has not been applied during the last twenty years in the EU to eradicate a CSF epidemic in the domestic pig population.

1.2 Motivation and objectives of the thesis

Stamping-out of infected herds and imposing quarantine zones is the current EU legislation and as such also obligatory for the Netherlands. Yet, sporadic epidemics in the 1990's in Belgium and Germany as well as the 1997/1998 Dutch CSF epidemic demonstrated that these measures might not always be suitable for a quick eradication of the disease, at least not in high-density populated livestock areas[2] (DPLA). In the Dutch CSF epidemic only the introduction of preventive slaughter as an additional control measure could cut down the disease spread (Elbers et al., 1998). In the future the development of a marker vaccine that

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[1] Hereafter "quarantine" zones refer to all restricted zones/areas (protection zone (0-3 km) and surveillance zones (3-10 km)) in which movement restrictions and control measures are imposed.

[2] In the context of CSF only one livestock species is considered: pigs.

permits vaccinated pigs to be distinguished from infected pigs by a serological test, which was impossible previously, may offer new opportunities for control. The introduction of a marker vaccine during a CSF epidemic in a DPLA had already been suggested by different people (Van Oirschot, 1994; Leopold-Temmler, 1996; Vågsholm, 1996; Jorna, 1997) even before the vaccine was available on the EU market. Finally, the large-scale slaughtering and rendering of healthy growers (25-kg piglets) and fatteners during the 1997/1998 Dutch CSF epidemic — a destruction of economic resources and human food — has aroused public opinion and ethical opposition, which have forced the EU to revise the CSF legislation. The EU authorities, in co-operation with the member states, are currently (2001) working on a revised CSF legislation.

People involved in CSF control strategy decision making are faced with many uncertainties, both epidemiological as well as economic and political. Epidemiological uncertainties involve the development of the epidemic as well as the expected efficiency of the applied control strategies. Economic uncertainties are the direct control costs, but also the indirect costs for the different stakeholders affected, whereby political and public uncertainties may play a role. The possibility of export bans set by other countries due to economic, political and/or public acceptance may result in possible market disruption for the whole sector involved. Despite these uncertainties, decision makers have to decide on what control strategy to apply. However, where can information be gathered on experience on how to behave adequately? Contagious disease outbreaks happen only sporadically, and experimenting with control measures would be too costly and too disruptive to the sector involved. For these reasons it is preferably to build a model as a representation of the "system" and study it as a surrogate for the actual system (Law and Kelton, 1991). In our study this "system" has to represent the Dutch pig herd population and also the Dutch pig sector and all stakeholders affected by possible trade restrictions.

Therefore the main goals of this thesis were: 1) to further develop an existing epidemiological model that simulates the spread of the virus between farms and permits a comparison of control measures of interest; 2) to develop an economic model that calculates not only the direct control costs of the animal health authorities but also the indirect costs for Dutch society as a whole, whereby different market scenarios are considered; and 3) with the help of these models, to analyse possible control strategies that might be applied in an epidemic and to give recommendations, on epidemiological and economic grounds, concerning which control strategies to apply in future epidemics.

1.3 Outline of the thesis

Chapter 2 focuses on possible emergency vaccination strategies that might be applied during an epidemic, using an existing epidemiological simulation model, InterCSF_v1. The 1997/1998 CSF epidemic in the Netherlands is used as an illustration of a possible epidemic in which emergency vaccination could have been applied as an additional control measure. We also use existing economic tools (Meuwissen et al., 1999) in which we implement additionally the cost of the vaccine and the vaccine application costs. Requests from the public sector and private industry as well as public debate on the use of a marker vaccine during the 1997/1998 Dutch CSF epidemic determined our decision to start with this subject at the beginning of the research project. Consequently, already existing tools were adapted for this purpose. The remaining chapters in the thesis use new tools that were developed within this research project.

Knowledge of Dutch consumer behaviour regarding demand for meat and fish is needed before being able to build an economic model to calculate the indirect costs for Dutch society as a whole (second objective of this study). Questions that need to be answered are: is there an adverse consumer reaction to pork during a CSF epidemic in the Netherlands; are there significant meat substitutions for pork; and what are the pork price elasticities? In Chapter 3 we therefore investigate the changing preferences of Dutch consumers for meat and fish using a switching almost ideal demand (AID) system (Moschini and Meilke, 1989).

The economic framework that is developed for the second objective of this study is described in the first part of Chapter 4. EpiPigFlow, a micro-economic model, calculates the weekly flow of pigs, and thus links InterCSF outputs with a simulation model of the Dutch pig market (Dupima). Dupima calculates market prices and trade flows, whereas EpiCost, also a micro-economic model, calculates the control programme costs and changes in producer surplus within a quarantine zone. EpiPigFlow and EpiCost are written in C++, whereas Dupima is written in GAMS. Using the results of EpiCost and Dupima, an economic welfare analysis for the Dutch economy is performed in an Excel spreadsheet. In the second part of Chapter 4 we calculate the net welfare effect for the Dutch economy for the simulated specific 1997/1998 Dutch CSF epidemic, simulating three different trade scenarios. Results of the epidemiological simulation model, InterCSF_v1, of Jalvingh et al. (1999) were linked with the developed economic framework to obtain the net welfare effect for the Dutch economy for this specific epidemic.

All adaptations made in InterCSF to obtain a more generic epidemiological simulation model, InterCSF_v3, are described in the first part of Chapter 5. Development of this model was the first objective of this thesis. For the generic study, the epidemic is started in 2 different areas in the Netherlands, including the locations and size of the Dutch pig herd population of the year 2000. Sensitivity analysis is carried out with InterCSF_v3. In the second part of chapter 5 we analyse possible control measures for a sparsely populated livestock area (SPLA) and a densely populated livestock area (DPLA) in the Netherlands, using the economic tools described in Chapter 4 as well as the adapted epidemiological model, InterCSF_v3. Based on epidemiological and economic grounds, we give some recommendations (third objective of this thesis) on which control strategies to apply in future epidemics in a DPLA or an SPLA.

In chapter 6 we analyse the epidemiological as well as the economic consequences of the use of supplementary measures to reduce later animal welfare problems on farms in an epidemic in a DPLA, using the modelling framework developed and described in Chapters 4 and 5. Insemination prohibition, forced abortion of pregnant sows and the killing of very young piglets are such supplementary measures. We also want to know when to decide to use these supplementary measures, whereby our hypothesis was that only in large and long-lasting epidemics might these non-ordinary supplementary measures be useful.

In Chapter 7 we discuss the major findings and the applied method and models as well as the shortcomings of those models. We also provide some directions for future research. Finally, in the last section of chapter 7 we summarise and discuss the main conclusions and give recommendations for future epidemics.

Chapter 2

Spatial and stochastic simulation to compare two emergency-vaccination strategies with a marker vaccine in the 1997/98 Dutch Classical Swine Fever epidemic

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Abstract

Two alternative emergency-vaccination strategies with a marker vaccine that could have been applied in the 1997/98 Dutch Classical Swine Fever (CSF) epidemic were evaluated in a modified spatial, temporal and stochastic simulation model, InterCSF. In strategy 1, vaccination would only be applied to overcome a shortage in destruction capacities (killing and rendering). Destruction of all pigs on vaccinated farms distinguishes this strategy from strategy 2, which assumes intra-community trade of vaccinated pig meat.

InterCSF simulates the spread of CSF between farms through local spread and 3 contact types. Disease spread is affected by control measures implemented through different mechanisms. Economic results were generated by a separate model that calculated the direct costs (including the vaccination costs) and consequential losses for farmers and related industries subjected to control measures. The comparison (using epidemiological and economic results) between the different emergency-vaccination strategies with an earlier simulated preventive-slaughter scenario led to some general conclusions on the Dutch CSF-epidemic. Both emergency-vaccination strategies were hardly more efficient than the non-vaccination scenario. The intra-community trade strategy (vaccination strategy 2) was the least costly of all three scenarios.

2.1 Introduction

When all regular measures to eradicate an CSF-epidemic fail, paragraph 14 of the directive 80/217/EEC of the EU legislation foresees an emergency-vaccination (CEC, 1980). In the case of an emergency vaccination, the same directive forces the member state to exclude all meat originating from vaccinated pigs (except when heat treated) from the regular pork market. In the last decade, some severe CSF-epidemics occurred in the EU, but no emergency vaccination was applied. In 1994, the German proposal for an emergency vaccination was refused by the European Commission (Blaha, 1994). During the 1997/98 Dutch CSF epidemic (hereafter referred as the Dutch CSF epidemic) in the Netherlands, emergency vaccination was only proposed at the national level (Jorna, 1997) mainly on ethical grounds.

The use of a marker vaccine to help control a CSF outbreak seems to be technically feasible (Van Oirschot, 1994; Leopold-Temmler, 1996; Vågsholm, 1996; Jorna, 1997), including serological test to distinguish infected pigs from vaccinated pigs. Changes in the swine herd structure combined with high-density pig populations incur logistic and organisational problems, as well as high costs, when adopting a regular stamping-out policy to eradicate an epidemic. Public objections against the destruction (killing and rendering) of healthy animals increase as well. Those factors are in favour of emergency vaccination. On the other hand, EU policy aims a high animal health status and therefore has adapted a non-vaccination policy for the control and eradication of animal diseases of major importance for international trade. In brief, the use of vaccine "means" the presence of disease (Westergaard, 1996).

Epidemiological, political and economic advantages and disadvantages have to be analysed and clarified before being able to decide if the use of marker vaccine is a realistic and attractive option. We improved the simulation model InterCSF, which was developed to simulate the Dutch CSF epidemic, (Jalvingh et al., 1999) by adding emergency-vaccination as a disease-control mechanism. InterCSF specifically was developed to answer "what-if" questions (Nielen et al., 1999). Vaccination costs were incorporated in EpiLoss (Meuwissen et al., 1999) for the present study, to be able to calculate the direct costs and consequential losses for farmers and related industries subjected to control measures.

The main goal of this chapter was to analyse the epidemiological and economic consequences of two possible emergency-vaccination campaigns that could have been used in the Dutch CSF epidemic. They are compared with an earlier simulated preventive-slaughter strategy (Nielen et al. 1999), which we will call (in this chapter) the "non-vaccination" (NV) scenario.

2.2 Material and methods

2.2.1 General outline

InterCSF is a spatial, temporal and stochastic simulation model (Jalvingh et al., 1999). InterCSF simulates disease spread from day to day from infected farms through 3 contact types (animals, vehicles, persons) and through local spread up to 1000 m. All Dutch pig farms are known by their geographical co-ordinates. The main disease-control mechanisms that influence the disease spread in InterCSF are: diagnosis of the infected farms, depopulation of infected farms, quarantine zones[1], tracing and preventive slaughter (see Appendix I for more details).

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[1] Hereafter "quarantine" zones refer to all restricted zones/areas (protection zone (0-3 km) and surveillance zones (3-10 km) in which movement restrictions and control measures are imposed.

Emergency vaccination was incorporated in the base scenario such that it reflected the start situation of the real epidemic as closely as possible. This involved incorporating historical data of 37 farms with an infection date before February 4 1997 (detection date of first farm) and fixed detection and herd-destruction dates later. New infections were simulated only after this date. In our simulations we assumed that after 5 detections in the first week, emergency vaccination would be ordered. In a densely populated area epidemiologists expect a large epidemic if there are at least 5 detections in the first week. In 1997, the first outbreak happened in a very densely populated pig area and 9 outbreaks were notified in the first week after the first detection (Elbers et al., 1999). In our simulation, the emergency-vaccination campaign was initiated 5 days after the decision on day 6 (assuming 5 days of preparation for a vaccination campaign). When the decision to start with the emergency-vaccination campaign was taken, all earlier-detected farms from the previous week were identified. In the base vaccination scenarios, a vaccination zone with a radius of 3 km was defined for each detected farm. To mimic restricted vaccination capacities, all defined vaccination zones were put on a vaccination list and all further-defined vaccination zones were listed also. If more than one new vaccination zone was defined on the same day, they were sorted depending on their pig-farm density, starting with the highest pig-farm density. We further assumed that emergency vaccination would be stopped based on certain criteria (defined later on in chapter).

Vaccination zones are vaccinated one by one - not in parallel - by 150 vaccination teams. Each vaccination team (1 veterinarian and 4 helpers) was supposed to handle about 2000 pig places (fatteners[2] and gilts[3]) or 465[4] farrowing places per day (or various equivalent combinations).

2.2.2 Vaccination effects

Vaccination has two effects: reduction in virus spread of an infected farm and protection against infection of a susceptible herd.

For virus reduction on an infected farm, two kinds of infected farms were distinguished. The first category consisted of infected farms that were never vaccinated and of farms that were

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[2] A fattener is a finishing or fattening pig, also called hog (from 45 kg until killed).

[3] A gilt is a female pig from 20-30 kg live weight until first insemination.

[4] Assuming 21.5 piglets/breeding sow/year, which is equal to 0.059 piglets born/breeding sow/day. We assume that a piglet will stay on a sow farm for 70 days. Because pigs need to be 14 days old for vaccination, we will have (0.059*56 days =) 3.30 piglets/farrowing place and 1 sow/farrowing place to vaccinate

first infected and later vaccinated. The second category was farms that were vaccinated and became later infected.

For the first category of infected farms, we assumed no reduction in virus spread. All parameters remained as described in Jalvingh et al. (1999). In short, the infectious period started between 5 and 10 days after infection. The infectivity of the farm remained the same for the total infectious period, which ended on the day that the farm was depopulated. The interval between infection and detection was modelled with a single probability distribution, based on observations of the real Dutch CSF epidemic. The selected interval could be influenced downward by certain events (see Table 2.1). The detection probabilities of non-vaccinated farms were used as a base to estimate the detection probabilities for all vaccinated farms (Table 2.1). Vaccination as such could also influence detection because infected farms could be detected earlier due to clinical inspection on the vaccination day. The detection probability depended on the time since infection and the source of infection (Table 2.2). For a direct animal contact we defined a higher probability of detection for the first weeks after infection than for all other contacts. If an infected farm was not detected during vaccination, we assumed that the virus was spread mechanically and massively over the farm during vaccination. After the incubation time of 1 week, the large number of sick animals could again lead to a possible earlier detection (Tielen; Personal communication). In both cases, we assumed that 2 days after suspicion, the diagnosis was established. For all other events, more time consuming tests are necessary; so, we defined 7 days after suspicion before diagnosis would be given (de Smit et al, 1999). For vaccinated farms infected after vaccination (the second category), a reduction in virus spread was expressed by a reduction factor. This reduction factor depended on the time interval between vaccination and infection and was modelled with a probability distribution, based on EU experiments (Appendix II). The reduction factor was multiplied by the probabilities of transmission for a simulated contact and for local spread.

For the farms in the second category, we assumed no change in the latent period but the infectious period was reduced to at most 1 month. Only small outbreaks typically are expected on vaccinated farms. Assuming that vaccinated pigs show no or few clinical signs when infected, detection could only be by serological screening (Table 2.1).

Susceptible farms also were classified in two categories: non-vaccinated and vaccinated farms. We defined a non-vaccinated susceptible farm as one without protection against a possible infection, whereas a vaccinated susceptible farm was partly protected. The degree of protection depended on the time interval between vaccination and a possible infection and

Table 2.1 Probability of detection based on a control event (such as traced contacts, surveillance, preventive slaughter, end-screening and animal welfare slaughter) depending on the time since infection and the farm specific vaccination status in a quarantine zone

Time since infection (days)	Probability of detection by control event (diagnosis date 7 days after event)														
	Traced contacts[a]			Surveillance (3 km radius)[a]			Preventive slaughter[a b]			End-screening[b]			Welfare slaughter[b]		
	NV[c]	IV[d]	VI[e]	NV[c]	IV[d]	VI[e]	NV[c]	IV[d]	VI[e]	NV[c]	IV[d]	VI[e]	NV[c]	IV[d]	VI[e]
0 – 14	0	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0
15 – 28	1	1	0	0	1	0	1	1	0.5	0.25	1	0.5	0	1	0.5
29 – 42	1	1	0	0.25	1	0	1	1	1	0.5	1	1	0	1	1
> 42	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1

a) Based mainly on clinical inspection.

b) Based mainly on serology.

c) NV: No vaccination; farm already has an (undetected) infection (Jalvingh et al., 1999).

d) IV: Vaccination of a farm already infected (but not yet detected).

e) VI: Vaccination of a farm which later becomes infected.

was expressed as a protection factor, modelled by a probability distribution (Appendix II). Similar to the reduction factor, the protection factor was multiplied by the probabilities of transmission for a simulated contact and for local spread. However, if an infectious pig was moved to a susceptible vaccinated farm, the protection factor was not considered. We assumed that this farm always became infected but could hardly ever become infectious.

Table 2.2 Probability of detection due to vaccination, relative to the time since infection on an (undetected) infected farm and depending on the source of infection

Time between infection entrance and vaccination (days)	Probability of detection related to vaccination (diagnosis date 2 days later)		
	Vaccination day[a]	Vaccination day[b]	1 week after vaccination
0 – 14	0.25	0.05	0.9
15 – 28	0.9	0.5	0.95
29 – 42	0.99	0.9	1
> 42	0.99	0.99	1

a) Farm infected by direct animal contact.

b) Farm infected by transport or person contact.

In the EU field experiments, horizontal transmission was significantly reduced 3 weeks after vaccination for both marker vaccines (Anonymous, 1999). In our base emergency-vaccination scenarios, we assumed that maximum protection and reduction was reached after 21 days. For sensitivity analysis, this time interval was reduced by 5 days to 16, as well as increased by 5 days to 26 days (Appendix II). In an additional analysis, only 1 week was assumed to be needed to build up the maximum protection level (simulating a live-virus vaccine).

2.2.3 Delayed-destruction alternatives

The first emergency-vaccination strategy (called "delayed-destruction" (DD)), assumed no political acceptance of vaccinated pig meat as fresh meat (i.e. the current EU policy). Vaccination would only be applied to overcome a shortage in destruction (killing and rendering) capacity, created by regularly applied control measures. Because vaccination will reduce the risk of virus spread the destruction of the vaccinated farms can be postponed until destruction capacity is available. All pigs in the vaccination zone needed to be destroyed (slaughtered and rendered) before the end-screening could be applied to declare the region free again of CSF. All pigs older than 14 days were vaccinated once. We assumed that vaccinated pigs had maximum protection for at least 6 months. If they were not slaughtered within 6 months, the pigs would be re-vaccinated to keep maximum protection.

As soon as a vaccination zone was defined, all farms inside this vaccination zone were put on the preventive-slaughter list. Priorities were set to deal with the insufficient destruction capacities. First, all farms located in the regular preventive-slaughter radius (1 km) and contact farms were destroyed. This group was further split up. Farms not predestined for vaccination had the highest priority, followed by farms where vaccination was not yet applied and finally vaccinated farms. In the category of the vaccinated farms, higher priority was given to farms without maximum protection. The second category consisted of farms lying in the vaccination zone (0-3 km), but outside the regular preventive-slaughter zone (0-1 km). Here again, the highest priority was given to non-vaccinated farms, followed by vaccinated, not maximum-protected farms and finally maximum-protected farms. Those priorities are handled over all the zones, whereby inside a subgroup, the farms of an older zone had priority to be destroyed. The decision criterion for stopping emergency vaccination depended on the delay caused by destruction capacities. The number of farms notified for preventive slaughter (including vaccinated farms) was divided by the daily destruction capacity to obtain the number of days needed for destruction of all those farms. When the delay was ≤ 3 days during a period of 14 days, no new vaccination zones were installed.

The installation of a breeding prohibition in a defined vaccination zone and the culling of newborn piglets on the vaccinated farms (not simulated as such) allowed the assumption that the pig population on vaccinated farms retained maximum protection. The implementation costs for both control measures were considered when calculating the costs and losses.

In the base scenario (DD-0), we assumed maximum vaccine protection in 21 days, 5 days of preparation, a 1 km preventive-slaughter zone and a vaccination radius of 3 km for each detected farm. In alternative scenarios (Table 2.3), we assumed that time to build maximum protection was reached in 1 week, 16 days or 26 days. In further sensitivity analysis, the time needed to prepare the emergency-vaccination campaign was changed from 5 days to 2 days (alternative I), to 8 days (alternative II) or to 25 days (alternative III). In alternative IV, the vaccination radius was reduced to 1 km instead of the 3 km, and alternative V assumed a 500 m regular preventive slaughter radius.

Table 2.3 An overview of the various alternatives for both emergency vaccination strategies: the Delayed Destruction strategy (DD) and the Intra-Community Trade strategy (ICT)

Assumption		DD - x[a]	ICT - x[a]
Preparation time	**5 days**	**0 (base)**	**0 (base)**
	2 days	I	I
	8 days	II	II
	25 days	III	III
Vaccination radius	**3 km**	**0 (base)**	**0 (base)**
	1 km	IV	IV
Preventive-slaughter radius	**1000 m**	**0 (base)**	-
	500 m	V	-
Applying preventive slaughter	**No**	-	**0 (base)**
	Yes	-	VI[b]

a) x stands for 21 (base) respectively 7, 16 or 26 days needed to build up maximal protection.

b) Preventive slaughter is only applied to non-vaccinated farms in a radius of 1 km.

2.2.4 Intra-community trade alternatives

For the second emergency-vaccination strategy (the intra-community trade strategy (ICT)), we assumed that after removing the quarantine zone, pig meat originating from vaccinated pigs could be sold on the EU market. However, we assumed that for the vaccination zones, a so-called "post-vaccination zone" was installed for 4 months at the moment the quarantine zone was lifted. All movements were allowed, except that live pigs could leave this zone only directly to slaughter in specific slaughterhouses. This supplementary measure should convince all trading partners that no live carrier piglets could leave the vaccination zone to spread the disease, in case an infected sow was overlooked during the serological screening. In the ICT strategy, emergency vaccination was stopped when there were less than two new detections during the previous 4 weeks.

In the ICT strategy, all pigs older than 2 weeks in a vaccination zone (0-3 km) were vaccinated once similar to the DD strategy. In addition, we imposed (for the duration of the quarantine zone in a vaccination zone) that all newborn piglets and also all breeding sows would be re-vaccinated. These measures would assure a maximally protected pig population. The emergency-vaccination capacities were not influenced by the continued vaccination, because we assumed that the local veterinarians carried out the re-vaccinations. A further assumption was that maximum protection of vaccinated farms would last for the total duration of a post-vaccination zone. After the ending of the post-vaccination zone, all farms lost their protection.

With the ICT strategy, vaccination reduces the susceptible pig population so preventive slaughter is optional and not applied in the base scenario. If preventive slaughter is applied, only non-vaccinated farms would be destroyed (alternative VI, Table 2.3).

For the base scenario (ICT-0), maximum protection was reached in 21 days, no preventive slaughter was applied, a vaccination radius of 3 km was installed for each detected farm and 5 days of preparation were needed before the start of the emergency-vaccination campaign. Alternative scenarios were simulated for sensitivity analysis, similar to DD (Table 2.3).

2.2.5 Vaccination costs

Related to vaccination were various additional control costs, above the cost per dose vaccine per pig. They consisted of preparation, travel and bio-security costs for the vaccination teams, and costs for the application of the vaccine. In case of the ICT strategy, the continued vaccination caused some more costs. Table 2.4 summaries all vaccination related costs in detail.

All sows on vaccinated farms should be tested to reduce the probability that a carrier piglet goes undetected before an area can be declared CSF-free. Despite this, we used the same lump sum (for comparison reasons) for serological costs as Meuwissen et al. (1999). Further we assumed that the discriminatory test would cost the same as the conventional one.

2.2.6 Comparison of alternatives

To compare the alternatives, both epidemiological and economic parameters were used. InterCSF simulated the spread and the control of the epidemic, whereby different events (summarised in Appendix III) related to economic costs and losses could occur. Vaccination was added as a new event. Breeding prohibition and killing of newborn piglets were applied only for the DD strategies. For each individual farm subjected to control measures, InterCSF wrote events per day to an event-output file. This event-file was used as input for EpiLoss, which calculated the total costs and losses for the epidemic (Meuwissen et al., 1999). Vaccination related costs (actually direct costs) were considered for comparison reasons as a separate cost factor.

Similar to Nielen et al. (1999), a two-tailed, two-sample Student's t-test with unequal variance was performed on mean final outcomes of the 100 replications per scenario, to test whether alternatives varied significantly from each other or from the non-vaccination scenario (NV). To correct for multiple comparisons, a Bonferroni correction was applied on a significance level of 0.05 (Jones and Rushton, 1982). Final outcomes that were compared were the mean total losses and the mean total number of infected farms, detected farms, preventively slaughtered farms and vaccinated farms. Testing was performed using SPSS software (version 8.02).

Table 2.4 The vaccination-related costs

Description of the costs		€ /farm or pig
1. Bio-security cost and transport during the emergency vaccination:		
- Material needed for a farm visit (Overalls, sterile materials (no re-use))[a]		~ 45.4 € /farm
- Preparation needed for a farm visit (1/2 h * (25.0 € /h + 17.5 % B.T.W.)[a]		16.8 € /farm
- 1 hour for transport and hygiene measures (4 helpers (33.6 € /h [a]) and 1 veterinarian (74.4 € /h [b]))		213.3 € /farm
	Total:	~ 272 € /farm
2. Vaccine and vaccination application during the emergency vaccination:		
- Vaccine		2.27 € /pig
- Application (2000 pigs/ vaccination group/ 8 hours) (4 helpers * 33.6 € /h [a] * 8 h + 1 vet. * 74.4 € /h [b] * 8)		0.83 € /pig
	Total:	3.10 € /pig [c]
3. Costs for continued vaccination (only for ICT)[d]:		
- Vaccine		2.27 € /pig
- Vaccination application		0.45 € /pig
- Veterinary visit (20.42 € /farm [b])		0.07 € /pig
- Bio-security cost (no helpers) (45.4 € /farm [a])		0.16 € /pig
	Total:	2.95 € /pig [e]

a) Consulting specialist from Animal Health Service, Boxtel, The Netherlands (1999).

b) Royal Netherlands Veterinary Association (1998).

c) It will be 3.10 € /fattener or gilt place and 13.34 € /farrowing place (1 breeding sow + 3.30 piglets).

d) Assuming an average sow herd of 150 breeding sows. Vaccination of new-born piglets and re-insemination of breeding sows will probably happen only once per month. In that case 292 pigs (piglets and breeding sows) will be re-vaccinated each month.

e) 2.95 € /treated pig * 0.065 treated pigs/day = 0.19 € /farrowing place/day; 0.065 treated pigs = 0.006 breeding sow/ day + 0.059 newborn piglets/sow/day.

2.3 Simulation results

Nielen et al. (1999) compared the real Dutch CSF epidemic with various alternative eradication strategies, all simulated with the InterCSF model (Jalvingh et al., 1999). All simulated strategies were performed 100 times, in which the simulation time was set at maximum 1 year. The most-effective scenario according to Nielen et al. (1999) was to start preventive slaughter in a radius of 1 km from the day of the first detection (the so-called "preventive-slaughter scenario"; in this chapter called the "non-vaccination scenario" (NV)). Complete results were shown in Nielen et al. (1999) and are partly shown in Tables 2.5 and 2.7. In the real epidemic, preventive slaughter of the neighbouring farms was only applied for the first 2 detected farms, stopped and re-started two months later for all newly detected farms (LNV, 1998). Table 2.5 recalls the most important key features of the real epidemic, the simulated epidemic and the NV. We chose the NV as the base scenario with which to compare all emergency-vaccination strategies. In the future, preventive slaughter would most likely be applied from the beginning making this scenario the best comparison for our simulated emergency-vaccination scenarios.

In Table 2.6, we compare the two base emergency-vaccination strategies with the NV scenario and with each other. Furthermore, all emergency-vaccination alternatives were compared to the corresponding base emergency-vaccination strategies. In total, 38 t-test comparisons were performed, which set the P-level for a significant difference between means to 0.001316 (0.05/38).

Table 2.5 Some key features of the real Dutch CSF epidemic, the median of the simulated epidemic and the median of the non-vaccination scenario [a] (Jalvingh et al., Nielen et al., 1999)

Real Dutch CSF epidemic or simulated scenario	Key features (median for simulations)				
	Number of farms			Duration	Costs
	detected	infected	preventive sl.	(in days)	(10^6 €)
Real Dutch CSF epidemic	429	?	1247	>365	2124
Simulated Dutch epidemic	374[b]	464[b]	743[b]	306	1137[c]
Non-vaccination scenario	70	99	450	164	590[c]

a) The preventive-slaughter scenario from Nielen et al. (1999) is in this chapter called the "non-vaccination scenario" (NV).

b) Numbers differ slightly from Jalvingh et al. (1999), due to some minor adaptations of InterCSF.

c) Numbers are slightly higher than in Jalvingh et al. (1999) and Nielen et al. (1999), because quarantine zones had been erroneously lifted 1 day too early for some farms in the initial EpiLoss.

2.3.1 Delayed destruction alternatives

Compared to the NV scenario, DD strategies (Tables 2.6 and 2.7) reduced both the number of infected and detected farms, but not significantly. The duration of the epidemic was sharply reduced (for example, the median decreased from 164 days to 108 days for DD-21-0). The number of preventively slaughtered farms was significantly increased by a factor of almost four. The total costs and losses were comparable, except for the extreme replications. In the case of DD, the worst cases showed smaller epidemics. The composition of the cost factors varied between the NV scenario and the DD scenario. The direct costs for preventive slaughter in the case of the DD vaccination scenario were nearly three-times higher. The consequential losses for the farmers increased, but the direct cost for animal welfare slaughter measures was sharply reduced. Compensation paid to the farmers for the breeding prohibition, as well as vaccination costs, were extra costs compared to the NV scenario.

The results of the different DD alternatives, including the base version (DD-21-0) of this scenario, are shown in Tables 2.6-2.9. There was no significant difference in the size of the epidemic, when maximum protection was changed from 21 days to 7, 16 or 26 (Tables 2.6 and 2.8). The effect of preventive slaughter according to the vaccination-related priorities was apparently greater than the vaccine efficacy.

In the base DD scenario (DD-21-0), we assumed 5 days of preparation before the emergency vaccination actually started. In alternatives I, II and III, we assumed respectively 2, 8 and 25 days to prepare an emergency-vaccination campaign, following the decision on day 6. A longer preparation time only showed a larger epidemic for the worst iterations (Table.2.8). There was no significant difference in the number of detected farms, the number of infected farms, the number of preventively slaughtered farms or in the costs when comparing the simulated alternatives with the base DD scenario (Tables 2.6 and 2.8). Comparing alternatives I, II and III with the NV scenario, the number of preventively slaughtered farms were always significantly higher.

By changing the vaccination radius from 3 km to 1 km (alternative IV), the number of detected farms was slightly but not significantly higher compared to the base DD scenario (Tables 2.6, 2.8 and 2.9). Except for the worst iterations, the duration of the epidemic was the same (results not shown), but the number of preventively slaughtered and vaccinated farms was significantly lower leading to lower costs (compared to the base DD scenario). The 1-km vaccination alternative was significantly less costly than the NV scenario (1-km preventively slaughter) mainly due to the shorter duration of the epidemic.

Table 2.6 Results of multiple comparisons (t-tests) between the results of the basic scenario, non-vaccination and the different emergency vaccination alternatives as calculated in InterCSF. The compared mean outcome parameters were: the number of infected farms (I), the number of detected farms (D), the number of preventive-slaughtered farms (P), the number of vaccinated farms (V) and the total losses (C), applying the Bonferroni corrected significance level [a]. Significantly different parameters are shown for comparison.

Scenario	97/98 simulated CSF epidemic	NV	DD-21-0	ICT-21-0[b]
Non-vaccination scenario				
NV[c]	I,D,P,C	-[d]	-	-
Delayed destruction alternatives				
DD-21-0	I,D,P,V,C	I[e],P,V	-	-
DD-7-0	-	I[e],P,V	n.s.[f]	-
DD-16-0	-	I[e],P,V	n.s.	-
DD-26-0	-	I[e],P,V	n.s.	-
DD-21-I	-	I[e],P,V	n.s.	-
DD-21-II	-	I[e],P,V,C[e]	n.s.	-
DD-21-III	-	I[e],P,V	I[e]	-
DD-21-IV	-	V,C	P,V, C[e]	-
DD-21-V	-	I[e],P,V	n.s.	-
Intra-community trade alternatives				
ICT-21-0	I,D,P,V,C	I[e],P,V,C	P,C	-
ICT-7-0	-	I[e],P,V,C	-	I,D,C
ICT-16-0	-	I[e],P,V,C	-	n.s.
ICT-26-0	-	I[e],P,V,C	-	n.s.
ICT-21-I	-	I[e],P,V,C	-	n.s.
ICT-21-II	-	I[e],P,V,C	-	n.s.
ICT-21-III	-	P,V,C[e]	-	I,D,V,C
ICT-21-IV	-	I[e],P,V,C	-	I[e],D[e],V
ICT-21-VI	-	I[e],P,V,C	-	P

a) Bonferroni corrected significance level for the two-tailed test was 0.001316, based on 38 comparisons for $P < 0.05$.

b) In case of ICT, preventive slaughter is with one exception (alternative VI) never applied.

c) Vaccination was not applied in the simulated Dutch CSF epidemic and in the NV scenario.

d) Not tested.

e) If the Bonferroni corrected significance level was not applied, this parameter would have been significant at $\alpha = 0.05$.

f) None of the compared parameters were significant for $\alpha = 0.05$ (n.s. = not significant) or for the Bonferroni-corrected significance level $\alpha = 0.001316$.

Table 2.7 Comparison of the non-vaccination NV strategy with the two base emergency-vaccination strategies, delayed destruction (DD-0) and intra-community trade (ICT-0) (maximum protection is reached on day 21)

Epidemiological and economic characteristics	Scenario											
	NV				DD-21-0				ICT-21-0			
	Mean	5%	**50%**	95%	Mean	5%	**50%**	95%	Mean	5%	**50%**	95%
Number of farms :												
Detected	120	47	**70**	232	68	48	**58**	92	74	57	**68**	133
Infected	166	69	**99**	349	76	54	**64**	113	75	57	**68**	133
Preventive slaughtered [a]	566	342	**450**	1210	1335	1084	**1177**	1930	-	-	**-**	-
Duration of epidemic (days)	-	114	**164**	344	-	99	**108**	177	-	236 [b]	**258[b]**	322 [b]
Route of infection:												
Local	107	29	**54**	222	32	15	**25**	52	32	18	**29**	63
Animal contact	2	0	**0**	9	1	0	**0**	4	0	0	**0**	4
Transport contact	12	0	**4**	41	4	0	**1**	18	3	0	**1**	14
Personal contact	8	0	**4**	19	2	0	**2**	6	2	0	**2**	6
# Vaccinated Farms	-	-	**-**	-	1240	958	**1038**	1602	1243	1043	**1135**	1961
# Infected farms vaccinated	-	-	**-**	-	32	20	**28**	38	32	21	**30**	56
# Vaccinated farms infected	-	-	**-**	-	7	3	**6**	12	10	5	**9**	19
Start of vaccination[c]	-	-	**-**	-	-	11	**11**	11	-	11	**11**	11
Decision to stop with vaccination[c]	-	-	**-**	-	-	96	**102**	154	-	78	**101**	164
Direct costs in 10^6 € :												
Stamping out infected herds	10	5	**7**	14	7	5	**7**	10	11	8	**10**	15
Preventive slaughter [a]	69	45	**59**	116	153	130	**141**	184	-	-	**-**	-
Animal welfare slaughter	347	226	**290**	677	201	157	**169**	250	305	253	**290**	423
Breeding prohibition	-	-	**-**	-	6	4	**5**	7	-	-	**-**	-
Costs of organisation	59	39	**49**	112	44	36	**39**	54	46	39	**44**	66
Consequential losses in 10^6 € for :												
Farmers	73	43	**61**	157	88	70	**78**	106	31	24	**29**	51
Related industries	154	103	**127**	277	141	115	**123**	170	114	99	**107**	155
Vaccination costs in 10^6 €	-	-	**-**	-	3	3	**3**	4	5	5	**5**	8
Total losses in 10^6 €	**712**	**465**	**590**	**1349**	**644**	**522**	**567**	**769**	**514**	**429**	**484**	**708**

a) In case of DD, preventive slaughter includes all vaccinated farms.

b) Includes 120-day post-vaccination zone.

c) The criteria to start or to stop respectively, installing new vaccination zones was fulfilled (days after 1st detection).

Table 2.8 Number of farms detected and preventive slaughtered for different simulated emergency-vaccination scenarios

Scenario	# Detection		# Preventive slaughter[a]		Costs 10^6 €	
	50 %	5% - 95%	50 %	5% - 95%	50 %	5% - 95%
Delayed destruction scenarios[b]						
DD-21-0	**58**	**48- 92**	**1177**	**1084-1930**	**567**	**522- 769**
DD-7-0	57	49-111	1174	1086-2051	560	522- 988
DD-16-0	58	48-135	1176	1084-2860	568	522-1155
DD-26-0	58	48- 93	1176	1084-1925	567	522- 806
DD-21-I	54	45- 79	1161	1076-1845	561	519- 831
DD-21-II	60	50- 80	1189	1088-1518	566	522- 751
DD-21-III	58	47-141	1267	1107-3049	595	530-1617
DD-21-IV	63	51-193	422	374-1082	451	405- 812
DD-21-V	59	49-110	1175	1083-2279	573	526- 962
Intra-community trade						
ICT-21-0	**68**	**57-133**	-[c]	-	**484**	**429-708**
ICT-7-0	59	50-95	-	-	370	330-538
ICT-16-0	66	56-102	-	-	477	420-687
ICT-26-0	69	58-133	-	-	486	434-710
ICT-21-I	64	53-117	-	-	481	415-720
ICT-21-II	73	61-125	-	-	489	432-702
ICT-21-III	113	92-169	-	-	554	487-909
ICT-21-IV	77	61-146	-	-	500	428-747
ICT-21-VI[c]	66	55-100	258[c]	237-307[c]	491	443-669

a) In case of DD, preventive slaughter includes all vaccinated farms.

b) All farms in a defined vaccination zone (0-3 km) will be slaughtered from day 6 onwards, if destruction capacities are available, independent of the vaccination preparation time. Except for alternative I until III this will be always 5 days extra. It will be 2 days for alternative I, 8 days for alternative II and 25 days for alternative III.

c) In case of ICT, preventive slaughter is only applied in strategy VI, where in only non-vaccinated farms can be preventively slaughtered.

2.3.2 Intra-community trade alternatives

The results of the different ICT alternatives, including the base version (ICT-21-0) of this scenario, are shown in Tables 2.6-2.9. In comparison to the NV scenario, the ICT base scenario was significantly cheaper (assuming no cost and losses for the post-vaccination zone). Preventive slaughter was not applied in the ICT scenario avoiding the large compensation costs. Furthermore, the consequential losses of the farmers were smaller compared to the NV scenario. No difference could be found for the number of detected and infected herds, except for the worst iterations. The same was true for the duration of the epidemic, when deducting the 120 days post-vaccination zone (Tables 2.6 and 2.7). Comparing the ICT base scenario with the DD base scenario, no farms were preventively slaughtered. Furthermore, the costs were significantly lower.

There was no significant difference in the size of the epidemic when the maximum protection level was varied from 21 days to 16 or 26 days (Tables 2.6 and 2.8). However, when maximum protection was reached in 7 days, the epidemic was shorter with a significantly lower number of infected and detected premises. This alternative was consequently less costly than the simulated base ICT. In comparison with the NV scenario, all three alternatives were significantly less costly.

There was no significant difference when comparing alternatives I and II of the intra-community trade with the base ICT (Tables 2.6 and 2.8). A slight (not significant) tendency of a decreased (increased) epidemic was found if the preparation time decreased (increased) by 3 days. However, alternative III (25 days preparation time) caused a significantly larger epidemic with significantly more detected, infected and vaccinated farms (as well as increased costs and losses). Alternatives I and II were significantly cheaper, when comparing with the NV scenario in contrast to scenario III.

Table 2.9 Comparing direct costs and losses of the base scenario with alternative IV for the intra-community trade strategy (ICT) and for the delayed destruction strategy (DD).

Scenario	DD-21-0		DD-21-IV		ICT-21-0		ICT-21-IV	
	50%	5-95%	50%	5 - 95%	50%	5 - 95%	50%	5 - 95%
Direct costs in 10^6 € :								
Stamping out infected herds	**7**	5-10	**8**	6-12	**10**	8-15	**12**	9-18
Preventive slaughter[a]	**141**	130-184	**56**	48-89	-	-	-	-
Welfare slaughter	**169**	157-250	**202**	181-391	**290**	253-423	**301**	255-443
Breeding prohibition	**5**	4-7	**0.5**	0.5-0.5	-	-	-	-
Costs of organisation	**39**	36-54	**36**	33-68	**44**	39-66	**45**	39-69
Consequential losses in 10^6 € for :								
Farmers	**78**	70-106	**44**	38-97	**29**	24-51	**31**	24-59
Related industries	**123**	115-170	**103**	95-178	**107**	99-155	**111**	99-160
Vaccination costs	**3**	3-4	**0.5**	0.5-0.9	**5**	5-8	**1.4**	0.9-2.3
Total losses	**567**	522-769	**451**	405-812	**484**	429-708	**500**	428-747

a) In case of DD, preventive slaughter includes all vaccinated farms.

A 1-km vaccination radius significantly reduced the number of vaccinated farms (for example the median decreased from 1135 vaccinated farms to 284 (result not shown)). The number of infected and detected farms was slightly higher (not significant) compared to the base (Tables 2.6, 2.8-2.9).

Applying preventive slaughter in ICT alternative VI showed no difference in the epidemiological parameters and did not increase the total costs significantly (Tables 2.6 and 2.8).

2.4 Discussion

Although the EU regulations currently prohibit routine vaccination against CSF, it is expected that the development of a marker vaccine will lead to a reassessment of the non-vaccination principle (Laddomada and Westergaard, 1999). Therefore, the main goal of our simulations was to analyse different possible emergency-vaccination campaigns, which could have been applied in the Dutch CSF epidemic. The vaccination alternatives were compared with the NV scenario discussed in Nielen et al. (1999). The NV scenario was considered to be the most effective that could have been reached with the regular control measures.

2.4.1 Comparison of vaccination strategies

The results of the significance testing should be used with caution as with more replications, even-smaller differences between alternatives would have become significant. The duration of the epidemic could not be tested in the current simulations because the epidemics were always stopped at 365 days. Other useful parameters not tested (such as the cost factors) could mostly be explained by changes in underlying parameters.

The main goal of any emergency-vaccination strategy (reduced number of infected herds) were reached in both emergency-vaccination scenarios compared to the NV strategy. The DD strategy seemed to be the most-effective strategy for reducing duration and size of an epidemic.

A shorter epidemic would lead to a reduction in direct costs paid for animal welfare slaughter measures and for organisation. For the DD strategy the reduction was countered by the higher preventive-depopulation costs (all vaccinated farms) as well as the higher consequential losses for farmers. Vaccination costs were only of minor importance. Except for the 95th percentile (DD was less costly), no overall difference could be found between a DD scenario and the NV strategy.

ICT entirely relies on a reliable and easy-to-handle serological test. Presuming no hindrance on the EU market for pig meat originating from vaccinated pigs and no extra cost and losses for the post-vaccination zone, ICT was significantly cheaper than NV or DD. The vaccination costs were more than compensated by the reduction in the direct costs paid for preventive slaughter and in the consequential losses. Furthermore, the numbers of infected and detected farms were on average smaller (but not significantly) for ICT than for NV. The worst-case iterations for ICT were never as severe as for the NV scenario. An ethical as well as an economic advantage of this strategy, compared to NV and also to DD, is that (except for animal welfare slaughter in the quarantine zone) no healthy pigs need to be destroyed.

The effectiveness of the DD strategy was mainly due to the applied preventive depopulation of the vaccination zones in which farms with the highest risk had the highest priority. When simulating a NV scenario with 3-km preventive-slaughter radius but without a classification into risk types the average epidemic increased from 120 to 209 detected farms (results not shown). So, the effectiveness of the DD scenario was partly the result of the classification into risk types and partly based on the reduced virus spread due to vaccination. The latter effect is mainly of importance in large epidemics and severely limited destruction capacity.

A small change in the effectiveness of the vaccine (16, 21, 26 days to maximum protection) had no extra influence on the epidemic for either emergency-vaccination strategy. Only a very-effective vaccine (maximum protection in 7 days) significantly reduced the epidemic for the ICT scenario. The 7 days refers more or less to the effectiveness of the conventional non-marker CSF vaccine, as has been used historically in Dutch epidemics (Brus, 1976; Tielen, 1977).

We presumed a fast implementation based on clear criteria about where and when to start an emergency-vaccination campaign ($\geq$ 5 detections in the 1st week) combined with a short preparation time of 5 days. A longer delay (alternative III) had a negative effect especially in the case of the ICT alternative. This effect was much lower for the DD alternative because this scenario also depended on risk-based depopulation as a control measure from day 6 onwards.

Changing the preventive-slaughter radius from 1000 m to 500 m in the DD scenario had no negative effect, because the 500-m preventive slaughter was only applied during the first week of the epidemic, followed by a 3-km vaccination and preventive-slaughter zone.

Applying preventive slaughter as an additional measure in the ICT scenario showed no significant effect on the course of the epidemic. The main effect was to change the composition of total cost: higher consequential losses for farmers; extra depopulation costs; lower costs for animal welfare slaughter.

A reduction in the vaccination radius from 3 km to 1 km was significantly cheaper than the NV scenario; for DD due to a reduced number of preventively slaughtered farms, for both DD and ICT due to reduced vaccination costs. However, potentially the control of the post-vaccination zone would become more difficult (thus, costly) for ICT.

2.4.2 Model constraints

A discriminatory diagnostic test with a specificity of less than 1 could lead to the detection of false positive farms. As a consequence, new quarantine zones would be installed and healthy pig farms would be slaughtered out. High sensitivity is required, because we want to detect all infected farms. In the current simulations, we assumed a specificity of 1 (simplification reasons) whereas the sensitivity was based on the current conventional diagnostic test. So in our simulation, we detected nearly all infected farms but we would never "find" false positive farms.

The addition of vertical transmission (the sow conveys the infection to its unborn offspring) would have meant a complete overhaul of the transmission structure in the model (Jalvingh et al. 1999), and was excluded. In the case of ICT, vertical transmission could lead to an underestimation of the epidemic. We assumed for vaccinated and later-infected farms an infectious period of only 1 month (which does not take into consideration the birth of carrier piglets) whereas all other infected farms remained infectious until being slaughtered.

We assumed that only vaccinated and later-infected farms would show a reduction in virus spread (further research is needed). Infected and later vaccinated farms were supposed to stay infectious until detection without any reduction in infectivity. Because those farms had a high probability of being detected earlier due to vaccination, their effect on the outcomes is rather small. Vaccination activities also could lead to earlier detection of infected farms, but the effect on the simulation outputs was rather small (results not shown).

We assumed maximum protection of all vaccinated farms during the 120-day post-vaccination zone. This is an over-estimation because the number of not-vaccinated pigs will increase in that period. The duration of maternal immunity against transmission was not modelled, but would reduce the above over-estimation. At removal of a post-vaccination zone, the protection level of all vaccinated farms was set to zero, leading to an underestimation of the vaccination effect.

No reduction in the effectiveness of the vaccine in the case of maternal immunity of the piglets was assumed. For simulation at the animal level, the effect of maternal immunity against virus transmission needs to be quantified. InterCSF simulates at the herd level.

Vaccination has some disadvantages and possible hazards as it may engender a false sense of security (leading to relaxation of other control measures and/or less-strict sanitary behaviour of people involved) (Anonymous, 1997). In our simulations, we presumed no relaxation.

The high number of required diagnostic tests could lead to a delay in diagnosis. This effect was not considered as such in our simulation model. We assumed minimum 49 days instead of 42 days before removing the standstill, to mimic a waiting period for the laboratory results.

Simulating the actual Dutch CSF epidemic, we knew in advance that we would have a large epidemic in a very densely populated area. So, the decision to start an emergency-vaccination campaign was based in the current study only on a single criterion (i.e. 5 detections in the first week). In a more-generic model, further criteria may be compared (such as the pig density or the total number of outbreaks in relation to the length of the epidemic).

2.4.3 Economic model constraints

The breeding prohibition was not simulated, but the compensation paid to the farmers was calculated in EpiLoss. Because a decreasing pig population was only considered for fattening farms in a quarantine zone (Meuwissen et al., 1999), the total depopulation costs could have been overestimated (especially in large epidemics) in the case of DD. To be able to compare with NV, we accepted this slight overestimation by not adapting EpiLoss.

Serological costs were only incorporated as a lump sum per tested farm derived from the Dutch CSF epidemic. Serological cost calculations based on farm size and type would allow better and more-detailed comparisons of different simulated alternatives.

The direct costs for animal welfare slaughter measures were based on average pig prices over the year 1997 because no market reaction was simulated. In a real epidemic, compensation paid for animal welfare slaughter measures is based on weekly fluctuating slaughter prices. In the case of a large epidemic, the demand and the supply of growers[5] and fatteners will certainly be interrupted or distorted (which would lead to large price movements (see Asseldonk et al., 2000)). Large price changes would mainly influence the direct costs of animal welfare slaughter measures, but also the consequential losses of the farmers subjected to control measures (such as higher repopulating costs). Consumer behaviour is not always rational, and a severe reaction against vaccinated meat could lead to a drastic price drop (not simulated).

EpiLoss is based on partial budgeting and calculates only the cost and losses of farms and related industries subjected to control measures. Benefits were not considered (such as higher profits of pig farmers outside the quarantine zones or profits of the pharmaceutical industry).

To control a post-vaccination some organisational costs will be involved. Farmers situated in a post-vaccination zone may be restricted in their choice to sell their pigs resulting in lower weekly pig prices than paid outside the zone. The current zero cost assumption is therefore too optimistic.

2.5 Conclusion

Emergency vaccination (assuming a reliable diagnostic test and no relaxation of other control measures) seemed to be an effective strategy for reducing the size of an epidemic. Emergency-vaccination alternatives were at least as effective as the optimal NV scenario. The worst iterations were never so severe as in the case of the NV scenario. The large number of preventively slaughtered farms in the DD strategy is a negative aspect of the DD strategy compared to the NV strategy. This effect mainly reduces the positive effect of a shorter epidemic. If we compare the ICT strategy with the NV strategy, emergency vaccination is certainly the tool to choose. Vaccination costs (which are of minor importance compared to all other costs and losses) are mainly in competition with the cost of preventive slaughter, assuming no extra costs and losses for the post-vaccination zone. ICT avoids the destruction of a large number of healthy pigs, which can still be used for human consumption.

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[5] A grower is a piglet of 20-45 kg

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Appendix I Chronological order of all control measures except vaccination in case of a newly detected CSF outbreak in InterCSF (Jalvingh et al., 1999)

Time	Measure
Day of detection	- Infected farm will be put on slaughter list and destroyed (slaughtered and rendered) as soon as capacities are available (highest priority) - Movement standstill is imposed on the protection (0-3 km) and on the surveillance zone (3-10 km) [a]; fewer person contacts (50%) are allowed. Animal contacts and vehicles contacts are forbidden. - Farms within a certain radius could be subjected to preventive slaughter, limited by destruction capacity (killing and rendering capacities). Preventive slaughter could lead to an earlier detection.
Start on 2nd day	- Surveillance (clinical inspection) of all farms in the protection zone (0-3 km), which may lead to earlier detection. - Tracing farms that had contact with the infected farm. Traced farms are put on surveillance (clinical inspection), which may lead to earlier detection, or may be subjected to preventive slaughter.
Start on day 28th	- Start buying-out schemes of fatteners and growers for animal welfare reasons (referred through out the chapter as animal welfare slaughter) in the quarantine zone until the quarantine zone is lifted. Welfare slaughter may lead to earlier detection.
Earliest on day 35th	- Start of serological end-screening of all farms situated in the quarantine zone, if no additional farm was detected during those last 35 days.
Earliest on day 49th [b]	- If there is no new detection in a quarantine zone, the quarantine zone is lifted up.

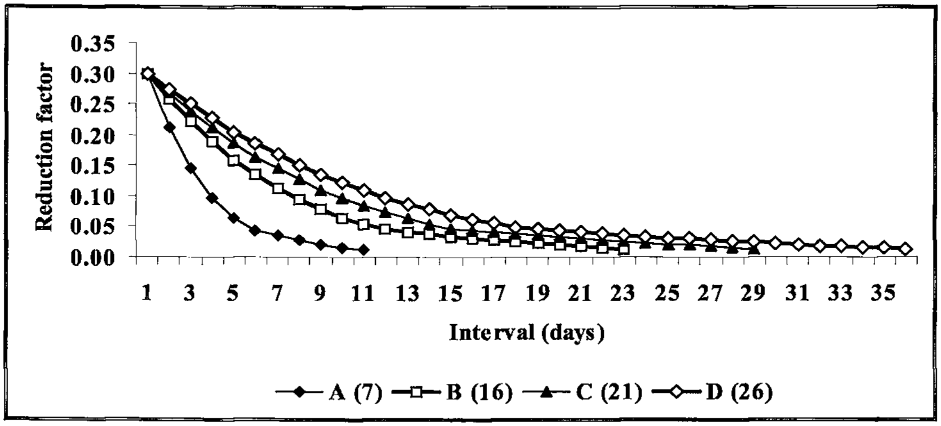
a) Surveillance and protection zone with imposed movement restrictions (movement standstill) are referred through out the chapter as quarantine zones.

b) We assumed 49 days instead of 42 days, to mimic a waiting period for the laboratory results.

Appendix II The calculated reduction and protection factors

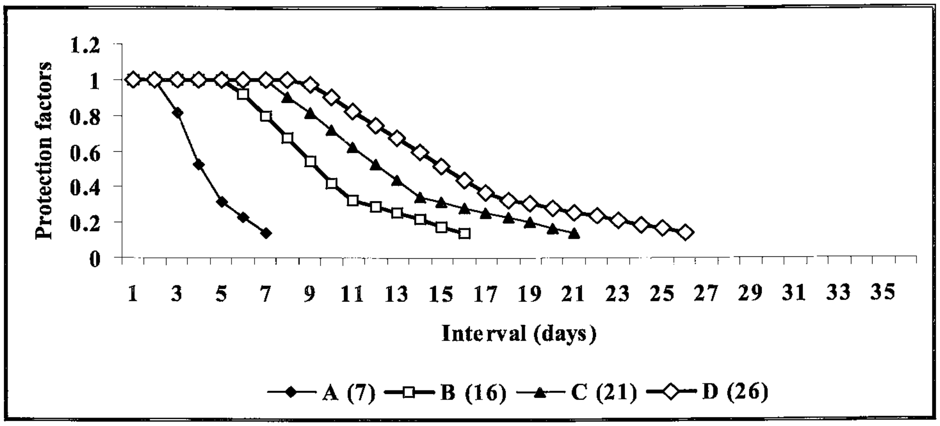
In horizontal-transmission experiments co-ordinated by the EU, animals in groups of 10 were vaccinated with one of two alternative vaccines and 5 of each group were inoculated with CSF 7, 10, 14 or 21 days after vaccination. From the data generated by these experiments, parameters of the standard SIR model were estimated (Klinkenberg et al., 2000). These parameters were used to calculate the reduction in total infectivity of a herd depending on the time between vaccination and infection. Results showed that for both vaccines, 21 days was the time from vaccination until maximum protection of the individual animal. The relative decline of the estimated between-animal transmission parameter was used as protection factor. To see what a faster or slower working vaccine would do, time scales of protection and reduction curves were changed. Reference point of these changes was the maximum-protection date of the individual animals (21 days) which was changed to 7, 16 or 26 days. Because the vaccines do not differ in their ability to reduce horizontal transmission, we used the average of the estimated parameters from both vaccines. The applied reduction and protection factors are shown in figures II-1 and II-2.

Figure II-1. Reduction factor for the probability of transmission from a vaccinated farm, related to the time interval between vaccination and subsequent infection. Vaccine efficacy was maximum at 7 (A), 16 (B), 21 (C) or 26 (D) days after vaccination.



Appendix II The calculated reduction and protection factors (suite)

Figure II-2. Reduction factor (called "protection factor") for the probability that a vaccinated farm became infected, related to the time interval between vaccination and a possible infection. Vaccine efficacy was maximum at 7 (A), 16 B), 21 (C) or 26 (D) days after vaccination.



Appendix III Control measures, related events in EpiLoss, and implications of the events

Control measures	Related events	Implications
Compulsory measures		
Stamping-out	- Depopulation	- Herd is destroyed, buildings empty till restocking
	- Restocking	- Restarting the farm
Quarantine zone	- Start quarantine zone	- No supply and delivery of animals allowed
	- End quarantine zone	- Supply and delivery of animals allowed
Preventive slaughter	- Depopulation	- Herd is destroyed, buildings empty till restocking
	- Restocking	- Restarting the farm
Additional measures		
Animal welfare slaughter	- Start welfare slaughter	- Animals for which measure applies are destroyed
	- End welfare slaughter	- End of destruction of animals under consideration
Breeding prohibition	- Start breeding prohibition	- Prohibition of insemination of sows
	- End breeding prohibition	- Insemination of sows allowed
Vaccination measures		
Vaccination	- Apply vaccination	- All pigs on the farm older than 14 days are vaccinated once, which may be repeated after 6 months - Continued vaccination may be included during the time of the quarantine zone for breeding sows and newborn piglets (only applied in the ICT strategy).
	- End quarantine zone	- Vaccination stops

Chapter 3

Decomposing Preference Shifts for Meat and Fish in the Netherlands

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Abstract

The changing preferences of Dutch consumers for meat and fish are investigated using a switching almost ideal demand system. Structural change in demand between January 1994 and May 1998 is decomposed into underlying trends, temporarily irreversible preference shifts triggered by the BSE crisis of March 1996, and a 'panic' reaction against beef in the month of the crisis itself. Preference shifts due to the BSE scare reduced expenditure shares for beef, minced meat and meat products by 2.5, 3.3 and 7.9 percentage points respectively. There were offsetting gains in the shares of pork, prepared meat and fish. Taking underlying trends also into account, changing preferences over the whole period reduced beef's share by 4.9 percentage points and increased those of poultry, prepared meat and fish by 4.1, 4.9 and 5.2 percentage points respectively.

3.1 Introduction

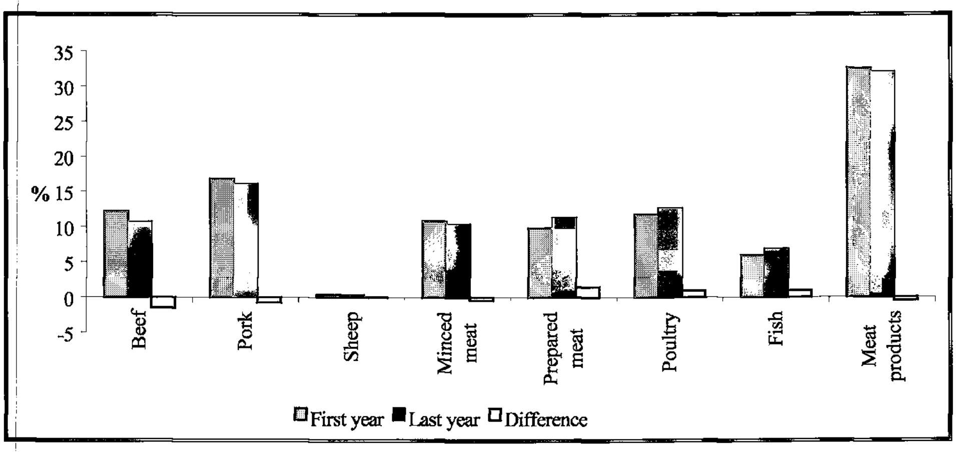
Various studies have indicated that observed demand shifts from beef to poultry and fish since the 1970's are not caused entirely by changes in relative prices or income (Eales and Unnevehr, 1988, Moschini and Meilke, 1989, Reynolds and Goddard, 1991, and Rickertsen, 1996) but are also partly due to changes in underlying consumer preferences.

Apart from Eales and Unnevehr (1988), most studies have disaggregated meat only by animal type and have not considered the product type. By contrast, our study recognises that consumers increasingly choose between products (such as traditional cuts, prepared and processed meats) rather than simply between type of animal (e.g. beef, pork).

The Dutch budget shares of prepared meat, poultry and fish have increased in the period 1994 - 1998, contrary to those of beef, pork, minced meat and meat products (see Figure 3.1). The observed changes in consumption may be due to changes in relative prices and income alone or to changes in other potential important demand variables.

Advertising and health concerns as well as quality changes, new products and the socio-economic composition of the population may have affected the demand for meat and fish. This chapter reports an attempt to separate the direct effects of economic factors (prices and income) from changes in the underlying demand structure using a switching Almost Ideal Demand (AID) System, including a trend and seasonal effects.

Figure 3.1 Product shares in total Dutch meat and fish expenditure (January - December 1994 to June 1997 – May 1998)



A major objective of the study in this chapter was to investigate whether there has been (temporarily) irreversible structural change in consumers' demand for meat and fish that could be attributed to the adverse publicity for beef linked specifically to the 1996 BSE scare[1]. This crisis, a media spectacle, started on 20 March 1996, when Stephen Dorrell, Secretary of State for Health in the British government, announced the possibility of a link between BSE and Creutzfeldt-Jakob disease (CJD) in humans. Up to that moment, there had been no reported cases of BSE in the Dutch cattle population. The following day, the Dutch government declared restrictions on the movement of cattle imported from Britain and on 27 March the EU took action by imposing an export embargo on British beef meat (EU, 1998). The compulsory slaughter of all imported British calves being fattened in the Netherlands was subsequently imposed (see Appendix IV). In this chapter we attempt to disentangle the impact on demand of these events from other underlying demand changes.

3.2 A switching AID system

The AID model (Deaton and Muellbauer, 1980) has frequently been used in demand studies for meat and fish[2]. In this study, we use a switching AID system following the approach of Moschini and Meilke (1989). Time trends are included to capture underlying trends in

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[1] For studies of the impact of BSE on beef demand in earlier periods, see Burton and Young (1996, 1997) and Burton et al (1998) (for the UK), and Leeuwen (1998) (for the EU).

[2] For example, Chen and Veeman (1991), Eales and Unnevehr (1988), Moschini and Meilke (1989), Reynolds and Goddard (1991), Rickertsen (1996).

unmodelled variables, as well as thirteen dummies (since 4-weekly data are used) to capture seasonal fluctuations within the year. The inclusion of a structural shift in the model and a dummy variable for the month of the crisis itself reflects our original hypothesis that the BSE scare could have had both reversible and irreversible effects on consumers' buying habits.

Demand may not adjust fully in response to contemporaneous changes in prices and income, due to established habits (Alessie and Kapteyn, 1992). In an empirical model, partial adjustment is more likely the shorter the unit time period. To allow adjustment to take longer than four weeks, the basic AID specification was made dynamic by including the full set of lagged shares, with appropriate homogeneity restrictions on their parameters to avoid multicollinearity.

In the basic specification of the model, w_{it}, the i-th good's expenditure share at time t, is given by:

$$\begin{aligned} w_{it} &= \alpha_i + \rho_i h_t + (\varphi_i + \kappa_i h_t)T + \chi_i D_{BSE} + \sum_{k=1}^{m} (\theta_{ik} + \gamma_{ik} h_t) D_k \\ &+ \sum_{j=1}^{n} (\beta_{ij} + \delta_{ij} h_t) \ln p_{jt} + (\beta_i + \delta_i h_t) \ln(\frac{x_t}{P_t}) + \sum_{j=1}^{n} \nu_{ij} w_{i,t-1} \end{aligned} \tag{1}$$

where P_t is a price index defined as:

$$\begin{aligned} \ln P_t = \alpha_0 + \sum_{i=1}^{n} \{(\alpha_i + \rho_i h_t) + (\varphi_i + \kappa_i h_t)T + \chi_i D_{BSE} + \sum_{k=1}^{m} (\theta_{ik} + \gamma_{ik} h_t) D_k\} \ln p_{it} + \\ \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} (\beta_{ij} + \delta_{ij} h_t) \ln p_{it} \ln p_{jt} \end{aligned} \tag{2}$$

In equations (1) and (2), x is the total per capita expenditure on all meats and fish included in the system; p_j denotes the per unit price of good j, (n=1,..., 8); T is a trend variable; D_k are dummy variables (k=1, ...13), D_{BSE} is a dummy variable taking the value 1 during the month of the media scare, and α_i , ρ_i, θ_{ij}, γ_{ij}, φ_i, κ_i, β_{ij} , β_i , δ_i, δ_{ij}, χ_i and ν_{ij} are parameters. The lagged shares do not appear in the price index on the grounds that habit persistence is a disequilibrium adjustment process applied to the share equations after they are derived from the cost function (see Bewley, 1986, pp.43-59). The estimated parameters therefore denote short-run (current-period) responses. h_t denotes the time path of the structural change given by

$$h_t = 0 \text{ for } t = 1,...,\tau_1; \qquad h_t = [\frac{(t-\tau_1)}{(\tau_2 - \tau_1)}]^{\lambda} \text{ for } t = \tau_1 + 1,...,\tau_2,\ 0 < \lambda \le 1$$

$$\text{and } h_t = 1 \text{ for } t = \tau_2 + 1,...,T. \tag{3}$$

In equation (3), τ_1 is the end point of the pre-structural change period and τ_2 the starting point of the post-structural change period. The transition path between the two structures may be non-linear, and it may be either abrupt or gradual, depending on the size of $\tau_2 - \tau_1$, as well as on the parameter λ.

Adding-up (I), homogeneity of degree zero in prices and total expenditure (II) and Slutsky symmetry (III) restrictions are imposed on the model. They imply the following parameter restrictions:

(I) $\sum_i \alpha_i = 1$; and

$$\sum_i \beta_i = \sum_i \delta_i = \sum_i \rho_i = \sum_i \kappa_i = \sum_i \varphi_i = \sum_i \theta_{ik} = \sum_i \gamma_{ik} = \sum_i \beta_{ij} = \sum_i \delta_{ij} = \sum_i \chi_i = \sum_i \nu_{ij} = 0;$$

(II) $\sum_j \beta_{ij} = \sum_j \delta_{ij} = 0$ for $\forall_i$

(III) $\beta_{ij} = \beta_{ji}$; and $\delta_{ij} = \delta_{ji}$ for $\forall_{i,j}$

Additional restrictions imposed to avoid multicollinearity are:

$\sum_k \theta_{ik} = \sum_k \gamma_{ik} = 0$[3] and $\sum_j \nu_{ij} = 0$.

Restrictions to ensure concavity of the cost function are not imposed. However, we check the compensated own-price elasticities for a negative sign, which is a necessary condition for concavity. When estimating the model, α_0 was set to zero (Moschini et al., 1994, Rickertsen, 1996).

3.3 Data and empirical implementation

Prices and quantities consumed at home of the different meat and fish groups were collected from 4400 consumption panel households by the Gesellschaft für Konsumforschung (GfK) in Dongen (Netherlands) and raised to the level of total Dutch demand. Dutch population figures were taken from monthly statistics collected by the Centraal Bureau voor de Statistiek and adjusted to a 4-weekly basis.

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[3] In this formulation, the seasonal effects represent deviations from the *average* seasonal effect, which is itself equal to zero.

The meats were disaggregated according to their retail classification into the following groups: beef, pork, lamb, poultry, minced meat, prepared meat and processed meat. The first three categories comprise traditional cuts of each animal type. Fish was considered as one group, regardless of whether it consisted of prepared fish dishes or ordinary fresh fish. The minced meat group is composed of 55 per cent pure minced beef meat, 40 per cent of a mixture of half beef and half pork and 5 per cent of poultry, veal or other non-beef origin (PVE, 1998a). Despite the fact that mince meat is 75 per cent beef, it is useful to distinguish between mince meat and traditional beef cuts since mince meat is a lower quality product, whose price is well below that of the beef category, and the prices of the two categories are only moderately correlated. Moreover, with relevance to the BSE scare, consumers are less able to assess the quality and composition of mince meat, or verify from which part of the beef animal it comes. The prepared meat consists of frying and cooking sausage, schnitzel, loins, shoarma, cordon bleu, hamburgers and other prepared meat. In the meat product group, all kinds of spreadable sausage, as well as cooked and raw ham, liver products, smoked and dried fat and bacon are included (GfK, 1998). About 80 per cent of meat products are derived from pork. The greater part of the remainder is poultry. Meat products play an important role, along with cheese, as sandwich filling. Sandwiches are the preferred lunch snack in the Netherlands.

This product grouping reflects the assumption that, when choices are driven by relative prices of individual retail lines, consumers are more likely to substitute between meats in the same retail category (e.g. sausage for hamburger, both of which are prepared meats) rather than between retail lines of the same animal type (e.g. roasting chicken for spreadable chicken liver paté, which are in different product groups). This assumption appears reasonable given that these retail categories group meat lines that are likely to be eaten in similar circumstances or that embody similar degrees of convenience in preparation (e.g. various traditional cuts of pork in one category, pork satay sticks and beef sausages – both ready-to-cook prepared meats – in another). It has been pointed out by a referee that when substitution occurs because of fears over the safety of beef rather than as a response to relative price changes, there is the possibility of some substitution between beef and non-beef products in the category "prepared meat", which our approach would not capture. However, since for many items in this category it is impossible for the consumer to be certain of the origin of the meat (e.g. sausages, hamburgers), a risk averse consumer who wanted to avoid eating beef could well opt to switch out of this category altogether rather than trying to substitute with another product from within the same group. Ideally, we would disaggregate this category into "prepared beef meat" and "prepared non-beef meat" to test for structural change in the preferences for these two types of prepared meat. Unfortunately, it is not permitted by the data.

Amongst the meat products, the shortest series was for poultry, where statistics were available only from January 1994. Since 4-weekly fish data began only in January 1995, the fish statistics were extrapolated back to January 1994[4]. This extrapolation increases the usable data set by another year and allows us to search for structural change over a longer period.

We used the SUR estimation procedure in SAS to estimate the parameters for the AID model[5]. The eighth equation for meat products was dropped to avoid singularity of the estimated error covariance matrix.

3.4 Results

3.4.1 Identifying structural change

The data set contains 57 observations, starting in the first week of January 1994 and finishing in the week ending 17 May 1998. The break-points (τ_1, τ_2) can either be set *a priori* or determined by searching over the sample in order to locate the structural breaks empirically. Our objective was to identify the structural change, if any, by empirical methods. Adding-up, symmetry and homogeneity restrictions were imposed when searching for structural change.

The search for the most likely break points involves estimating the switching system for various combinations of break points. The end of the first regime, τ_1, was allowed successively to be any observation in the data set from observation 15 to 55. For each τ_1, the starting point of the second regime, τ_2, was then allowed to be any subsequent period. The pair of break points that produced the lowest residual sum of squares (RSS) for the model, when estimated by maximum likelihood methods, was selected as having the greatest empirical support.

In the model given by equations (1) and (2) and with $\lambda=1$ (linear time path of the structural change) the most likely break points were identified as $\tau_1 = 26$ and $\tau_2 = 54$, which implied a

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[4] Details of the extrapolation method, based on regression analysis, are available on request.

[5] We tested for endogeneity of prices and expenditure in each equation, using the test developed by Spencer and Berk (1981). In every case, endogeneity was rejected.

structural shift between the beginning of January 1996 and the end of January 1998. However, when the time path of the structural change was allowed to be non-linear, the optimal combination of λ, τ_1 and τ_2 was found for λ=0.69, τ_1 = 29 and τ_2 = 50. This specification locates the beginning of the parameter shift in the same month that the BSE crisis broke, and allocates over 12 per cent (nearly 20 per cent) of the parameter shift (which took 21 months to complete) to the first four (eight) weeks of the scare.

To compare these two alternatives, a non-nested test was performed (Davidson and Mackinnon, 1981). The test used was the J-test, whereby H_0 is:

$$H_0 : w_i = f_i(X, \beta_i) + \varepsilon_{0i} \qquad i=1,\ldots,7 \tag{4}$$

and the alternative hypothesis is:

$$H_1 : w_i = g_i(Z, \gamma_i) + \varepsilon_{1i} \qquad i=1,\ldots,7 \tag{5}$$

where w_i is the vector of the i-th share, X and Z are matrices of observations on exogenous variables, β_i and γ_i are vectors of parameters to be estimated, and the error terms ε_{0i} and ε_{1i} are assumed to be normally and independently distributed. To test H_0 using the J-test, the following system is estimated:

$$w_i = (1-\alpha) f_i(X, \beta_i) + \alpha \hat{g}_i + \varepsilon_i \qquad i=1,\ldots,7 \tag{6}$$

where $\hat{g}_i = g_i(Z, \hat{\gamma}_i)$ and $\hat{\gamma}_i$ is the maximum likelihood estimate of γ_i. Under H_0, α is zero. Rejection of H_0 with the J-test does not allow us to accept H_1 as being the better model. To test H_1, the test has to be done again, with the roles of H_0 and H_1 reversed. It can happen that both hypotheses are accepted or rejected.

Table 3.1 The J- test

$f_i(X,\beta_i)(H_0)$	$g_i(Z,\gamma_i)$	Restricted RSS	Nonrestr. RSS	Calc.Chi-Sq.[a]
26,54 (λ=1.00)	29,50 (λ=0.69)	0.000329	0.000243	118.06
29,50 (λ=0.69)	26,54 (λ=1.00)	0.000330	0.000287	54.70

a) χ^2 for α=5% (1%) is 3.84 (6.63)

The J-test reported in Table 3.1 does not allow us to accept one version in preference to the other, although rejection of the model with λ=1.00, τ_1=26 and τ_2=54 is stronger. This does not contradict our preference, based its greater plausibility, for the model with non-linear parameter changes that begin in the month of the BSE scare itself. It is this model (29,50, λ=0.69) that is reported in greater detail below.

3.4.2 Tests of the chosen specification

Adding-up, homogeneity and symmetry restrictions were imposed on the system. The necessary condition for concavity was not fully satisfied, although the two elasticities (out of 16) with a positive sign were not significantly different from zero even at very high significance levels[6].

Symmetry and homogeneity were rejected by the data (see Appendix V). Rejection could be due to possible omitted variables (Deaton and Muellbauer, 1980) or data errors. Even if symmetry and homogeneity (which are derived from the theory of the individual consumer) do not hold at the level of aggregate demand, it is desirable to impose them as it reduces the number of parameters to be estimated and forces the demand elasticities to be mutually consistent.

The specification incorporating the structural change chosen above was tested against simpler versions of the model using nested tests. Table 3.2 reports the results of testing simpler versions (obtained by imposing k exclusion restrictions) against the preferred model. Two alternative chi-square statistics are reported. In all cases, the restrictions were rejected at the 5 per cent significance level.

Table 3.2 Testing the chosen specification against simpler versions

Excluding	URSS	RRSS	k	LR	LM	χ^2 (α=0.05)
No dynamics	0.000329	0.000946	49	414.5	255.8	66
No BSE-dummy	0.000329	0.000504	7	167.9	136.5	14
No time trend	0.000329	0.000491	14	157.4	129.6	24
No 4-week dummies	0.000329	0.003525	168	930.3	355.5	199
No structural change imposed on 4-week dummies	0.000329	0.001131	84	484.6	278.1	106
No structural change imposed on trend and on dummies	0.000329	0.000125	91	525.1	289.3	114
No structural change	0.000329	0.001790	133	664.5	320.1	161

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[6] These elasticities are fish (before structural change) and poultry (after structural change).

The R^2 and the Durbin Watson values were also considered in order to evaluate the model specification (see Appendix VI). In all cases, these statistics are satisfactory and do not signal problems of fit or serial correlation with any particular equations. The estimated parameters of the chosen specification and their standard errors are summaries in Appendix VII.

3.4.3 Elasticities

The short-run own-price, η_{ii}, cross-price, η_{ij}, and the expenditure elasticities, ε_i, are calculated by

$$\eta_{ij} = (\frac{1}{w_i})[(\beta_{ij} + \delta_{ij}h_t) - (\beta_i + \delta_i h_t)\{\alpha_j + \rho_j h_t + (\varphi_j + \kappa_j h_t)T + \sum_{k=1}^{n} \beta_{jk} \ln p_k\}] - \omega_{ij} \tag{7}$$

where ω_{ij} is the Kronecker delta, which is 1 if $i=j$ and 0 if $i \neq j$, and

$$\varepsilon_i = 1 + \frac{(\beta_i + \delta_i h_t)}{w_i} \tag{8}$$

The approach of Klein (1953) was used to calculate the t-values of the price elasticities.

Short-run elasticities were calculated for the period before and after the parameter shift[7], using the average estimated shares and other data means for the relevant sub-period. h_t was set equal to zero in the first period, and to one in the second.

After the structural change, the elasticity of demand for beef with respect to meat and fish expenditure increased from 1.41 to 2.78, whereas poultry meat changed from being a normal good to an inferior good (see Table 3.3). An expenditure elasticity greater than one indicates that a meat is a 'relative luxury', in so far as its percentage change exceeds the percentage increase in expenditure on meat and fish. The elasticity for meat and fish as a group, with respect to total consumer expenditure, was estimated (using results from Terris-Prestholt and Kersbergen (1997) and Sun and Koppelman (1998)) to be 0.334. This allows us to calculate pre- and post-structural change elasticities of beef with respect to total consumer expenditure of 0.47 and 0.93 respectively.

The increase in the expenditure elasticity for beef can be partly explained by the fact that the decrease in demand for beef meat was accompanied an increased demand for expensive cuts,

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[7] We took the last thirteen observations (equivalent to one year) as the post-structural change period as there were only eight observations left after the second break points.

such as roasting beef, entrecote and beefsteak (PVE, 1998c). Moreover, when beef demand is lower, a given increase represents a larger percentage change. It must be stressed that these elasticities represent the ceteris paribus response to an income change, holding preferences constant. For interest, the last two columns of Table 3.3 report the expenditure elasticities obtained from the model estimated without a parameter shift, although this specification was rejected on statistical grounds (see Table 3.1). These figures are closer to typical estimates obtained with annual data over longer periods, but we suggest that such models are inadequate for estimating elasticities for shorter periods characterised by preference volatility.

We calculated that, on average, 76 per cent of the change in the expenditure elasticities is due to structural parameter changes, the rest being due to changes in data averages.

Table 3.3 Short-run expenditure elasticities (t-ratios in italics)

	Before the structural change		After the structural change		No structural change	
	ε_i^b	$t(\varepsilon_i^b)$	ε_i^a	$t(\varepsilon_i^a)$	ε_i	$t(\varepsilon_i)$
Beef meat	**1.41**	*2.51*	**2.78**	*2.85*	**1.71**	*7.89*
Pork meat	-0.31	*-0.73*	0.76	*1.19*	**0.65**	*4.35*
Sheep meat	-10.28	*-1.90*	-6.64	*-0.78*	-0.59	*-0.48*
Minced meat	**2.06**	*3.63*	**1.87**	*2.25*	**1.29**	*6.70*
Prepared meat	**-1.07**	*-2.29*	**-1.76**	*-2.42*	0.35	*1.81*
Poultry	**1.15**	*2.36*	**-1.42**	*-2.13*	**0.88**	*4.66*
Fish	-1.83	*-1.66*	-2.40	*-1.66*	**0.69**	*2.81*
Meat products	**2.40**	*5.22*	**2.98**	*5.02*	**1.16**	*11.51*

a) a = after;
b) b = before.

All own-price elasticities have the correct sign, except for fish in the first period and poultry in the second period, but these estimates are not significant. After the structural change, the own-price pork elasticity and the own-price meat product elasticities became significant. The demand for minced meat and meat products became more price-elastic, whereas beef and poultry became insensitive to price changes. Since the pre- and post-structural change elasticities were calculated at the sub-sample means for each period, part of their change is due to differences in average budget shares and prices. We calculated that, on average, 71 per cent of the change in the price elasticities is due to structural parameter changes, the rest being due to changes in data averages. The full set of own- and cross-price elasticities, before and after structural change are summaries in Appendix VIII.

3.4.4 Estimated trends and dummy effects

The underlying trend (φ_i) in demand for meat products decreased over the whole period, contrary to the trend in demand for prepared meat.

The structural change that began with the BSE scare influenced the underlying trends significantly in the cases of pork, sheep meat and prepared meat, as shown by the values of κ_i in Table 3.4. By contrast, this structural change significantly altered the intercept of the share equations (ρ_i) against beef and in favour of poultry.

The reversible (one-period) impact of the BSE crisis was strongly negative for beef demand and also for prepared meat, but caused a rise in the share of poultry meat and meat products, as shown by the parameters χ_i in Table 3.4[8].

Table 3.4 Estimated parameters for trend (φ_i and κ_i), structural change in intercept (ρ_i), and BSE dummy (χ_i) (t-ratios in italic)

	Beef	Pork	Sheep	Minced Meat	Prepared Meat	Poultry	Fish	Meat Products
φ_i	-0.0000	0.0001	0.0001	0.0001	**0.0007**	0.0002	0.0005	**-0.0017**
	-0.02	*0.48*	*1.51*	*0.19*	*3.31*	*1.06*	*1.68*	*-2.50*
κ_i	-0.0008	**-0.0013**	**-0.0003**	0.0004	**-0.0014**	0.0010	0.0000	0.0025
	-1.46	*-2.92*	*-2.40*	*0.85*	*-2.84*	*1.40*	*0.07*	*1.89*
ρ_i	**-0.3326**	0.0666	-0.0307	-0.0688	0.0529	**0.4415**	0.1118	-0.2406
	-2.97	*0.62*	*-1.31*	*-0.79*	*0.61*	*5.32*	*1.39*	*-1.61*
χ_i	**-0.0244**	-0.0030	-0.0025	-0.0032	**-0.0102**	**0.0175**	-0.0053	**0.0311**
	-4.91	*-0.59*	*-1.82*	*-0.76*	*-2.75*	*4.17*	*-1.10*	*2.73*

The set of seasonal dummies was not rejected when tested. However, relatively few seasonal effects were significant. In the period before the structural change, minced meat share increases during early summer to early autumn, whereas its share decreases during the colder months. In December, the higher pork share was offset by a decrease in the shares of minced meat and prepared meat. The share of poultry rose significantly in December. In the period after the structural change, the December increase for pork disappears and that for poultry increases.

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[8] BSE dummies of one, two and three periods were tried. The data strongly supported a reversible effect lasting only one period (25.03.96 to 21.04.96).

3.4.5 Effects of the structural change

Structural change can be summarised by its bias. The bias of the structural change is the change in the expenditure share of each category between the two regimes that is due to factors other than the economic variables price and expenditure. This involves calculating the shares in the two sub-periods with the economic variables set at their overall sample means. The share differences are then due only to the parameter changes, which represent changes associated with preferences. If the structural change reduces the demand for good *i*, then it is biased against that good.

Table 3.5 Bias of the structural change

	Without trend			With trend		
	Bias	Budget shares		Bias	Budget shares	
		Before	After		Before	After
Beef meat	-0.025	0.1218	0.0971	-0.049	0.1220	0.0732
Pork meat	0.052	0.1400	0.1915	0.022	0.1361	0.1580
Sheep meat	0.010	0.0003	0.0099	0.007	-0.0030	0.0040
Minced meat	-0.033	0.1140	0.0812	-0.020	0.1126	0.0928
Prepared meat	0.050	0.0876	0.1380	0.049	0.0689	0.1178
Poultry	-0.000	0.1305	0.1301	0.041	0.1242	0.1649
Fish	0.025	0.0522	0.0773	0.052	0.0398	0.0913
Meat products	-0.079	0.3536	0.2748	-0.102	0.3995	0.2980

Table 3.5 reports two calculations of bias. The first reflects only the changes in structure due to the parameter shift between the two periods. Since the shift began in the period of the BSE scare, we can interpret this bias as due to the irreversible component of the BSE effect. These changes were most strongly biased against beef, minced meat and meat products, and in favour of pork, prepared meat and fish. The second calculation of bias includes an additional component of preference change, namely the underlying structural change as picked up by the time trend that was in operation during the whole period from t=1 to t=57. We see that the underlying trends reinforce the BSE-related biases against beef and meat products, and in favour of fish. On the other hand, in the case of pork and prepared meat, the underlying trends work in the opposite direction to the BSE-related shift but without offsetting the BSE-related preference shift.

The figures in Table 3.5 show that, ceteris paribus, preference changes triggered by the BSE scare reduced the expenditure share of beef, minced meat and meat products by 2.5, 3.3 and 7.9 percentage points respectively, and increased the shares of pork, prepared meat and fish by nearly 5.2, 5.0 and 2.5 percentage points respectively. When the preference changes picked up by the underlying trends are included, the ceteris paribus shift in preferences over the whole period reduced the shares of beef, minced meat and meat products by 4.9, 2.0 and 10.2 percentage points respectively, and increased the shares of pork, prepared meat, poultry and fish by over 2.2, 4.9, 4.1 and 5.2 percentage points respectively. By comparison, over this period the actual beef share fell by just 1.4 percentage points, and that of poultry rose by only 0.3 per cent, indicating how changes in prices and total meat and fish expenditure acted to counteract the effects of preference changes.

3.5 Discussion and conclusions

The evidence presented in this chapter supports the idea that the observed meat and fish demand patterns of the four and a half years studied cannot be fully explained by changes in prices and income alone. The hypothesis of constancy of the parameters of a richly specified AIDS model for seven meat categories and fish was rejected against a more general time-varying parameter model.

Part of the effect of the BSE crisis was a short-run negative impact on beef demand and prepared meat, and in favour of poultry and meat products (largely pork) that disappeared after one period. Rapid and effective action by the Dutch government helped to some extent to restore consumer confidence in the product's safety.

However, in contrast to the finding by Schifferstein et al. (1998) of no change in the image of beef meat amongst Dutch meat consumers surveyed 1995 and 1997, our results show that the BSE scare also triggered a uni-directional shift in preferences that was mainly biased against beef, minced meat and meat products, and in favour of pork, prepared meat and fish. Over 12 per cent of this shift occurred in the same period as the BSE scare, but the shift took 21 months to complete. In order to see whether it is reversible in the longer term, this study should be repeated in 2-3 years' time.

The combined effect of the underlying trends and the irreversible component of the BSE effect was against beef, minced meat and meat products, and in favour of pork, prepared meat, poultry and fish. Health concerns could perhaps partly explain the shift to white meat and fish. However, other evidence suggests an important reason for these changes is probably the consumer's increased preference for convenience. Verbeke and Viaene (1998) found that socio-cultural changes in Belgium have increased demand for easy and quick to prepare meat dishes, and greater variety. In 1990, about 20% of Dutch households owned microwave ovens, whereas this figure had risen to 50% in 1996 and 67 % in 1997 (Hammink, 1997, 1998). Poultry meat, prepared meat and some pork cuts are quick and easy dishes. Herring, smoked or fried fish and prepared fish dishes, which are also easy to prepare, compose the larger part of Dutch fish demand (GfK, 1998). Supermarkets recognised this trend towards convenience products and have adapted the range of meat lines they offer in order to cater for it (PVE, 1998b). Thus we conclude that convenience reasons have also played an important part in the observed structural changes.

After the irreversible BSE-related parameter shift, pork, minced meat and meat products became more price-elastic. Thus, the lower pork prices recorded at the end of the period boosted actual demand for pork meat more than they would have before the structural change took place. By contrast, beef and poultry demand became insensitive to price changes.

The implications of these results are particularly relevant for the beef industry, indicating the need for quality adjustment in production in order to satisfy the demand for beef as a "luxury" meat, an increased effort in promotion and marketing and more attention to the development of prepared beef meat lines.

Acknowledgement

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Appendix IV A short history of the BSE-crisis in 1996

Date	Events	Source
20.03.96	The British government announces a possible link between BSE and CJD disease.	EU, 1998
21.03.96	The Dutch agricultural ministry imposes a movement restriction on all imported British cattle.	LNV, 1996
27.03.96	The European Union imposes an export embargo on British beef meat and products derived from beef meat. (96/239/CE)	EU, 1998
27.03.96	The Dutch agricultural ministry decides to slaughter and render all imported British calves being fattened in the Netherlands.	LNV, 1996
03.04.96	The Dutch agricultural ministry appoints an extra Commission, to control the preventive slaughter of all imported British calves.	LNV, 1996
10.04.96	Start of slaughtering of some 64 000 British calves in the veal sector in the Netherlands.	LNV, 1996

Appendix V Testing the chosen model for symmetry and homogeneity

	URSS	RRSS	k	LR	χ^2 (α=0.05)
Imposing symmetry and homogeneity	0.00003	0.000329	56	885.2	74
Imposing homogeneity	0.00024	0.000329	14	126.9	24
Imposing symmetry	0.00010	0.000329	42	465.5	58

Appendix VI R^2 and Durbin Watson of the chosen model

	Beef	Pork	Sheep	Minced Meat	Prepared Meat	Poultry	Fish
R^2	0.99	0.98	0.88	0.95	1.00	0.99	0.97
DW	2.35	2.04	1.88	2.37	2.07	1.90	1.96

Appendix VII The estimated parameters

	Beef	Pork	Sheep	Minced meat	Prepared meat	Poultry	Fish	Meat products
α_i	0.0955	-0.0831	-0.0004	0.0384	-0.1769	**0.5184**	0.1031	0.5050
	0.84	*-0.47*	*-0.01*	*0.34*	*-1.46*	*4.65*	*1.07*	*1.68*
ρ_i	**-0.3326**	0.0666	-0.0307	-0.0688	0.0529	**0.4415**	0.1118	-0.2406
	-2.97	*0.62*	*-1.31*	*-0.79*	*0.61*	*5.32*	*1.39*	*-1.61*
β_i	0.0490	**-0.2158**	**-0.0395**	0.1129	**-0.2104**	0.0176	**-0.1683**	**0.4545**
	0.72	*-3.06*	*-2.09*	*1.87*	*-4.43*	*0.31*	*-2.57*	*3.04*
δ_i	0.1403	**0.1766**	0.0154	-0.0223	-0.1011	**-0.3232**	-0.0633	0.1776
	1.51	*2.08*	*0.61*	*-0.28*	*-1.54*	*-4.88*	*-0.75*	*1.03*
β_{ij}								
	0.0155	0.0272	0.0023	-0.0035	0.0641	0.0319	0.0096	-0.1471
	0.32	*0.76*	*0.29*	*-0.10*	*1.73*	*1.01*	*0.46*	*-1.79*
	0.0272	-0.1108	-0.0057	-0.0245	**0.1171**	-0.0372	0.0343	-0.0004
	0.76	*-1.84*	*-0.58*	*-0.57*	*2.87*	*-1.02*	*1.11*	*0.00*
	0.0023	-0.0057	0.0011	**0.0178**	-0.0064	**-0.0132**	0.0002	0.0039
	0.29	*-0.58*	*0.40*	*2.20*	*-0.73*	*-2.17*	*0.04*	*0.20*
	-0.0035	-0.0245	**0.0178**	-0.0203	**0.1235**	0.0241	-0.0412	-0.0761
	-0.10	*-0.57*	*2.20*	*-0.35*	*3.29*	*0.71*	*-1.81*	*-0.91*
	0.0641	**0.1171**	-0.0064	**0.1235**	-0.0604	**-0.1790**	-0.0045	-0.0544
	1.73	*2.87*	*-0.73*	*3.29*	*-1.26*	*-5.65*	*-0.15*	*-0.65*
	0.0319	-0.0372	**-0.0132**	0.0241	**-0.1790**	-0.0110	**-0.0411**	**0.2255**
	1.01	*-1.02*	*-2.17*	*0.71*	*-5.65*	*-0.25*	*-2.74*	*3.45*
	0.0096	0.0343	0.0002	-0.0412	-0.0045	**-0.0411**	**0.0946**	-0.0520
	0.46	*1.11*	*0.04*	*-1.81*	*-0.15*	*-2.74*	*2.91*	*-0.72*
	-0.1471	-0.0004	0.0039	-0.0761	-0.0544	**0.2255**	-0.0520	0.1005
	-1.79	*0.00*	*0.20*	*-0.91*	*-0.65*	*3.45*	*-0.72*	*0.41*
δ_{ij}								
	-0.0603	0.0213	0.0171	-0.1308	-0.1224	**-0.2089**	-0.0235	**0.5074**
	-0.53	*0.27*	*0.91*	*-1.74*	*-1.50*	*-2.53*	*-0.35*	*2.93*
	0.0213	0.0341	0.0133	0.0802	0.0020	**0.2225**	0.0970	**-0.4706**
	0.27	*0.36*	*0.75*	*1.08*	*0.03*	*3.00*	*1.62*	*-2.97*
	0.0171	0.0133	0.0018	**-0.0432**	-0.0060	-0.0345	0.0029	0.0486
	0.91	*0.75*	*0.29*	*-2.57*	*-0.38*	*-1.81*	*0.17*	*1.34*
	-0.1308	0.0802	**-0.0432**	-0.1215	**-0.2804**	0.0753	0.0700	**0.3504**
	-1.74	*1.08*	*-2.57*	*-1.19*	*-4.42*	*1.04*	*1.21*	*2.40*
	-0.1224	0.0020	-0.0060	**-0.2804**	0.0721	-0.1158	0.0809	**0.3696**
	-1.50	*0.03*	*-0.38*	*-4.42*	*0.55*	*-1.45*	*1.25*	*2.76*
	-0.2089	**0.2225**	-0.0345	0.0753	-0.1158	0.1175	-0.0786	0.0225
	-2.53	*3.00*	*-1.81*	*1.04*	*-1.45*	*0.96*	*-1.07*	*0.13*
	-0.0235	0.0970	0.0029	0.0700	0.0809	-0.0786	**-0.1767**	0.0280
	-0.35	*1.62*	*0.17*	*1.21*	*1.25*	*-1.07*	*-2.03*	*0.19*
	0.5074	**-0.4706**	0.0486	**0.3504**	**0.3696**	0.0225	0.0280	-0.8558
	2.93	*-2.97*	*1.34*	*2.40*	*2.76*	*0.13*	*0.19*	*-1.89*

Appendix VII The estimated parameters (suite)

	Beef	Pork	Sheep	Minced meat	Prepared meat	Poultry	Fish	Meat products
φ_i	-0.0000	0.0001	0.0001	0.0001	**0.0007**	0.0002	0.0005	**-0.0017**
	-0.02	*0.48*	*1.51*	*0.19*	*3.31*	*1.06*	*1.68*	*-2.50*
κ_i	-0.0008	**-0.0013**	**-0.0003**	0.0004	**-0.0014**	0.0010	0.0000	0.0025
	-1.46	*-2.92*	*-2.40*	*0.85*	*-2.84*	*1.40*	*0.07*	*1.89*
χ_i	**-0.0244**	-0.0030	-0.0025	-0.0032	**-0.0102**	**0.0175**	-0.0053	**0.0311**
	-4.91	*-0.59*	*-1.82*	*-0.76*	*-2.75*	*4.17*	*-1.10*	*2.73*
θ_{im}								
1	-0.0055	**0.0183**	0.0005	**-0.0165**	**0.0248**	0.0056	0.0143	**-0.0416**
	-0.73	*2.11*	*0.25*	*-2.55*	*4.17*	*0.93*	*1.98*	*-2.33*
2	0.0060	0.0062	0.0005	**-0.0139**	0.0015	**-0.0141**	**0.0138**	0.0000
	1.08	*1.11*	*0.35*	*-2.96*	*0.37*	*-3.22*	*2.53*	*0.00*
3	-0.0034	**-0.0150**	**-0.0030**	-0.0083	**-0.0087**	**0.0098**	0.0006	**0.0280**
	-0.63	*-2.56*	*-2.23*	*-1.87*	*-2.03*	*2.21*	*0.12*	*2.32*
4	0.0028	0.0019	0.0002	-0.0046	**-0.0107**	-0.0030	0.0014	0.0119
	0.96	*0.62*	*0.28*	*-1.66*	*-4.86*	*-1.30*	*0.50*	*1.62*
5	**-0.0099**	-0.0064	-0.0001	-0.0025	-0.0017	**0.0053**	-0.0019	**0.0171**
	-3.26	*-1.80*	*-0.12*	*-0.89*	*-0.67*	*2.20*	*-0.64*	*2.32*
6	0.0025	**-0.0136**	-0.0006	0.0009	-0.0021	0.0020	-0.0034	0.0143
	0.80	*-3.13*	*-0.62*	*0.31*	*-0.84*	*0.71*	*-1.14*	*1.70*
7	-0.0133	**-0.0186**	-0.0019	**0.0173**	-0.0030	0.0104	-0.0125	0.0216
	-1.99	*-2.55*	*-1.05*	*3.08*	*-0.57*	*1.89*	*-1.85*	*1.32*
8	-0.0007	-0.0169	-0.0017	**0.00259**	-0.0097	-0.0022	**-0.0203**	0.0256
	-0.08	*-1.64*	*-0.69*	*3.37*	*-1.31*	*-0.30*	*-2.31*	*1.17*
9	0.0065	0.0112	**0.0048**	**0.0238**	**0.0229**	-0.0080	0.0008	**-0.0620**
	0.78	*1.34*	*2.17*	*3.18*	*3.39*	*-1.12*	*0.10*	*-3.33*
10	**0.0158**	0.0053	0.0026	0.0007	0.0066	**-0.0183**	0.0053	-0.0180
	2.93	*1.04*	*1.81*	*0.17*	*1.84*	*-4.32*	*1.04*	*-1.50*
11	0.0022	0.0021	-0.0006	0.0043	0.0046	**-0.0061**	-0.0015	-0.0050
	0.70	*0.52*	*-0.75*	*1.43*	*1.86*	*-2.18*	*-0.55*	*-0.63*
12	0.0029	-0.0006	-0.0015	-0.0067	-0.0001	-0.0018	-0.0004	0.0082
	0.71	*-0.10*	*-1.56*	*-1.86*	*-0.02*	*-0.53*	*-0.14*	*0.82*
13	-0.0059	**0.0261**	0.0008	**-0.0206**	**-0.0244**	**0.0204**	0.0038	-0.0001
	-0.96	*4.05*	*0.48*	*-3.95*	*-6.75*	*5.09*	*0.72*	*-0.01*

Appendix VII The estimated parameters (suite)

	Beef	Pork	Sheep	Minced meat	Prepared meat	Poultry	Fish	Meat products
γ_{im}								
1	-0.0167	0.0040	0.0003	0.0101	-0.0126	0.0172	0.0011	-0.0034
	-1.72	*0.37*	*0.12*	*1.22*	*-1.47*	*1.91*	*0.14*	*-0.14*
2	-0.0028	0.0108	0.0011	-0.0024	0.0123	0.0017	0.0028	-0.0234
	-0.39	*1.43*	*0.58*	*-0.39*	*1.92*	*0.24*	*0.38*	*-1.27*
3	-0.0019	**0.0153**	0.0022	0.0003	**0.0131**	0.0036	-0.0002	**-0.0324**
	-0.30	*2.18*	*1.33*	*0.06*	*2.26*	*0.64*	*-0.04*	*-2.12*
4	-0.0112	0.0006	-0.0004	-0.0052	0.0083	**0.0210**	0.0105	-0.0236
	-1.67	*0.10*	*-0.29*	*-1.05*	*1.65*	*3.91*	*1.95*	*-1.89*
5	-0.0043	**0.0118**	-0.0016	-0.0075	**0.0126**	0.0022	-0.0036	-0.0095
	-0.80	*2.39*	*-1.11*	*-1.67*	*2.93*	*0.44*	*-0.70*	*-0.77*
6	-0.0209	-0.0063	-0.0029	-0.0009	**-0.0270**	-0.0166	-0.0074	**0.0820**
	-1.80	*-0.54*	*-0.97*	*-0.09*	*-2.58*	*-1.36*	*-0.64*	*3.18*
7	**0.0222**	0.0065	0.0028	-0.0005	-0.0016	**-0.0364**	0.0043	0.0026
	2.62	*0.65*	*1.27*	*-0.06*	*-0.22*	*-5.14*	*0.54*	*0.12*
8	0.0054	0.0100	0.0010	-0.0010	-0.0026	**-0.0217**	0.0025	0.0064
	0.55	*0.93*	*0.37*	*-0.11*	*-0.34*	*-2.46*	*0.26*	*0.24*
9	0.0093	**-0.0292**	-0.0051	-0.0062	**-0.0263**	-0.0197	**-0.0258**	**0.1029**
	0.81	*-2.20*	*-1.64*	*-0.58*	*-2.76*	*-1.93*	*-2.24*	*3.91*
10	-0.0098	0.0027	-0.0015	**0.0128**	0.0011	**0.0126**	-0.0034	-0.0144
	-1.62	*0.46*	*-0.87*	*2.34*	*0.25*	*2.56*	*-0.53*	*-0.97*
11	0.0105	-0.0024	0.0023	-0.0091	-0.0019	-0.0022	0.0046	-0.0018
	1.41	*-0.33*	*1.30*	*-1.48*	*-0.32*	*-0.27*	*0.71*	*-0.10*
12	0.0041	0.0090	0.0037	0.0033	0.0129	0.0125	0.0013	**-0.0468**
	0.49	*1.01*	*1.75*	*0.46*	*1.48*	*1.44*	*0.16*	*-2.35*
13	0.0161	**-0.0329**	-0.0017	0.0064	0.0117	**0.0257**	0.0135	-0.0387
	1.14	*-2.80*	*-0.53*	*0.60*	*1.00*	*2.26*	*1.05*	*-1.29*
υ_{ij}								
	0.3199	0.3185	0.0650	-0.3689	**0.5076**	**-0.5705**	0.0964	-0.3680
	1.52	*1.62*	*1.12*	*-1.94*	*3.04*	*-3.04*	*0.49*	*-0.84*
	0.0537	0.3391	0.0011	0.1402	**0.3351**	**-0.6977**	0.1913	-0.3628
	0.28	*1.69*	*0.02*	*0.79*	*2.52*	*-4.61*	*1.09*	*-0.85*
	0.0859	**-2.3075**	-0.1201	0.7121	**-3.1209**	**2.3564**	-0.3501	2.7442
	0.10	*-2.27*	*-0.51*	*0.89*	*-3.90*	*3.06*	*-0.47*	*1.37*
	-0.3273	0.1110	-0.0418	0.5140	0.3132	0.4141	-0.2849	-0.6984
	-1.18	*0.40*	*-0.52*	*1.97*	*1.49*	*1.67*	*-1.08*	*-1.12*
	-0.2647	**0.7185**	0.0072	**-1.0005**	**0.6868**	-0.4236	0.4587	-0.1823
	-0.75	*2.04*	*0.08*	*-3.13*	*2.38*	*-1.56*	*1.43*	*-0.26*
	-0.2322	0.0804	-0.0614	-0.0897	0.0181	-0.0743	**-0.3406**	0.6997
	-1.32	*0.44*	*-1.18*	*-0.53*	*0.14*	*-0.56*	*-2.01*	*1.76*
	0.2233	-0.0182	0.0244	-0.0789	**0.5546**	-0.0934	-0.0462	-0.5657
	1.06	*-0.09*	*0.43*	*-0.42*	*3.33*	*-0.57*	*-0.24*	*-1.25*
	0.1414	**0.7582**	0.1256	0.1715	**0.7055**	**-0.9109**	0.2753	**-1.2665**
	0.55	*2.63*	*1.97*	*0.73*	*3.40*	*-3.81*	*1.30*	*-2.43*

Appendix VIII Short-run elasticities

Before the structural change

The uncompensated elasticities

	Beef	Pork	Sheep	Minced meat	Prepared meat	Poultry	Fish	Meat products
Beef	**-0.894**	0.246	0.017	-0.038	**0.600**	0.027	0.031	**-1.396**
	-2.88	*0.95*	*0.30*	*-0.15*	*2.08*	*0.07*	*0.15*	*-2.40*
Pork	0.237	-1.739	-0.031	-0.120	0.495	0.543	0.364	0.561
	0.33	*-1.93*	*-0.19*	*-0.16*	*0.69*	*0.95*	*0.65*	*0.28*
Sheep	1.262	-2.202	-0.646	5.341	-3.701	2.851	1.408	5.966
	0.23	*-0.35*	*-0.44*	*0.92*	*-0.63*	*0.56*	*0.30*	*0.38*
Minced	-0.090	-0.177	0.164	**-1.213**	**1.333**	-0.395	-0.512	-1.168
meat	*-0.19*	*-0.31*	*1.41*	*-2.25*	*2.62*	*-0.81*	*-1.16*	*-0.87*
Prepared	0.744	1.048	-0.056	1.260	-1.936	-0.547	0.202	0.354
meat	*0.75*	*0.94*	*-0.24*	*1.23*	*-1.86*	*-0.69*	*0.24*	*0.12*
Poultry	0.261	-0.307	**-0.112**	0.200	**-1.486**	**-1.180**	**-0.364**	**1.839**
	1.07	*-1.02*	*-2.29*	*0.72*	*-5.07*	*-3.69*	*-2.49*	*3.48*
Fish	0.317	0.436	0.013	-0.631	-0.544	0.971	0.929	0.343
	0.23	*0.28*	*0.04*	*-0.46*	*-0.36*	*0.77*	*0.70*	*0.08*
Meat	-0.529	0.069	0.007	-0.264	0.064	-0.126	-0.326	-1.291
products	*-1.38*	*0.17*	*0.10*	*-0.70*	*0.19*	*-0.27*	*-1.42*	*-1.31*

The compensated elasticities

	Beef	Pork	Sheep	Minced meat	Prepared meat	Poultry	Fish	Meat products
Beef	**-0.724**	0.478	0.022	0.112	**0.743**	0.193	0.115	-0.938
	-2.33	*1.68*	*0.38*	*0.43*	*2.38*	*0.63*	*0.57*	*-1.76*
Pork	0.200	-1.790	-0.032	-0.153	0.463	0.506	0.346	0.460
	0.28	*-1.98*	*-0.19*	*-0.21*	*0.64*	*0.92*	*0.62*	*0.23*
Sheep	0.024	-3.894	-0.682	4.245	-4.746	1.633	0.798	2.621
	0.00	*-0.61*	*-0.47*	*0.73*	*-0.79*	*0.34*	*0.17*	*0.17*
Minced	0.158	0.162	0.171	-0.994	**1.542**	-0.151	-0.390	-0.498
meat	*0.33*	*0.28*	*1.47*	*-1.84*	*2.96*	*-0.34*	*-0.89*	*-0.38*
Prepared	0.615	0.872	-0.060	1.146	-2.045	-0.674	0.138	0.007
meat	*0.62*	*0.78*	*-0.25*	*1.12*	*-1.95*	*-0.87*	*0.16*	*0.00*
Poultry	0.400	-0.118	**-0.108**	0.323	**-1.370**	**-1.044**	**-0.296**	**2.213**
	1.64	*-0.37*	*-2.21*	*1.15*	*-4.89*	*-3.86*	*-2.16*	*4.54*
Fish	0.096	0.134	0.007	-0.827	-0.731	0.753	0.820	-0.254
	0.07	*0.08*	*0.02*	*-0.60*	*-0.48*	*0.63*	*0.62*	*-0.06*
Meat	-0.240	0.463	0.016	-0.009	0.308	0.158	-0.184	-0.512
products	*-0.63*	*1.11*	*0.22*	*-0.02*	*0.87*	*0.36*	*-0.81*	*-0.53*

Appendix VIII Short-run elasticities (suite)

After the structural change

The uncompensated elasticities

	Beef	Pork	Sheep	Minced meat	Prepared meat	Poultry	Fish	Meat products
Beef	-1.197	0.845	0.192	-1.324	-0.556	-3.379	-0.552	3.188
	-0.97	*0.72*	*0.66*	*-1.27*	*-0.34*	*-1.78*	*-0.40*	*0.89*
Pork	0.272	**-1.532**	0.046	0.356	0.745	**1.391**	**0.877**	**-2.911**
	0.30	*-3.64*	*0.48*	*0.89*	*1.52*	*2.75*	*2.12*	*-2.27*
Sheep	5.165	0.752	-0.134	-7.787	-3.921	-7.781	2.804	17.540
	0.59	*0.11*	*-0.06*	*-1.06*	*-0.46*	*-0.90*	*0.34*	*0.73*
Minced meat	-1.183	0.727	-0.239	**-2.396**	-1.515	0.119	0.072	2.543
	-1.46	*1.10*	*-1.34*	*-3.12*	*-1.90*	*0.13*	*0.09*	*1.18*
Prepared meat	-0.866	0.456	-0.127	-1.299	-0.886	0.039	1.331	3.115
	-0.37	*0.23*	*-0.24*	*-0.71*	*-0.31*	*0.01*	*0.55*	*0.45*
Poultry	-1.708	0.942	-0.392	0.869	-2.328	2.171	-0.377	2.244
	-0.80	*0.52*	*-0.80*	*0.52*	*-1.06*	*0.89*	*-0.17*	*0.36*
Fish	-0.633	1.189	0.026	0.538	1.136	1.509	-1.404	0.039
	-0.20	*0.47*	*0.04*	*0.22*	*0.37*	*0.47*	*-0.42*	*0.00*
Meat products	**1.376**	**-1.043**	**0.176**	**0.791**	**0.978**	-1.124	-0.542	**-3.589**
	3.36	*-2.31*	*2.14*	*2.22*	*2.57*	*-1.53*	*-1.69*	*-5.25*

The compensated elasticities

	Beef	Pork	Sheep	Minced meat	Prepared meat	Poultry	Fish	Meat products
Beef	-0.902	1.291	0.201	-1.036	-0.242	-3.028	-0.362	4.078
	-0.73	*1.05*	*0.69*	*-1.02*	*-0.15*	*-1.66*	*-0.27*	*1.14*
Pork	0.352	**-1.410**	0.048	0.435	0.830	**1.487**	**0.929**	-2.670
	0.44	*-3.14*	*0.51*	*1.16*	*1.70*	*3.14*	*2.24*	*-1.90*
Sheep	4.460	-0.312	-0.155	-8.476	-4.669	-8.618	2.352	15.417
	0.54	*-0.04*	*-0.07*	*-1.36*	*-0.55*	*-1.08*	*0.29*	*0.55*
Minced meat	-0.985	1.027	-0.233	**-2.202**	**-1.304**	0.355	0.200	3.142
	-1.26	*1.28*	*-1.31*	*-3.56*	*-1.71*	*0.47*	*0.26*	*1.29*
Prepared meat	-1.053	0.173	-0.132	-1.482	-1.085	-0.183	1.210	2.551
	-0.45	*0.09*	*-0.25*	*-0.82*	*-0.39*	*-0.07*	*0.50*	*0.37*
Poultry	-1.859	0.714	-0.397	0.721	-2.488	1.992	-0.474	1.789
	-0.86	*0.40*	*-0.81*	*0.44*	*-1.13*	*0.80*	*-0.22*	*0.28*
Fish	-0.888	0.804	0.019	0.289	0.865	1.207	-1.567	-0.729
	-0.29	*0.31*	*0.03*	*0.12*	*0.28*	*0.37*	*-0.46*	*-0.08*
Meat products	**1.692**	-0.566	**0.185**	**1.100**	**1.313**	-0.748	-0.339	**-2.638**
	4.15	*-0.91*	*2.32*	*4.40*	*5.51*	*-1.40*	*-1.25*	*-3.24*

Chapter 4

Welfare effects of controlling the 97/98 Classical Swine Fever epidemic in the Netherlands

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Abstract

The Dutch pig market is simulated during a CSF epidemic in the Netherlands. A sector-level market model and a spatial, stochastic epidemiological simulation model are used, and the control measures prescribed by European Union legislation are implemented. Welfare changes of producers and consumers, and government costs, are calculated. In a medium-sized epidemic, Dutch pig producers' surplus increases by EUR 454 mn without export restrictions, although producers within quarantine areas lose. Consumer surplus falls by EUR 463 mn. With a ban on live pig exports, pig producers' collective loss is EUR 251 mn whereas consumers gain EUR 111 mn. Government costs are also lower when exports are banned. The net welfare effects for the Dutch economy relative to a non-epidemic situation are EUR –297 mn and EUR –394 mn respectively, without and with an export ban.

4.1 Introduction

Classical swine fever (CSF), known in the US as hog cholera, is a viral disease of pigs. In countries where CSF is endemic, it is common practice to vaccinate pigs against the disease to avoid serious losses. However, pigs vaccinated with the conventional vaccine cannot be distinguished from infected pigs. Therefore, importing countries do not usually allow the import of live pigs or fresh pig products from countries that vaccinate against CSF (Moening, 2000).

CSF has been largely eradicated from the EU pig population. Current EU policy requires rapid control measures involving slaughter of infected and at-risk animals, and quarantine zones[1]. Vaccination is banned. Trading partners may close their borders on sanitary grounds depending on the control measures used. A partial or total export ban for live pigs and fresh pig products would have a disastrous impact on the Dutch pig sector (Buijtels and Burrell, 2000).

Various studies have looked at the costs related to an incidental outbreak of a contagious animal disease. Garner and Lack (1995b), and Mahul and Gohin (1999), calculated the economy-wide costs, whereas Berentsen et al. (1992) used a partial equilibrium approach to estimate only a subset of the indirect costs. Other studies have evaluated eradication

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[1] Hereafter "quarantine" zones refer to all restricted zones/areas (protection zone (0-3 km) and surveillance zones (3-10 km)) in which movement restrictions and control measures are imposed.

programmes for endemic animal diseases (Ellis, 1972; Ebel et al., 1992; Miller et al., 1996; Andersson et al., 1997).

This study reports the welfare effects of a small, medium and large CSF epidemic in the Netherlands. A partial equilibrium model encompassing the whole chain is used. Welfare effects are calculated under three different trade scenarios. In all scenarios, quarantine zones are set up around infected farms. In the first scenario, producers outside the quarantine zones continue to trade with foreign countries. In the second scenario, trade in live pigs stops. The third scenario adds the assumption that 50 % of the export demand for live pigs (now banned) is switched to demand for exported pig meat.

This research estimates the net welfare effects of an outbreak and their distribution over different groups. It allows us to investigate whether a trade ban exacerbates the consequences of an outbreak, and to consider whether additional control measures to reduce an epidemic might be economically justified.

4.2 Simulating the 1997-8 Dutch CSF epidemic

The primary outbreak of CSF was confirmed on 4 February 1997. The last confirmed case of 6 March 1998 brought the number of farms where infection was detected to 429. 4 February was also the starting date for our simulations. The 37 farms that were already infected but not detected before 4 February in the real epidemic were considered as fixed events and were the starting point for all the simulated scenarios (Jalvingh et al., 1999).

4.2.1 EU minimum measures in the case of CSF

Once CSF is detected on a pig farm, all pigs on the farm are slaughtered and rendered. Farmers receive compensation equal to the value of the animal as estimated by a government assessor. A ban on all animal transport is imposed within a quarantine zone of 10 km radius for at least 42 days. Restocking of the infected farm is not allowed till the quarantine zone is lifted.

Veterinary measures, such as clinical inspection and serological screening, are used for all farms in the quarantine zone. Earlier contacts with the infected farm are traced and the contact farms inspected. If no new infected farms are detected after all farms have been serologically tested, then the quarantine is lifted.

4.2.2 Extra control measures applied in the Dutch 1997-8 epidemic

Preventive slaughter is the destruction of the pigs on all neighbouring farms in a fixed radius (500 to 1000 m) around a detected farm in order to reduce the spread of the virus to other farms. As with infected farms, compensation is paid for the slaughtered pigs depending on their estimated value and restocking of the farm is not allowed until the quarantine zone is lifted. Under EU legislation, preventive slaughter is an optional control measure. In the 1997-8 Dutch CSF epidemic (hereafter referred as the "Dutch CSF epidemic"), preventive slaughter (26 farms) was applied within a radius of 1 km around the first two infected farms and was reintroduced after 2 months (Pluimers, 1999).

4.2.3 Animal welfare slaughter measures

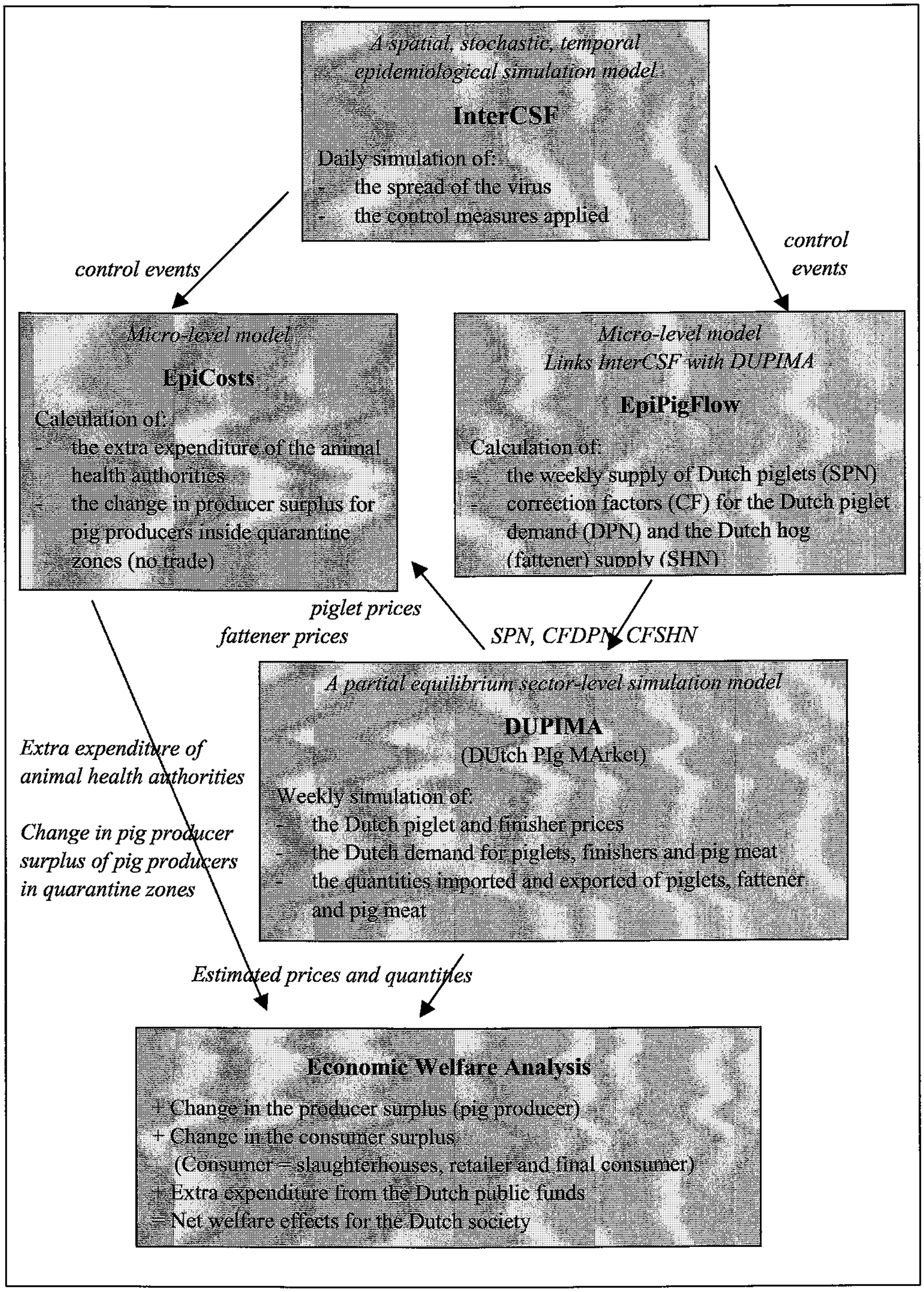
In the Dutch CSF epidemic, the prolonged duration of quarantine zones led to animal welfare problems. To avoid overcrowding and to reduce the risk of illegal animal movements, buying-out schemes were used for 25-kg-ready-to-deliver piglets and for 120-kg-ready-to-deliver pigs (hereafter referred to as animal welfare slaughter). These healthy pigs were bought at current market price and were slaughtered and rendered. As no animal transport or restocking was allowed inside a quarantine zone, fattening farms remained empty if the quarantine zone lasted for longer than 4 months.

4.3 Methodology

4.3.1 Model structure and content

The modelling framework comprises five parts and is summarised in Figure 4.1. A spatial, dynamic, stochastic, epidemiological model (InterCSF) simulates the spread of the disease and the control measures, a micro-economic model (EpiPigFlow) calculates the weekly flow of pigs, a micro-economic model (EpiCosts) calculates the control programme costs and changes in producer surplus within a quarantine zone, a simulation model of the Dutch pig market (DUPIMA) calculates market prices and trade flows, and an Excel worksheet calculates the other welfare effects. The first three models are written in C++ whereas DUPIMA simulates in GAMS.

Figure 4.1 The modelling framework



4.3.2 Epidemiological simulation model (InterCSF)

InterCSF (Jalvingh et al., 1999) depicts all Dutch pig farms, their geographical co-ordinates, their farm type (multiplier, finisher, multiplier-finisher or breeding stock farm) and farm size. InterCSF simulates the daily spread of CSF between farms by contact (animals, vehicles, and persons) and through local spread (neighbouring farms within 1000 m of an infected farm have a higher potential risk of infection). The median of the simulation model was calibrated on the number of detected cases in the first year of the Dutch CSF epidemic (Jalvingh et al., 1999). InterCSF allows us to simulate the main disease-control mechanisms that influence disease spread. Our simulations assume virtually the same disease control measures as were applied in the Dutch CSF epidemic.

4.3.3 EpiPigFlow

The main task of EpiPigFlow is to convert daily farm-level output from InterCSF to weekly input for the market module, DUPIMA. To calculate the piglet flow during an epidemic, EpiPigFlow aggregates to a weekly basis the piglets that would have been supplied from inside a quarantine zone, or that could not be supplied from outside a quarantine zone due to earlier depopulation, and subtracts them from average weekly 1996 piglet supply. Dutch demand for piglets (DPN) in DUPIMA is corrected for the fact that there is no demand for 25-kg piglets from fattening farms within quarantine zones.

DUPIMA assumes that the national supply of hogs[2] (SHN) is equal to the national demand for piglets (DPN) 17 weeks before, corrected for 2 % hog mortality. Since piglets purchased 17 weeks earlier on the market and now situated in a quarantine zone cannot be supplied on the hog market, a further correction has to be made. However, some farms have not only a multiplier unit but also a fattening unit. On such a farm, piglets may pass to the fattening operation even within a quarantine zone. If the quarantine zone is lifted in time, these hogs may be supplied onto the market. The correction factors for both these cases are calculated in EpiPigFlow.

On average, 0.059[3] piglets per day per sow place are weaned and sold. A newborn piglet takes 70 days to become a 25-kg-piglet, and the fattening period for a hog (25 to 110/120 kg) is a further 120 days, whereas the rearing period for a gilt (25 to 110-120 kg) is assumed to be 155 days. Hogs equal to 1/120 of all hog places are delivered each day to the hog market, and

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[2] A fattening pig (from 25 kg to 120 kg) is called hog, fattener or finisher.

[3] 0.059 piglets weaned or sold per sow per day = 21.5 piglets sold per sow per year.

their places are filled with 25-kg-piglets. Restocking of a previously depopulated farm is assumed to occur gradually. For example, 1/120 of all fattening places of the farms concerned are repopulated per day. For sow places, the farm's normal 25-kg-piglet supply is restored only after a minimum of 196 days[4].

4.3.4 DUPIMA

DUPIMA (Dutch Pig Market) is a sector-level partial equilibrium simulation model, adapted from Buijtels and Burrell (2000). Imports and exports of live animals occur at both levels in the vertical production chain, and pig meat is allocated between domestic and export markets. Unlike Buijtels and Burrell (2000), all foreign prices are endogenous.

We assume that in the short run the Dutch piglet supply is completely inelastic. Long production lags (minimum 4 to 6 months) and the need for an expansion permit (taking over 1 year to obtain) restrict expansion in the short run. The production lags, uncertainty about how long a quarantine zone will last and the animal welfare slaughter compensation on the basis of the actual weekly pig market prices, will all encourage farmers to continue in production.

DUPIMA depicts the structure of the Dutch piglet market in the following equations:

$$SPN_t = f_1\,(BS_{t-26}, Z_{1t}) \tag{1}$$

$$SPI_t = f_2\,(PPN_t, PPI_t, Z_{2t}) \tag{2}$$

$$DPN_t = f_3\,(PPN_t, PHN_t, Z_{3t}) \tag{3}$$

$$DPE_t = f_4\,(PPN_t, PPE_t, Z_{4t}) \tag{4}$$

$$SPN_t = DPN_t + DPE_t - SPI_t = f_5\,(PPN_t, PHN_t, PPI_t\ PPE_t, Z_{2t}, Z_{3t}, Z_{4t}) \tag{5}$$

$$PPI_t = f_6\,(PPN_t, PPN_{t-n}, PPI_{t-n}, Z_{5t}) \tag{6}$$

$$PPE_t = f_7\,(PPN_t, PPN_{t-n}, PPE_{t-n}, Z_{6t}) \tag{7}$$

where SPN = Dutch supply of piglets, BS = number of breeding sows, SPI = supply of piglets imported into the Dutch market, DPN = Dutch demand for piglets from fatteners, DPE = export demand for piglets; PPN = price of piglets on the Dutch market, PHN = price of hogs on the Dutch market, PPI = price of piglets in a representative import source, PPE = price of piglets in a representative export destination. Z_i are other exogenous factors (including List A disease outbreaks in the EU, feed price, seasonal effects, time trends) and n = 1 and/or 2 lagged periods. The unit time period is one week.

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[4] 196 days, assuming that on average a sow will first be inseminated 11 days after purchase, the pregnancy lasts 115 days and the rearing period for a piglet is 70 days.

Equation (5) is the equilibrium condition for the piglet market, which implicitly defines the Dutch piglet price: in each weekly period, the piglet price on the Dutch market adjusts to equate total demand, net of imported supplies, to the domestic supply of piglets, which is assumed independent of current price. Thus, the model assumes a virtual market where all piglets are marketed. This is only an approximation to the Dutch situation, where about a quarter of piglets remain for fattening with the producer who bred them (Backus et al., 1994).

The structure of the Dutch hog market is as follows:

$$SHN_t = (1\text{-}m)*DPN_{t-17} \tag{8}$$

$$SHI_t = f_8\ (PHN_t, PHI_t, Z_{7t}) \tag{9}$$

$$SCI_t = f_9\ (PHN_t, PHI_t, Z_{8t}) \tag{10}$$

$$DCN_t = f_{10}\ (PHN_t, Z_{9t}) \tag{11}$$

$$DHE_t = f_{11}\ (PHN_t, PHE_t, Z_{10t}) \tag{12}$$

$$DCE_t = f_{12}\ (PHN_t, PHE_t, Z_{11t}) \tag{13}$$

$$\begin{aligned} SHN_t &= DCN_t + DHE_t + DCE_t - SHI_t - SCI_t \\ &= f_{13}\ (PHN_t, PHI_t\ PHE_t, Z_{7t}, Z_{8t}, Z_{9t}, Z_{10t}, Z_{11t}) \end{aligned} \tag{14}$$

$$PHI_t = f_{14}\ (PHN_t, PHN_{t-n}, PHI_{t-n}, Z_{12t}) \tag{15}$$

$$PHE_t = f_{15}\ (PHN_t, PHN_{t-n}, PHE_{t-n}, Z_{13t}) \tag{16}$$

where SHN = supply of hogs from within the Netherlands, SHI = import of hogs, SCI = import of pig meat (converted to pig carcasses[5]), DHE = export of hogs, DCE = export of pig meat (converted to pig carcasses); PHN = price of hogs on the Dutch market, PHI = price of hogs in a representative import source, PHE = price of hogs in a representative export destination. Equation (14) is the equilibrium condition for the hog market.

4.3.4.1 Estimated demand relationships

The behavioural equations were econometrically estimated with monthly data[6] as import and export statistics were available only on a monthly basis (until 1996 and thereafter only quarterly). Because the Dutch CSF epidemic greatly increased and then severely reduced pig prices, we decided to estimate the model with data from 1992-1996 only. The model was converted to a weekly basis post-estimation.

Dummy variables for outbreaks of List A pig diseases were included in the model. Piglet and hog feed prices were tested in the model in equation (3), but both were rejected on statistical grounds. Cattle prices and chicken prices were also dropped from the equation after statistical

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[5] A pig carcass equals 87 kg pig meat.

[6] If not indicated others, the Commodity Board for Livestock, Meat and Eggs (PVE) supplied the data.

tests. Monthly dummies and a time trend were retained if significant, but were not active in the simulation model.

Equations (1) and (8) were not estimated econometrically. Equations (2), (3), (4), (9), (10), (11), (12) and (13) were estimated in a block by Iterative Three Stage Least Squares, using all the predetermined (exogenous and lagged endogenous) variables as instruments. All functions are linear. The foreign price equations (6), (7), (15) and (16) were estimated separately by Ordinary Least Squares.

Parameter estimates and elasticities are available on request. The signs and magnitudes of the coefficients are all satisfactory, as are for the most part the t-ratios although much of the variation remains unexplained.

4.3.4.2 Calibration of DUPIMA

The simulation model was first calibrated on monthly 1996 data. In order to reproduce the 1996 data as closely as possible, we adjusted several intercepts and estimated price parameters. The price elasticity for domestic carcass demand was increased from -0.35 to -0.75. (Note that in Chapter 3 we estimated the own-price elasticity for pork at retail level to be -1.53.) It was also necessary to increase the price responses of exported carcass demand and piglet demand in order to capture the 1996 fluctuations.

The simulation model was first calibrated on monthly 1996 data. When the monthly model was converted to a weekly basis, it was tested on weekly 1996 data (where available), after which small adjustments to some intercepts were made. Non-negativity constraints on trade flows were imposed when simulating.

4.3.4.3 Simulated scenarios and assumptions

In 1998 we surveyed 10 “experts” from the Dutch pig sector on the likely trade policy reactions to a Dutch CSF epidemic with and without emergency vaccination as an extra control measure. The results of this survey are summarised in the Appendix IX and more information are available on request. The survey strongly indicated that the European Union would accept the concept of regionalisation, i.e. quarantine zoning of whole provinces. This means that the most likely market scenario would be a regional rather than national export ban on all live pigs. If emergency vaccination were to be used, an export ban on pig meat originating from vaccinated pigs would certainly be added. The experts believed that the Dutch government would avoid control measures such as emergency vaccination that conflict with EU policy, so as to prevent total closure of the Dutch market.

Therefore, we assume that there will be either trade restrictions on quarantine zones only (no trade in live pigs and of pig meat from these areas (scenario Q)) or that, in addition, there will also be a ban on all live pig exports. In the second case, we simulated two different scenarios. In the first (Q + exp) the demand for exported pig meat (DCE) is unaffected, whereas in the second (Q + exp + switch), some of the demand for live hogs (now unavailable) switches to exported pig meat. In this case, the intercept of DCE increases by half the average number of live hogs exported each week in a non-epidemic situation.

At the beginning of an epidemic a total export ban on live pigs for at least 1 week will always occur. Subsequently, if regionalisation is accepted and if the authorities keep the epidemic "under control", provinces without quarantine zones would be allowed to export live pigs (scenario Q). If the Netherlands does not succeed in controlling an epidemic or uses control measures that are not approved by other EU partners, a total export stop on live pigs would follow. In the Dutch CSF epidemic, a ban on all live pig exports was imposed for most of the epidemic (Q + exp). The extent of any export switch from live hogs to pig meat is unknown. The consequences of a full export ban are probably somewhere between the two export scenarios shown (with and without switch).

4.3.4 EpiCost

EpiCosts is an adapted version of EpiLoss (Meuwissen et al., 1999). Farm-level serological costs and clinical inspection, which were calculated as a lump sum in Meuwissen et al. (1999), are represented here by a fixed component per farm plus a component depending on the number of animals on the farm per visit and on the number of visits. Except for small adaptations, all other government expenditures are calculated as in Meuwissen et al. (1999). Further details on EpiCosts are available on request.

4.4 Economic Welfare Analysis

We assume a vertical framework of factor and product markets, in which all prices, except those of piglets, hogs and pork, are constant. Following Just et al. (1982), producer surplus includes only the quasi-rents accruing to inputs used in farming. Quasi-rents accruing to marketing inputs are included along with the surplus of the final consumer in "consumer surplus". The welfare effects for the Netherlands are measured in comparison with the simulated (non-epidemic) market situation in 1996.

In the Dutch CSF epidemic, the EU budget financed 50 % of organisation costs and veterinary compensation payments and 70 % of compensation payments for animal welfare slaughter measures (LNV, 1998). Other payments are funded partly by the Dutch government and partly by the Dutch farm sector via contributions. In the Dutch CSF epidemic, the contribution from the industry was very small. Therefore, to simplify we include it with Dutch government expenditure.

Government expenditure is calculated by EpiCosts. The compensation payments for animal welfare slaughter are calculated using the simulated weekly prices obtained from DUPIMA.

4.4.1 Consumer surplus (CS)

The slaughterhouses and the processing industry operate under competitive conditions, which force them to keep their margin fixed in the short-run. It is assumed that this margin is equal to average cost per pig slaughtered and processed (PVE, 1999)[7]. A further assumption is that the slaughterhouses are distributed over the Netherlands in proportion to pig density. The number of pigs slaughtered ($Q_{PS} = SHN + SHI - DHE$) was compared with a simulated non-epidemic situation($_0$). For $\Delta Q_{PS} > 0$, ΔSS (surplus for slaughterhouses) = $\Delta Q_{PS} * MS_0$; and for $\Delta Q_{PS} < 0$, $\Delta SS = \Delta Q_{PS} * (MS_0 -$ variable costs saved). Changes on the hog market are directly transferred to the wholesale price. An asymmetric price reaction (as was found for the German pork market by Cramon-Taubadel, 1998), is not considered in this study.

At retail level, we assume for simplification reasons a fixed marketing margin (MR). When estimating econometrically, using monthly data for 1992-1999, we could not find any significant dynamic margin adjustment. In the given calculations the marketing margin was equal to average marketing margin of 1996. Besides we assume no noticeable effect on the profit of food retailers in the Netherlands[8]. Therefore welfare changes of retailers were assumed to be zero. Dutch retail demand for pig meat is then derived from the Dutch demand for pig carcasses (DCN)[9]. The change in the surplus of the final consumer (ΔCS) is given by $\Delta CS = (-(P_1 - P_0) * Q_0) - (0.5 * (P_1 - P_0) * (Q_1 - Q_0))$, assuming that the Dutch demand for pig carcasses (DCN) equals the Dutch demand for pig meat, converted at the rate 1kg pig carcass = 0.6 kg pig meat at retail level (PVE, 2000). The consumer price per kg pig meat is derived from the hog price per kg pig carcass and the margins of the slaughterhouses and the retailer.

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[7] Due to a lack of data, we estimate the change in welfare surplus of slaughterhouses by reduction in number slaughtered * average fixed cost per pig at normal capacity.

[8] This fact was not contested by people from the field when unofficially discussed.

[9] 1kg pig carcass is assumed to yield 0.6 kg pig meat at retail level (PVE, 2000).

We assume further that a CSF epidemic does not change consumer tastes for pork. This assumption is supported by the findings of Chapter 3, where we found no evidence of a taste shift that might have been due to the Dutch CSF epidemic.

4.4.2 Producer surplus (PS)

Producers belong to one of three subcategories (piglet producer, hog producer and breeding stock producer). In any given week, producers in each of these categories may be outside or inside a quarantine zone. Producers outside a quarantine zone fall into two subcategories: a) those whose pigs are sold on the pig market; b) those whose farms were depopulated in a quarantine zone that has now been lifted and who are now restocking. There are three sub-categories of producers inside a quarantine zone: a) those whose pigs are slaughtered and rendered by animal welfare slaughter measures; b) those whose pigs are slaughtered and rendered because the farm is newly detected or in a newly defined preventive slaughter zone and c) those with 100 % idle capacity because their farm was depopulated or emptied by animal welfare slaughter and restocking is forbidden. These sub-categories are summarised in Table 4.1. The changes in their surpluses are calculated separately.

For the first category outside a quarantine zone, the change in producer surplus for piglets is equal to $\Delta PS^P = (P^P_{1,t} - P^P_{0,t}) * S^P_{1,t}$, assuming all input costs are fixed. In the case of hog producers, the cost of the piglet purchased 17 weeks ago is endogenous in our model. Therefore, the change in producer surplus for hog producers is equal to $\Delta PS^H = (\Delta P^H_t - \Delta P^P_{t-17}) * Q^H_{1,t}$. For simplification, we assume that the prices for breeding stock[10] remain constant during the epidemic. As a consequence, the change in producer surplus of breeding stock farms outside a quarantine zone is assumed to be zero. For the second category outside a quarantine zone, the change in producer surplus is equal to ΔPS = (- $P_{0,t}$ + variable costs saved) * number of pigs not supplied, as the farm is still restocking.

Inside a quarantine zone, the changes in producer surpluses for piglets and hogs slaughtered and rendered under animal welfare slaughter are similar to the calculations done for pigs traded on the market, except that when pigs are kept longer than necessary, an allowance is made for extra variable costs, mainly feed costs. For breeding stock farms, we simulated the EU legislation, that is breeding stock bought under animal welfare slaughter schemes are compensated at the fattening pig price, which implies a loss for the breeding stock producers.

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[10] In 2000 only 688 of all 16 606 Dutch pig farms were categorized as "breeding" pig farms (Mourits et al., 2001).

Pigs slaughtered and rendered because the farm was either infected or because the farm was preventively slaughtered, are compensated at their average market value in a regular year (non-epidemic situation). The change in producer surplus is assumed to be zero.

Table 4.1 Subgroups of piglet, hog and breeding stock producers

Subgroups [a]		
I. Outside a quarantine zone [b]		
	a)	Normal pig production. Pigs are sold on the market.
	b)	After lifting the quarantine zone restrictions: Restocking empty places. Has not yet ready-to-market animals to deliver the pig market.
II. Inside a quarantine zone		
	a)	Current production continues: Animal welfare slaughter (with or without delay) of ready-to-market animals; weekly pig market prices are paid for pigs slaughtered and rendered under this measure. Thereafter hog farms become empty (switch to II.c)
	b)	Infected and depopulated, or preventive slaughtered; average non-epidemic values are paid as compensation. Thereafter, no production (switch to II.c).
	c)	Production interrupted (idle production); no compensation was paid.

a) Farms may switch weekly between categories. From subcategory I they may switch to II and back. Inside II they may switch from a) to b) to c) or directly from a) to c). When switching from I to II farms may enter either a) or b), and only if they were in I.b) they may directly switch to II.c).

b) Only a not depopulated piglet producer may switch without interruption from II.a) to I.a). All other farms will switch to I.b) when quarantine zone restrictions are lifted. Only after the farm is fully repopulated and back in a normal cycle may a farm in I.b) switch to I.a).

If quarantine zones in which animal welfare slaughter measures are applied lasted more than 4 months, hog stables are empty as restocking is forbidden. Furthermore, depopulated farms (detected or preventively slaughtered farms) are not allowed to repopulate until the quarantine zone is lifted, after which it takes time before pig farms are back in their normal production cycle. The change in the producer surplus for all those farms is: $\Delta PS = (-P_0 + \text{saved variable costs}) * Q_D$, whereby Q_D = "theoretical" number of ready-to-deliver pigs on depopulated farms.

4.5 Results

InterCSF was used to perform 100 replications of the Dutch CSF epidemic. All replications began by identifying the same 37 infected farms, but thereafter the epidemics developed differently according to the stochastic specification of the model. To summarise the results according to size of epidemic, two alternative definitions of size were used: length of the epidemic in days and the number of detected farms.

All replications were ranked according to each of these criteria. The average of the three replications centred on the 10th, 50th and 90th represent "small", "medium" and "large" epidemics respectively. Table 4.2 summarises the key parameters for small, medium or large epidemics according to each criterion.

4.5.1 Welfare changes of main participants

The total changes in producer and consumer surplus, as well as the changes in Dutch government expenditure and the net welfare effect, are given in Table 4.3 for both size categorisations and for the three export market assumptions. Recall that "consumer surplus" is the net change in surpluses downstream from the producer.

When foreign trade continues from non-quarantine zones, the reduction in national supply is not matched by a fall in total demand. Therefore, prices outside quarantine zones arise. Hence, producers collectively gain and consumers lose. With an export ban, a segment of demand is removed from the Dutch market. When the epidemic is small, the fall in demand outweighs the reduction in supply due to quarantine zones and so prices fall. Producers lose surplus. However, if there is a switch in export demand from live animals to pig meat, the price falls are reversed at the expense of consumers and the cost of compensation payments to the government budget.

4.5.2 Distribution of welfare changes among pig producers

The changes in the surpluses of piglet, hog and breeding stock producers depend on whether the farms are situated inside a quarantine zone or not (see Table 4.4). An overall gain to pig producers hides the fact that producers outside a quarantine zone gain, in contrast to those in quarantine zones. Moreover, pig producers inside a quarantine zone are not a homogeneous group, being either piglet, hog or breeding stock producers. Since piglet producers that are not depopulated continue in production and sell their ready-to-deliver piglets for animal

Table 4.2 Categorisation of the simulations according to different size criteria.

	Length of the epidemic (days)[a]	**# infected and detected farms**	**# preventively slaughtered farms**	**# farms in a quarantine zone**
Size of epidemic defined by the length of epidemic (days)				
Small epidemic				
9[b]	259	164	241	3860
10[b]	262	355	752	7826
11[b]	262	187	538	6047
Average	**261**	**235**	**510**	**5911**
STD	2	104	257	1986
Medium epidemic				
49[b]	306	458	1100	9789
50[b]	307	577	1166	9045
51[b]	307	296	662	5956
Average	**307**	**444**	**976**	**8263**
STD	1	141	274	2033
Large epidemic				
89[b]	428	304	1267	11507
90[b]	435	483	1738	12389
91[b]	446	2467	2583	17621
Average	**436**	**1085**	**1863**	**13839**
STD	9	1200	667	3305
Size of epidemic defined by the number of infected and detected farms				
Small epidemic				
9[b]	271	193	300	4073
10[c]	317	197	383	4795
11[c]	299	199	539	6866
Average	**296**	**196**	**407**	**5245**
STD	23	3	121	1450
Medium epidemic				
49[c]	302	288	592	5870
50[c]	397	289	1130	7863
51[c]	279	294	672	7152
Average	**327**	**290**	**798**	**6962**
STD	61	3	290	1010
Large epidemic				
89[c]	290	537	994	8564
90[c]	374	541	1887	8290
91[c]	458	566	2401	17330
Average	**374**	**548**	**1761**	**11395**
STD	84	16	712	5142

a) An epidemic is finished when the quarantine zone for the last detected infected farm is lifted.

b) Ranking of simulation according to length in days.

c) Ranking of simulation according to the total number of detected farms welfare slaughtering, they may gain as well. Depopulated piglet farms suffer losses due to idle production, for which they receive no compensation. If prolonged, these losses may lead to closure of the pig business depending on the individual financial situation. For specialised fattening farms (hog producers), animal welfare slaughter leads to empty stables after a few months. Idle capacity, whether due to depopulation of detection, preventive slaughter or animal welfare slaughter may cost some hog farmers their business.

Table 4.3 Changes in producer surplus, consumer surplus and government expenditures (*10^6 EURO) for small, medium and large epidemics.

Scenario	Δ Producer surplus	Δ Consumer surplus	Δ Govern-ment	Net welfare effect
Size of epidemic defined by the length of epidemic (days)				
Small epidemic				
Q	412	-386	-247	-221
Q + Exp	-226	115	-218	-329
Q + Exp + switch	42	-9	-228	-195
Medium epidemic				
Q	502	-552	-358	-407
Q + Exp	-73	-76	-318	-467
Q + Exp + switch	204	-201	-330	-326
Large epidemic				
Q	529	-815	-577	-863
Q + Exp	-50	-263	-515	-827
Q + Exp + switch	276	-398	-532	-660
Size of epidemic defined by the number of infected and detected farms				
Small epidemic				
Q	415	-402	-251	-238
Q + Exp	-277	150	-220	-346
Q + Exp + switch	12	15	-229	-202
Medium epidemic				
Q	454	-463	-289	-297
Q + Exp	-251	111	-254	-394
Q + Exp + switch	52	-30	-265	-243
Large epidemic				
Q	506	-665	-450	-609
Q + Exp	-100	-136	-400	-636
Q + Exp + switch	208	-273	-415	-479

In our calculations, animal welfare slaughter on breeding stock farms caused losses since breeding pigs were compensated at the same rate as fattening pigs. So, as in the Dutch CSF epidemic, the government may also opt in the future to pay higher compensation to avoid creating an incentive for smuggling breeding stock out of a quarantine zone. However, this also creates an incentive to declare all pigs on breeding stock farms as breeding stock, whereas in reality only a proportion of the female piglets will become replacement gilts and only a very small fraction of the male piglets are used as breeding boars.

4.5.3 Government expenditure

Table 4.5 shows that government expenditure to control the epidemic increases with the size of the epidemic, on both definitions of size. The total amount paid to compensate for animal welfare slaughter depends not only on the number of pigs slaughtered but also on the actual weekly market pig price as simulated in DUPIMA. All other government expenditure depends only on the number of pigs slaughtered and/or of farms in quarantine zones, since the cost per pig in these categories are independent of the simulated market price.

Animal welfare slaughter compensation is the biggest part of all government expenditure on control programmes. These payments are strongly related to the length of the epidemic and the number of farms in quarantine zones. For the same epidemic length, more farms per week in quarantine zones led to higher animal welfare slaughter compensation due to higher weekly market pig prices. Reducing the compensation paid per pig under animal welfare slaughter or breaking its link with market price would decrease these costs, but could increase non-compliance. Measures to reduce the length of an epidemic will be more successful in limiting the compensation payments for animal welfare slaughter. Reducing the number of farms in quarantine zones by reducing either the duration of an imposed quarantine zone and/or the radius of a quarantine zone may be another measure to reduce the cost of animal welfare slaughter, but those two measures may increase then the risk of spreading the virus. More epidemiological research is needed here.

4.5.4 The marketing chain and final consumers

When exports are banned, slaughterhouses gain as more animals are slaughtered domestically (see Table 4.6). This matches the reality of the Dutch CSF epidemic, whereas final consumers always lose surplus. However, the relative sizes of these changes depend on the size of the epidemic and the trade situation, and so the net welfare change downstream from the producer may be positive or negative.

Table 4.4 Changes in producer surplus of piglet, hog and breeding stock producer (*10^6 EURO) for small, medium and large epidemics.

	Δ PS of piglet producer		Δ PS of hog producer		Δ PS of breeding stock producer		Δ Total PS
Scenario	Outside Q	Inside Q	Outside Q	Inside Q	Outside Q	Inside Q	Δ Total PS
Size of epidemic defined by the length of epidemic (days)							
Small epidemic							
Q	262	28	368	-221	-[a)]	-26	412
Q + Exp	-81	-18	172	-269	-	-30	-226
Q + Exp + switch	-23	-9	351	-249	-	-29	42
Medium epidemic							
Q	362	41	436	-304	-	-32	502
Q + Exp	23	-22	334	-371	-	-37	-73
Q + Exp + switch	82	-10	512	-345	-	-36	204
Large epidemic							
Q	480	93	483	-477	-	-50	529
Q + Exp	84	-3	498	-572	-	-57	-50
Q + Exp + switch	152	15	699	-536	-	-55	276
Size of epidemic defined by the number of infected and detected farms							
Small epidemic							
Q	272	34	378	-240	-	-28	415
Q + Exp	-102	-19	167	-291	-	-32	-286
Q + Exp + switch	-39	-9	361	-270	-	-31	12
Medium epidemic							
Q	305	31	435	-285	-	-31	454
Q + Exp	-89	-25	241	-343	-	-35	-251
Q + Exp + switch	-22	-14	442	-320	-	-34	52
Large epidemic							
Q	415	60	468	-394	-	-42	506
Q + Exp	32	-15	404	-474	-	-48	-100
Q + Exp + switch	98	-1	599	-443	-	-46	208

a) Assuming that the price of breeding stock remains constant. Δ PS of breeding stock producer outside a quarantine zone (Q) is equal to zero.

Table 4.5 Government expenditure (*10^6 EURO) for small, medium and large epidemics.

Scenario	Organisation costs for			Compensation payments for			Total costs	Financed by:	
	Depopulation	Control of quarantine	Welfare slaughter	Detected farms	Preventive slaughter	Welfare slaughter		NL	EU
Size of the epidemic defined by the length of epidemic (days)									
Small epidemic									
Q	7	18	67	21	34	579	726	247	479
Q + Exp						483	630	218	412
Q + Exp + switch						514	661	228	433
Medium epidemic									
Q	13	23	90	34	69	813	1042	358	684
Q + Exp						678	907	318	589
Q + Exp + switch						719	948	330	618
Large epidemic									
Q	21	38	133	58	112	1319	1681	577	1104
Q + Exp						1110	1472	514	958
Q + Exp + switch						1169	1531	532	999
Size of epidemic defined by the number of infected and detected farms									
Small epidemic									
Q	6	18	70	19	30	597	740	251	489
Q + Exp						493	636	219	417
Q + Exp + switch						525	668	229	439
Medium epidemic									
Q	8	21	78	23	43	674	847	289	558
Q + Exp						559	735	254	478
Q + Exp + switch						594	767	265	502
Large epidemic									
Q	15	30	108	40	86	1035	1314	450	864
Q + Exp						869	1148	400	748
Q + Exp + switch						917	1196	415	781

Table 4.6 Changes in welfare surplus of slaughterhouses/processing industry, retailer and final consumer (*10^6 EURO) for small, medium and large epidemics.

Scenario	Slaughterhouses/ Processing industry	Retailer	Final consumer	Total CS
Size of the epidemic defined by the length of epidemic (days)				
Small epidemic				
Q	-21	0	-365	-386
Q + Exp	76	0	39	115
Q + Exp + switch	75	0	-84	-9
Medium epidemic				
Q	-36	0	-517	-552
Q + Exp	49	0	-126	-76
Q + Exp + switch	48	0	-248	-200
Large epidemic				
Q	-63	0	-752	-815
Q + Exp	43	0	-306	-263
Q + Exp + switch	42	0	-446	-404
Size of epidemic defined by the number of infected and detected farms				
Small epidemic				
Q	-22	0	-380	-402
Q + Exp	85	0	65	150
Q + Exp + switch	83	0	-68	15
Medium epidemic				
Q	-26	0	-437	-463
Q + Exp	81	0	30	111
Q + Exp + switch	80	0	-110	-30
Large epidemic				
Q	-47	0	-618	-665
Q + Exp	48	0	-184	-136
Q + Exp + switch	47	0	-319	-273

4.6 Assessment of the assumptions made

4.6.1 Pig producer

Assuming gradual restocking of a depopulated farm may be an oversimplification. Small hog producers in particular tend to populate their hog farms all at once (all-in all-out system), although larger farms tend to have a more continuous flow of tradable pigs. Sow farms are mostly limited by expensive farrowing places.

In the case of depopulation, pig farmers receive the assessed value of their stock. This value is defined for each pig and depends on age, weight, stage in the production cycle with reference to the current market value (RVV, 2000). The value paid should allow the farmer to buy an equivalent animal. When restocking, farmers may face prices that are higher or lower than the compensation they received. In our analysis, we assume they can restock at the same price they received as compensation. Extra costs due to more health problems when restarting farms, more likely with sow farms, were also not considered.

Assuming that breeding stock prices stay constant may underestimate the restocking costs for piglet producers, especially when large quarantine zones are lifted at the same time and many depopulated sow farms start to restock. However, if gilt prices rise, breeding stock farms will make extra profit. These effects will cancel each other out, and the welfare changes for producers as a whole will not be affected.

Our analysis assumes that animal welfare slaughter of breeding stock (piglets and gilts) is compensated at the same rate as fattening pigs, as per EU legislation. In the Dutch CSF epidemic, animal welfare slaughter compensation for breeding stock was paid at a higher rate to increase farmers' co-operation and to avoid creating an incentive for smuggling animals out of a quarantine zone. In this case, the costs for the breeding stock producer would be lower than calculated here; on the other hand, the government expenditure would be higher.

4.6.2 Intermediate and final consumers

Slaughterhouses are not distributed over the Netherlands in strict proportion to the pig population. Their losses or gains depend strongly on whether they are situated inside or outside a quarantine zone. For slaughterhouses situated outside a quarantine zone, our assumptions are correct as in the case of a total export stop they may have more pigs to slaughter than they would do in a non-epidemic situation. Slaughterhouses inside a quarantine zone cannot slaughter pigs, except if they participate in animal welfare slaughter measures. Those last categories of slaughterhouses will experience losses (fixed costs cannot be covered), whether there is an export stop for live pigs or not.

The assumption that there are no gross substitutes for pig meat may be too simple, even though this agrees with the findings of Chapter 3, where we found no significant substitution for pig meat in the meat and fish category. If there are rationing effects that are not fully represented by price changes, there may be spillover effects onto markets for other meats.

4.6.3 Other stakeholders

In this study we ignore the welfare effects on other European pig producers, slaughterhouses, retailers and final consumers. However, they too will experience a welfare change if pig price rises when Dutch pig supply falls.

In the first days of a newly imposed quarantine zone, non-pig producers situated inside the zone needed extra permission to move their animals. This may have caused extra costs for them. In our study we assume that all prices, especially beef, chicken and sheep meat remain constant. If this is not the case, non-pig-producers may also experience a welfare change.

The feed industry may experience losses if many pig farms stay empty, leading to a reduction in feed sold. For a small epidemic without animal welfare slaughtering, however, the feed industry may benefit from the epidemic by selling extra feed to pig farmers inside a quarantine zone that are forced to keep their ready-to-deliver-hogs longer than usually.

Breeding organisations will have extra costs due to extra hygiene measures and the lack of semen demand from depopulated farms. Veterinarians in quarantine zones may also have losses as the number of pigs to treat may be reduced; on the other hand, they may participate in the control programme and earn extra money.

4.7 Discussion and conclusion

Our analysis yields some important conclusions. First, as long as trade continues from non-quarantine zones, producers collectively *gain* from the epidemic, assuming the package of control measures that were used in the most recent CSF outbreak. This result is independent of the size of the epidemic. It occurs because producers outside quarantine zones benefit from the higher prices caused by lower supply, and because the loss of some producers inside a quarantine zone is moderated by compensation payments for animal welfare slaughter. With a trade ban on live pigs and no increase in exports of pig meat, market price is weaker and so the gain of non-quarantined producers no longer outweighs the losses of other producers; collectively, producers lose. However, the total producer loss in this situation is inversely related to the size of the epidemic: the larger the epidemic, the greater the shortfall in marketable supply and hence the smaller the downward pressure on market price.

Although a trade ban changes producers' collective gain to a loss, the net welfare loss increases by far less due to the offsetting changes in consumer surplus and programme cost.

Therefore, although a trade ban – assuming no switch in export demand to pig meat – is bad news for the industry, policy makers should also be aware of the offsetting welfare changes downstream.

Another striking finding is that the share of the costs going to compulsory EU measures (depopulation, setting up of a quarantine zone) is small relative to the cost of optional measures (preventive and animal welfare slaughter). In particular, the major share of animal welfare slaughter compensation in total control cost is worth noting. We note also the significant contribution from the EU budget, without which the net welfare losses for the Netherlands would have been much greater.

Finally, our analysis strongly indicates that additional control measures to reduce the length of an epidemic and/or the number of detected farms could well be economically rational. For example, with a trade ban, the net welfare loss of a large epidemic is EUR 636 million whereas that of a medium epidemic is just EUR 394 million. If the Dutch authorities had used additional measures costing less than EUR 242 million that guaranteed a small epidemic, net welfare would have suffered less.

Additional control measures to keep the epidemic "small" in scale would be to start preventive slaughter immediately (rather than after 2 months) or to use emergency vaccination. Nielen et al. (1999) show that immediate preventive slaughter reduces the median length of the epidemic by half. Another extra control measure might be emergency vaccination. In Chapter 2, we simulated two alternative emergency vaccination strategies, assuming the availability of a marker vaccine, a reliable diagnostic test and political acceptance. Whether or not vaccinated animals are subsequently slaughtered, emergency vaccination could shorten the length of the epidemic by more than 50 %. Both these additional control measures would have produced a "small" epidemic rather than a "medium" or "large" epidemic. A smaller epidemic lowers the welfare costs for producer and consumers, as well as reducing government expenditure. Ethical and animal welfare objections against preventive slaughter, left out of consideration in our analysis, would also be less intense. Clearly, more analysis is needed to examine the cost and benefits of various additional measures to reduce the epidemic.

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Appendix IX Average probabilities, most likely outcomes and economic impacts of various market scenarios

Market scenarios	Total n = 10[a] Average probability	Commerical n = 7 Average probability	Authorities n = 3 Average probability	Most likely n = 10[a]	Economic impact 1-3[b]
I. No application of an emergency vaccination during a CSF epidemic					
a) There is only an export ban on live pigs. This could be:					
- national	22	23	20	1.0	1.6
- regional by EU & national by Third countries	39	43	30	4.0	2.2
- regional	39	34	20	5.0	2.5
II. Application of an emergency vaccination with a marker vaccine during a CSF epidemic, agreed by the EU					
a) What will happen with the pig meat originating from healthy vaccinated pigs?					
- destroyed	7	6	10	0.0	1.3
- heat treated	17	21	5	0.5	1.4
- sell inside NL	51	41	73	6.5	2.0
- no ban	26	31	12	3.0	2.9
b) Will there be a national or regional export ban on live pigs and/or on pig meat?					
- national ban on both	18	22	10	1.0	2.4
- regional by EU & national by Third countries on both	24	27	17	1.0	2.5
- regional ban on pigs only	29	28	32	5.0	2.5
- regional ban on both	29	23	42	3.0	1.5
c) Will there be a national or regional export ban on live pigs and on pig meat? [c]					
i) There will be a national export ban on live pigs, whereas on pig meat there will be:					
- national ban	2	2	4	0.0	1.1
- regional ban	14	16	12	3.0	1.7
- only “vaccinated” meat	10	10	8	0.0	1.8
ii) There will be a regional export ban by EU and a national export ban by Third countries on live pigs, whereas on pig meat there will be:					
- national ban	5	3	10	0.0	1.3
- regional ban	20	19	20	0.5	2.3
- only “vaccinated” meat	21	25	14	3.5	2.2
i) There will be a regionalexport ban on live pigs, whereas on pig meat there will be:					
- national ban	2	2	0	0.0	1.3
- regional ban	21	14	35	1.0	2.2
- only “vaccinated” meat	6	9	0	1.0	2.4
d) Possible boycotts due to an emergency vaccination with a marker vaccine in the Netherlands:					
All Third countries	60	58	63	[d]	1.9
Northerly EU-member-states	28	32	22	[d]	1.8
Third countries & northerly EU states	24	26	21	[d]	1.7
British retailer	42	40	45	[d]	2.4
German consumer	29	27	33	[d]	2.0
Asia boycotts EU	19	8	40	[d]	1.8
III. Application of an emergency vaccination with a marker vaccine without the permission of the EU					
	6	5	9	[d]	1.1

a) Representatives from the Dutch ministries (3), large Dutch slaughterhouses companies (2), pharmaceutical industry working on a marker vaccine against CSF (2) and three people, considered to represent Dutch pig farmers were responding; in total 10 people.

b) The economic impact on the Dutch pig chain could be very large (1), large (2) or small (3).

c) 9 experts were responding.

d) Each scenario could get a probability between 0 and 100%, independent of others.

Chapter 5

Effect of pig population density on epidemic size and choice of control strategy for Classical Swine Fever epidemics in the Netherlands

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Abstract

The paper examines the importance of pig population density in the area of an outbreak of CSF for the spread of the disease and the choice of control measures. A sector-level market and trade model and a spatial, stochastic, dynamic epidemiological simulation model for the Netherlands were used. Outbreaks in sparsely and densely populated areas were compared under four different control strategies and with two alternative trade assumptions.

Results indicate that the obligatory control strategy required by current EU legislation is enough to eradicate an epidemic starting in an area with sparse pig population. By contrast, additional control measures are necessary if the outbreak begins in an area with high pig population density. The economic consequences of using preventive slaughter rather than emergency vaccination as an additional control measure depend strongly on the reactions of trading partners. Reducing the number of animal movements significantly reduces the size and length of epidemics in areas with high pig density. The phenomenon of carrier piglets is included in the model with realistic probabilities of infection by this route, but it is found to make a negligible contribution to the spread of the disease.

5.1 Introduction

5.1.1 Aims of the paper

Epidemics of exotic contagious animal diseases such as Classical Swine Fever (CSF) and foot-and-mouth disease (FMD) can have a high cost for the national economy. In Chapter 4 we found negative net welfare effects for the Dutch economy of 243 to 466 mn Euro (assuming an export ban on live pigs) for an epidemic comparable to the 1997/1998 Dutch CSF epidemic (hereafter "the Dutch CSF epidemic"). The effect of the 2001 FMD epidemic on the UK economy in the same year has been estimated at £2.4 - £4.1 bn (Houlder, 2001). A large part of these costs is directly related to the size and duration of the epidemic.

Among the factors determining the spread of an infectious animal disease are the number and type of off-farm contacts in the period after a herd becomes infected but before the infection is detected and the farm is isolated, and the presence of carrier piglets born on sow farms in the course of an undetected minor outbreak. In this paper we study the interaction between these factors and the pig population density in the area of the initial outbreak. We hypothesise that, if routine off-farm contacts are numerous for apparently uninfected farms or if (undetected) carrier piglets are born on sow farms outside control areas, the risk of a large epidemic is greater, and particularly so in areas of high pig density.

The main goal of this study is to provide decision-makers with insights into the epidemiological and economic effects of control strategies for epidemics, given the uncertainties related to these factors. Three specific questions are addressed. (1) Should different control strategies be used in areas with sparse and dense pig populations? (2) Does reducing the number of direct animal contacts and transport contacts per farm reduce the size of the epidemic? (3) What is the effect of carrier piglets on the disease spread?

We simulated epidemics beginning in either a SPLA or a DPLA[1], and assuming four different control strategies: the current minimum controls as mandated by EU legislation (EU), preventive slaughter in addition to EU (PS), and two options for an emergency vaccination strategy: vaccination in addition to PS, with subsequent destruction of vaccinated animals (DD), and vaccination in addition to EU with monitored intra-community trade in the meat from vaccinated animals (ICT). The economic benefits and costs of epidemics assuming each of these four strategies and the two livestock densities were calculated using the economic framework described in Chapter 4. In addition, we considered two different trade reactions: a partial trade ban for the quarantine zones (protection and surveillance zones) only or in addition a total export ban for all Dutch live pigs. This results in 16 different combinations of pig population density + control strategy + trade reaction.

Furthermore, we implemented two alternative sets of assumptions regarding the number of direct animal contacts and the number of transport contacts per farm for some of these combinations.

A carrier piglet is infected as a foetus because the mother had an undetected infection. Carrier piglets will spread the virus during their whole lifetime. The birth of carrier piglets in a non-susceptible herd will usually remain undetected. They may, however, become a source of infection when they are transported to another farm. Although the phenomenon of carrier piglets has always been recognised as a theoretical possibility, it has not previously been incorporated into the modelling framework used for analyses of the Dutch CSF epidemic.

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[1] SPLA (DPLA) stands for sparsely (densely) populated livestock area. In this study only one livestock species is considered: pigs. A SPLA (DPLA) has up to 300 (>300) pigs per square km at regional level (De Vos, 2000).

5.1.2 Overview of earlier work

Simulation of the epidemiological and economic consequences of disease-control strategies requires a modelling approach that simulates both the spread of the virus between farms as well as the effects of control strategies used and the economic consequences, such as direct costs of eradication and indirect costs due to market disruptions and trade restrictions.

InterCSF[2], a spatial, temporal and stochastic simulation model, was developed in 1997 to simulate CSF spread and control measures during the Dutch CSF epidemic (Jalvingh et al., 1999, Nielen et al., 1999). InterCSF simulates daily disease spread from infected farms through three contact types (animals, vehicles, persons) and through local spread. All Dutch pig farms are known by their geographical co-ordinates, their farm type and their stock numbers. The main disease-control mechanisms that influence the disease spread in InterCSF are: diagnosis of the infected farms, depopulation of infected farms, movement controls within quarantine areas, tracing and preventive slaughter. Jalvingh et al. (1999) introduced different types of transport into the model, with transport types and their frequency over time specific to different farm types. The source farm type determines the destination farm type for a direct animal contact. In Chapter 2, we added emergency vaccination as a control option to InterCSF with a gradual non-linear increase over time of protection from vaccination as well as limited vaccination capacities.

Jalvingh et al. (1999), Nielen et al. (1999) and in Chapter 2, we too used EpiLoss (Meuwissen et al., 1999) and output from InterCSF to calculate the direct costs of CSF control measures on pig farms, as well as the consequential economic losses of pig farmers and related industries affected by control measures, assuming fixed average pig prices.

In Chapter 4 an economic framework was developed to calculate the impact on the Dutch economy of epidemics simulated in InterCSF, assuming different trade scenarios (see Figure 1). In this framework, EpiPigFlow converts the daily output of InterCSF to a weekly flow of piglets that becomes an input into DUPIMA, a partial equilibrium model of the Dutch pig market. DUPIMA simulates market prices, domestic offtake and trade flows. A second micro-economic model (EpiCosts) uses output from InterCSF and the estimated market prices from DUPIMA to calculate the expenditure by the animal health authorities to control the epidemic. EpiCosts also calculates the changes in producer surplus for pig producers

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[2] InterCSF was based on InterSpread, a simulation model for FMD covering disease spread and its interaction with control measures. InterSpread was developed in New Zealand by Sanson (1993) and was further adapted by Jalvingh et al. (1995).

inside quarantine zones. An Excel worksheet combines the results of EpiCosts and DUPIMA to calculate the economic welfare changes of producers and consumers (slaughterhouses and processing industry, retailer and final consumer), as well as the extra expenditure of the Dutch health authorities. The economic welfare changes of the different stakeholders are aggregated to determine the net welfare effect for the Dutch economy.

5.2 Methodology

5.2.1 Further adaptations for the current work

For the current study, a more generic version of the InterCSF model was needed, in order to predict the course of epidemics and include the possibility of carrier piglets. We next describe the most important changes and adaptations of InterCSF, now called InterCSF_v3.

5.2.1.1 Carrier piglets, minor and major within-herd outbreaks

Infection of a susceptible herd can lead to a minor (3-5 infected animals) or a major (> 5 infected animals) within-herd outbreak. The probabilities of a minor or a major within-herd outbreak depend on farm type and farm status. For certain events (e.g. detection) we distinguish three farm types, according to type of animal: (1) sows and piglets only; (2) no sows; (3) sows and finishing pigs. For other events (e.g. disease spread) five farm types, defined according to production system, are used: (1) multiplier; (2) finisher; (3) multiplier-finisher; (4) breeding farm and (5) AI-stations.[3] Two farm statuses are distinguished: (1) vaccinated or (2) non-vaccinated. For a sow farm with a minor within-herd outbreak, the probability of carrier piglets later on is now included in the model. Farms with a minor within-herd outbreak remain susceptible if not vaccinated, and we assume that, with the birth of carrier piglets on a susceptible farm, a major within-herd outbreak will occur. Table X-1 (Appendix X) shows some of the input parameters used.

5.2.1.2 Infectivity

Farm type, farm status and farm size (we distinguish small, medium and large farms) are now factors that determine the maximum length of infectivity for farms with a major within-herd infection. After the infectious period, a farm can infect other farms only via transport of carrier piglets. Farms with a minor within-herd outbreak will never be infectious towards other farms, except for carrier piglets transported off. Currently a flat infectivity curve is used

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[3] The probability of infecting a neighbouring farm by local spread seems to depend on that farm's type (preliminary findings of Crauwels, 2001).

that is either “0” (not infected) or “1” (infected), but other curves (where infectivity varies over time) may be incorporated in InterCSF_v3.

Increased bio-security related to transport contacts may have an impact on virus transmission. To reflect that, once an epidemic has started, increased bio-security measures will be taken within a quarantine zone, we reduce the probability of infection by 50 % for transport contacts for the purpose of welfare slaughter.

5.2.1.3 Detection

Because of the distinction between minor and major within-herd outbreaks, the concept of detection of an infected herd is changed drastically. By assumption, minor within-herd outbreaks are detected by serology only. The period before the first detection of an epidemic for major within-herd outbreaks is randomly drawn from a log-normal distribution with a minimum of 21 days (3 weeks), a maximum of 100 days (Elbers et al., 1999) and a mean of 49 days. After the first detected case, all major-within herd outbreaks may be detected based on clinical signs, with the interval based on a lognormal distribution with a minimum of 1 week and a maximum of 12 weeks. The detection probabilities due to clinical signs range from 70 % for AI-station to 85 % for multiplier farms (Fritzmeier et al., 2000, and Elbers et al., 1999). As in Chapter 2, we assume that vaccinated and later infected farms will never show clinical signs, and can only be detected by serology.

Control events, such as tracing, surveillance, preventive and welfare slaughter, intermediate screening, end-screening and vaccination, can all lead to the detection of an infected farm (Tables X-2 and X-3 in Appendix X). Sample size, the within-herd outbreak type, the farm type and the time interval between infection and the control event affect the probability of such detection. The frequency of different control events is based on the Dutch animal health authorities guidelines for a future epidemic (RVV, 2000).

5.2.1.4 Adaptations related to emergency vaccination

Infection of a vaccinated and maximum protected farm will cause only a minor within-herd outbreak, with a 50 % lower probability of the birth of carrier piglets than on a non-vaccinated farm (Dewulf et al., 2001). Vaccinated but not yet maximum protected farms that become infected are assumed similar to non-vaccinated farms with a major within-herd outbreak. However, the infectious period of vaccinated farms is 30 days (see Chapter 2) and carrier piglets will never cause a major within-herd outbreak. After 30 days' infectivity only the transport of carrier piglets off the farm can lead towards an infection of another susceptible herd.

Criteria may be defined to trigger the decision to start an emergency vaccination campaign. The first criterion is a minimum pig density around the first detected herd. Other criteria are: a minimum number of detected farms in the first week; detection in a DPLA within the 6 first weeks; a minimum number of detected farms in 7 days within the 6 first weeks. As soon as one of those criteria is fulfilled, emergency vaccination begins immediately. In our emergency vaccination simulations in this paper, these thresholds are all set to 0. Consequently, emergency vaccination always begins on the day of the first detection.

5.2.1.5 Other adaptations

In InterCSF_v3, empty farms may be repopulated as soon as the quarantine restrictions are lifted. All repopulated farms are considered susceptible again and may become newly infected. We further allow that an infected farm that is not detected becomes susceptible again after an appropriate time.

All input parameters were revised, according to the most recent literature and expertise from different fields and from different countries. Where no information was available, assumptions were made. A new contact matrix is included that will be discussed in section 2.3, as well as new transmission probabilities based on Stegeman et al. (2002). A detailed description of all input parameters used and their sources is available on request from the first author.[4]

5.2.2 Validation and calibration

After verification of the newly incorporated mechanisms by consulting literature and experts from the field, InterCSF_v3 was newly validated and re-calibrated. Having only one recent epidemic in the Netherlands, the simulated output could not be compared with real data. As an alternative validation measure, sensitivity analysis was applied by increasing or decreasing input parameters before and after calibration (Law and Kelton, 1991).

InterCSF_v3 was not calibrated on a specific Dutch epidemic, in contrast to the original InterCSF_v1. We did not know whether to classify the Dutch CSF epidemic as a small, medium or worst-case epidemic. However, the long high-risk period, the increased number of

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[4] We tried to build in herd-specificity (i.e. finding false positive farms when testing blood samples) by assuming that for each false positive farm found new quarantine zones were installed. Decreasing the herd-specificity from 100% (base) to 99.9 % slightly increased the length of the simulated epidemic without changing the number of infected farms. A specificity of 99% or lower, however, resulted in unrealistic "never ending" epidemics. Clearly, a more complex approach is needed than used here.

movements the day before the installation of the first movement stand-still zone and the infection of two AI-station in this specific epidemic (Elbers et al., 1999) are all reasons for assuming that it was rather a worst-case scenario. We therefore calibrated our model such that using the contact matrix of Jalvingh et al. (1999), we would obtain - at least in the worst case replication - at least as many infected and detected farms as occurred in the Dutch CSF epidemic.

To be able to compare simulated epidemics of InterCSF_v3 with earlier InterCSF results (Jalvingh et al., 1999), we simulated the minimum EU strategy with an additional preventive slaughter strategy after 3 months. During calibration, we doubled the transmission probabilities of Stegeman et al. (2002) (Appendix XI) as discussed in more detail in section 5.4.1. We also corrected the estimated transmission probabilities of Stegeman et al. (2002) for a 15% probability of minor within-herd outbreaks.

5.2.3 Contact matrix

Three contact types between pig farms are defined: (1) direct animal contact, (2) transport contact and (3) professional contact.[5] The contact matrix defines the number of contacts between all farm types and is specific for the Dutch situation. After the Dutch CSF epidemic, the Dutch authorities adapted the legislation for pig transport with the aim of reducing the spread of disease in future epidemics (LNV, 2000). A newly estimated contact structure, based on analysis of recent Dutch identification and registration data (Mourits et al., 2001) and on new Dutch legislation for pig transports (Regeling varkenslevering, LNV 2000) resulted in a lower number of transports off or to the farm for all farm types as well as in a slight reduction in indirect contacts. The frequency of professional contacts was assumed unchanged. Simulated epidemics using this new contact matrix (see Appendix XII) are compared with the simulated epidemics using the contact structure of Jalvingh et al. (1999).

5.2.4 Simulating epidemic control with different pig densities

5.2.4.1 Control strategies simulated

Different control strategies to control CSF epidemics in both a SPLA and a DPLA are simulated with the new InterCSF_v3 model.

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[5] The spread of the virus by semen is not considered in InterCSF_v3. Although two AI-stations became infected in the Dutch CSF epidemic, the risk that an AI-station will be infected and remain in production during an epidemic is low. Moreover, the risk that a farm will be infected by artificial insemination was estimated, on the basis of the Dutch CSF epidemic, to be rather low (Hennecken et al., 2000).

Stamping-out infected herds and tracing all contacts with infected herds, in addition to the installation of quarantine zones, is the current minimum EU legislation (***EU strategy***). Inside quarantine zones, surveillance and serological screening are used. In the case of a quarantine zone that will last longer than the minimum 42 days, slaughter and rendering of ready-to-deliver finishers and piglets begins after 4 weeks.

The preventive slaughter strategy (PS strategy) involves the use of preventive slaughtering on farms in a radius of 750 to 1000 m around a detected herd as an additional control measure (Nielen et al., 1999). When emergency vaccination is used as an additional control measure, we distinguish between the delayed destruction strategy (DD strategy) and the intra-community trade strategy (ICT strategy) (Chapter 2). With the DD strategy all vaccinated herds are slaughtered and rendered, whereas with the ICT strategy, pig meat of vaccinated pigs may be traded within the EU as soon as the quarantine zone is lifted.

5.2.4.2 Economic framework

We calculate economic welfare changes for Dutch pig producers and Dutch consumers (slaughterhouses and processing industry, and final consumer), and the extra expenditure of the Dutch health authorities, using the procedures described in Chapter 4 (see figure 4.1 on page 71). Retailers' total margins are assumed to be unchanged in all scenarios. As in Chapter 4, we assume two alternative trade scenarios for each simulated epidemic: a partial ban imposed only on the quarantine zone and a total export ban on all live pigs.

DUPIMA was originally calibrated on prices and quantities of 1996 (Chapter 4), a year with exceptionally high pig prices. We now re-calibrate the model to the last half of 1999 and the first half of 2000. During this period, pig prices were recovering but were still at a low level. We correct downwards the variable cost saved per finisher not produced, which were based on a 5 year average (Snoek et al., 1999), which results in a zero change in producer surplus for finisher producers inside a quarantine zone with empty stables.

5.3 Results

5.3.1 Carrier piglets

The number of minor within-herd infections resulting in carrier piglets is very low (Tables 5.1 and 5.2) and the impact of carrier piglets on the size and the length of an epidemic is of minor importance. For sensitivity analysis, we set the probability of carrier piglets on sow herds with minor and major within-herd infections to zero to simulate epidemics in a DPLA with a PS control strategy. The mean of the different epidemiological criteria is the same in both simulations, the only difference being in the number of minor infected farms resulting in carrier piglets (results not shown).

5.3.2 Contact reduction

The effect of adopting the new contact matrix is shown in Table 5.1, simulating an epidemic in a DPLA using the EU strategy in the 3 months after the first detection and the PS strategy thereafter. Fewer animal and transport contacts result in fewer infected and detected farms for medium and large-scale epidemics, although epidemic duration is not much shorter.

Table 5.1 Effect of the changed contact matrix in a DPLA area on the simulated results, given the EU strategy as control measure for the first 3 months and followed by the PS-strategy: mean effects and effects for the simulations ranked 5, 50 and 95 according to the corresponding epidemiological outcome

Contact structure	Old contact structure (Jalvingh et al., 1999)				New contact structure (Mourits et al., 2001)			
Percentile/ Mean	Mean	5%	50%	95%	Mean	5%	50%	95%
# Infected	296	65	231	752	130	51	113	226
- minor	49	9	38	125	21	9	19	39
- minor & carrier	1	0	1	5	1	0	0	2
- major	245	55	190	617	108	41	95	186
# Detected	254	57	197	638	112	46	98	186
# Preventive slaughter	324	64	258	887	129	33	98	312
Duration (days)	245	178	239	321	220	168	214	281
Infected due to:								
- local spread	244	56	189	645	114	45	99	196
- animal contact	17	2	12	43	3	0	2	10
- transport contact	15	2	13	33	3	0	2	7
- professional	19	2	14	54	9	2	7	19

5.3.3 Epidemics in a SPLA compared with a DPLA

5.3.3.1 Epidemiological results

We simulate CSF epidemics in the Netherlands that start in either a DPLA or a SPLA. For each region, we simulate CSF epidemics using the four alternative control strategies. For each variant, 100 replications are performed. We present results at the 5th, 50th and 95th percentile of various output parameters.

The first infected farm (index farm) for the DPLA simulations is located in Boekel, in the South West region which has the highest pig density of the Netherlands. The PS, DD or ICT strategies reduce the length and the size of the simulated epidemics by more than 75% compared to the EU strategy (Table 5.2). These three strategies reduce the number of susceptible herds in the close neighbourhood of an infected herd, and as a consequence fewer farms are infected via local spread. The DD strategy results in epidemics that are smallest in size and length. However, with this strategy, a large number of pig farms have to be preventively slaughtered whereas with ICT, only infected and detected farms are slaughtered for control purposes.

The index farm for the SPLA simulations is located in Berkel en Rodenrijs in the province of South Holland. For SPLA epidemics, all control strategies seem to be similarly effective (Table 5.2). Reducing the number of susceptible herds in the close neighbourhood of an infected herd has little or no impact, because there are hardly any neighbouring farms within the endangered radius. As long as the epidemic remains in a SPLA, the spread of the virus is strongly linked to movement contacts.

5.3.3.2 Economic results

Two alternative definitions of epidemic size are used: length of the epidemic in days and the number of detected farms[6]. All 100 replications are ranked according to each of these criteria. The average of the three replications centred on the 5th, 50th and 95th percentiles of "size" represent “small”, “medium” and “large” epidemics respectively.

The economic welfare changes of the different stakeholders for small, medium and large epidemics for both definitions of size are shown for the DPLA region in Table 5.3 and for the SPLA region in Table 5.4.

For all four strategies, the reduction in national supply is not matched by a fall in total demand when export continues from non-quarantine zones. Pig prices outside quarantine zones rise. Hence, producers collectively gain and consumers lose. We assume a 50 %

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[6] We assume throughout that there are no false positive test results. If false positives occur, then the size of epidemics in terms of both duration and number of “detected” farms is likely to be greater.

Table 5.2 Effects of different control strategies, given different control strategies applied and different densely populated pig areas: effects for the simulations ranked 5, 50 and 95 according to the corresponding epidemiological outcome (new contact matrix)

Strategy	Minimum required by the EU			+ Preventive slaughter			+ Emergency vaccination					
							Delayed destruction			Intra-community trade a)		
Percentile	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%
	DPLA (Boekel)											
# Infected	65	170	963	9	38	92	9	29	69	10	34	73
- minor	12	29	169	1	6	13	1	5	14	2	8	17
- minor & carrier	0	1	4	0	0	1	0	0	1	0	0	1
- major	52	139	792	7	32	68	6	24	57	6	26	59
# Detected	65	166	923	4	25	65	4	19	50	10	33	73
# Preventive slaughtered	-	-	-	40	113	281	134	375	971	-	-	-
# Vaccinated	-	-	-	-	-	-	84	249	781	173	419	1079
Duration (days)	235	373	787	65	127	210	60	96	135	93 a)	139 a)	171 a)
Infected due to:												
- Local spread	57	150	877	6	32	71	6	22	48	7	28	52
- Direct animal contact	0	3	10	0	2	10	0	2	10	0	2	10
- Transport contact	0	3	7	0	2	7	0	2	6	0	2	6
- Professional contact	3	15	75	0	2	8	0	1	6	0	1	6
	SPLA (Berkel en Rodenrijs)											
# Infected	2	5	24	2	5	16	2	5	13	2	5	16
- minor	0	1	3	0	1	3	0	1	2	0	1	3
- minor and carrier	0	0	0	0	0	0	0	0	0	0	0	0
- major	1	5	20	1	4	13	1	4	12	1	4	13
# Detected	2	5	24	1	3	11	1	3	10	2	5	16
# Preventive slaughtered	-	-	-	12	22	52	16	32	104	-	-	-
# Vaccinated	-	-	-	-	-	-	0	0	54	8	31	157
Duration (days)	54	100	201	50	67	140	50	64	123	54 a)	84 a)	136 a)
Infected due to:												
- Local spread	0	1	12	0	1	6	0	1	5	0	1	6
- Direct animal contact	0	1	4	0	1	4	0	1	4	0	1	4
- Transport contact	0	1	4	0	1	4	0	1	4	0	1	4
- Professional contact	0	1	4	0	0	3	0	0	3	0	0	3

a) In the case of the intra-community trade scenario we have to add 120 days extra for the imposed post-vaccination zone.

Table 5.3 Economic welfare analysis of two different trade scenarios, given the EU, the PS, the DD and the ICT strategy in a DPLA: economic welfare analysis in 10^6 EUR for a small, medium and large sized epidemics, ranked on the length of the epidemic, respectively on the number of detected farms

Scenario	EU strategy			PS strategy			DD strategy			ICT strategy		
Epidemic size	small	medium	large	small	medium	large	small	medium	large	small	medium	large
	Trade bans imposed on the quarantine zones only											
a) Ranked on the length of the epidemic												
Welfare change in PS	318	488	914	79	169	261	84	204	359	107	182	235
Welfare change in CS	-198	-316	-558	-45	-102	-171	-49	-129	-230	-63	-109	-142
Public funds	-125	-191	-351	-25	-61	-102	-26	-74	-162	-37	-69	-90
Net welfare effect	-5	-19	5[a]	9	6	-12	8	1	-32	7	5	-3
b) Ranked on the number of detected farms												
Welfare change in PS	276	495	869	83	288	411	96	185	275	151	242	357
Welfare change in CS	-178	-320	-533	-49	-166	-254	-58	-113	-181	-89	-145	-211
Public funds	-104	-201	-338	-27	-111	-175	-31	-65	-108	-55	-96	-155
Net welfare effect	-6	-26	-2	8	11	-17	7	7	-14	7	1	-9
	Trade bans imposed on the quarantine zones combined with a total export ban on all Dutch live pigs											
a) Ranked on the length of the epidemic												
Welfare change in PS	-200	-160	-167	-295	-273	-249	-283	-167	-9	-296	-262	-268
Welfare change in CS	230	262	520	218	237	249	208	143	55	231	231	264
Public funds	-107	-162	-297	-23	-55	-91	-24	-70	-152	-33	-62	-79
Net welfare effect	-77	-60	56[b]	-100	-91	-91	-99	-94	-107	-98	-92	-83
a) Ranked on the number of detected farms												
Welfare change in PS	-336	-119	-91	-292	-146	-12	-269	-201	-91	-306	-200	-67
Welfare change in CS	351	219	410	216	167	78	200	173	94	264	194	111
Public funds	-88	-170	-286	-24	-100	-160	-29	-61	-101	-49	-87	-142
Net welfare effect	-72	-69	33[b]	-100	-80	-94	-98	-89	-99	-91	-93	-97

a) Fewer farms in quarantine zones for replication 95 leads to much lower control expenditure, resulting in a positive net welfare effect.

b) A large number of farms were in quarantine zones. As a consequence, the price drop for finisher producers was more than compensated by the lower piglet prices. Finisher producers collectively gained and piglet producer collectively loss, resulting in a total low negative welfare effect of pig producer.

Table 5.4 Economic welfare analysis of two different trade scenarios, given the EU, the PS, the DD and the ICT strategy in a SPLA: economic welfare analysis in 10^6 EUR for a small, medium and large sized epidemics, ranked on the length of the epidemic, respectively on the number of detected farms

Scenario	EU strategy			PS strategy			DD strategy			ICT strategy		
Epidemic size	small	medium	large	small	medium	large	small	medium	large	small	medium	large
	Trade bans imposed on the quarantine zones only											
a) Ranked on the length of the epidemic												
Welfare change in PS	8	8	19	8	28	20	9	11	19	7	11	10
Welfare change in CS	-5	-4	-9	-5	-15	-11	-5	-6	-11	-4	-6	-5
Public funds	-1[a]	-1	-6	-1[a]	-7	-6	-1[a]	-2	-5	-1[a]	-2	-3
Net welfare effect	3	2	4	3	5	4	3	3	3	2	3	2
c) Ranked on the number of detected farms												
Welfare change in PS	7	7	49	8	9	22	9	11	26	7	9	39
Welfare change in CS	-4	-4	-25	-5	-5	-13	-5	-7	-15	-4	-4	-21
Public funds	-1[a]	-1	-14	-1[a]	-1	-6	-1[a]	-2	-7	-1[a]	-2	-11
Net welfare effect	2	2	9	3	2	3	3	3	5	2	3	7
	Trade bans imposed on the quarantine zones combined with a total export ban on all Dutch live pigs											
a) Ranked on the length of the epidemic												
Welfare change in PS	-373	-429	-547	-363	-356	-469	-363	-378	-445	-380	-403	-468
Welfare change in CS	264	326	465	254	257	378	253	272	350	272	300	371
Public funds	-1[a]	-1	-5	-1[a]	-7	-5	-1[a]	-2	-5	-1[a]	-2	-3
Net welfare effect	-110	-104	-88	-110	-106	-96	-110	-108	-100	-109	-106	-99
b) Ranked on the number of detected farms												
Welfare change in PS	-402	-414	-478	-363	-381	-447	-363	-372	-397	-377	-406	-411
Welfare change in CS	295	309	406	254	274	354	253	265	301	268	301	328
Public funds	-1[a]	-1	-12	-1[a]	-1	-6	-1[a]	-2	-6	-1[a]	-1	-12
Net welfare effect	-107	-106	-85	-110	-109	-98	-110	-109	-101	-110	-106	-95

a) Less than 1 million euro.

contribution from the EU budget towards the total extra expenditure on controlling the epidemic. However, if the EU contribution were lower, the extra expenditure from Dutch public funds would increase, resulting in a larger negative net welfare effect for the Dutch economy. In the case of a DPLA, the PS, DD and ICT strategies result in smaller economic welfare changes for all stakeholders than the EU strategy. Epidemics in a SPLA are smaller in size and length than epidemics in a DPLA, with lower welfare changes for producers and consumers.

With an export ban on live pigs, a segment of demand is removed from the Dutch market. When the epidemic is small, the fall in demand outweighs the small reduction in pig supply due to movement restrictions and so prices fall. Producers lose surplus. With an increased number of affected farms (large epidemics in size and/or length), a larger share of the pig population is taken out of the market and so the drop in simulated market prices is smaller. This leads to the unexpected result that, with a total export ban, SPLA epidemics cause larger negative net welfare effects than epidemics in a DPLA although SPLA epidemics are on average smaller in size and length. The changes in the surpluses of piglet, finisher and breeding stock producers depend on whether the farms are situated inside a quarantine zone or not (results not shown). In Chapter 4, we present details of the distribution of welfare changes across the industry for the two trade scenarios.

Tables 5.3 and 5.4 show that government expenditure to control the epidemic increases with the size of the epidemic. Animal welfare slaughter compensation takes the largest share of total government expenditure on control programs. These payments are highly related to the length of the epidemic and the number of farms in quarantine zones.

When exports are banned, slaughterhouses gain as more animals are slaughtered domestically and final consumers gain due to the decreased prices (details not shown). For both these stakeholders, the welfare change is negative when foreign trade continues from non-quarantine zones.

5.4 Discussion

5.4.1 Sensitivity analysis

In all the simulations shown, the index farm is always a multiplier farm. To check the sensitivity of the results to this assumption, the farm type of the index farm was changed to be either a finisher, a multiplier-finisher or a breeding farm in each region. The impact of the index farm type is negligible, although there is a slight tendency for smaller epidemics when it is a finisher farm (on average a lower number of movement contacts) and larger epidemics when it is a breeding farm (on average a higher number of movement contacts).

Sensitivity analysis performed by varying key parameters generally had little impact on the results. Only contact and local spread transmission probabilities had a large impact on the simulated results. Two studies on transmission probabilities (Stegeman et al., 1998, 2002) are currently available, both based on data from the Dutch CSF epidemic. The first of these studies was preliminary, and our new infection probabilities are based mainly on the second (Stegeman et al., 2002). A change in the estimation method as well as more data (Stegeman et al., 2002) in the second study led to downward corrections by 80 to 95 per cent of all estimated transmission probabilities. We did not use the point estimates from Stegeman et al. (2002), because a worst-case epidemic of 42 detected farms (using our old contact matrix), or 32 detected farms (with the new contact matrix) was deemed far too small. Only by doubling the 95% confidence interval of Stegeman et al. (2002) for all transmission probabilities (local spread and contacts) were we able to reproduce larger epidemics (see Appendix XI). Extra bio-security measures and the control measures implemented during the Dutch CSF epidemics may have biased the estimated transmission probabilities downwards and therefore a doubling of the estimates may be justified. Additionally, we corrected the transmission probabilities 15% upwards because we also simulate minor within-herd outbreaks and Stegeman's analysis was based on large within-herd outbreaks only.

In how far these adjustments are justified for local spread is questionable, therefore sensitivity analysis was necessary. In the case of a SPLA, the value of the transmission probabilities for local spread are of minor importance for the size and the length of an epidemic (results not shown), whereas for a DPLA the simulated epidemic is larger in size and with a longer duration when the parameters for local spread are doubled (Appendix XI).

The factors that determine local spread are still unknown apart from the inverse relationship between the distance to an infected farm and the probability of becoming infected. Staubach et al. (1997) estimated a relative risk curve for neighbouring farms, depending on the distance to an infected source farm. The decrease in the risk of infection as distance increased is not linear. For sensitivity analysis, we forced our transmission probabilities to follow an 11-step "curve" similar to that described by Staubach et al. (1997). This reduced the duration and size of the simulated epidemics (Table 5.5), compared to our original 3-step decline in local spread parameters.

Table 5.5 Effects of functional form of local spread transmission function, given the PS strategy in a DLPA area: Mean effects, effects for the simulations ranked 5, 50 and 95 according to the corresponding epidemiological outcome

Scenario	3-Step function [a]				11-Step function [b]			
Percentile/ Mean	Mean	5%	50%	95%	Mean	5%	50%	95%
# Infected	46	9	38	92	33	7	29	75
# Detected	29	4	25	65	21	3	18	49
# Preventive sl.	136	40	113	281	110	37	98	230
Duration (days)	134	65	127	210	116	63	111	186
Infected due to:								
- local spread	36	6	32	71	25	5	23	53
- animal contact	3	0	2	10	3	0	2	7
- transport contact	3	0	2	7	2	0	2	6
- professional	3	0	2	8	2	0	1	8

a) Following Stegeman et al. (2002), transmission probabilities for local spread were set at three levels, depending on the distance from the infected source herd: 0-500, 501-1000 and 1001-2000 m.

b) We forced the transmission probabilities into an 11-step function approximating the continuous non-linear curve fitted empirically by Staubach et al. (1997). The areas under the 3-step and 11-step functions were the same.

5.4.2 Carrier piglets

The inclusion of carrier piglets added a vertical transmission route to the simulation model. The number of simulated minor within-herd outbreaks with carrier piglets is rather low, regardless of whether vaccination is used or not. Therefore, we can conclude that the probability of moving carrier piglets from infected areas into susceptible areas is small although, were this to happen, the effects could be devastating. In a vaccinated pig population where the vaccinated pigs are not killed but traded, carrier piglets are hard to detect and extra serological screening (assuming a reliable test is available) may be needed to detect them. Imposing extra-long movement restrictions, such as the so-called post-vaccination zone (see Chapter 2) may be another valid measure to convince trading partner that everything is being done to reduce the risk of spread by carrier piglets outside the area.

5.4.3 Frequency of contacts

The new Dutch pig transport legislation aims to reduce the spread of future epidemics. Our simulations assume a reduced number of transport contacts off the farm compared to Jalvingh et al. (1999). These results indicate that a reduced number of animal contacts can significantly reduce the spread of the virus. Even so, we might still overestimate the number of farm contacts per infected farm and so overestimate the size of the simulated epidemics. This is because, in InterCSF_v3, all contacts are randomly drawn and no fixed trading partners are assumed. The current legislation, however, puts a maximum on the number of contact herds resulting in a relatively small number of fixed trading relationships. Even without reflecting this, our results already clearly show the potential of less frequent animal transport between farms for reducing the size of future epidemics.

5.4.4 Different control strategies applied in a DPLA respectively a SPLA.

The probability of transmission by local spread, as well as the form of the transmission curve, both have an impact on the size and the length of an epidemic in a DPLA (see Appendix XI), whereas for a SPLA local spread is of little importance due to the absence of close neighbouring farms. The assumptions made in InterCSF_v3 summarise current knowledge as far as possible, but have a large impact on the simulated results. Which factors influence the local spread of the virus, and how, is still an on-going research question.

For a SPLA, the standard EU strategy is always sufficient to control and eradicate the epidemic whereas for a DPLA, the EU strategy is generally insufficient. Additional control measures that decrease the number of susceptible herds in the close neighbourhood of an infected farm are needed in order to reduce the size and the length of the epidemic. Emergency vaccination strategies are risk averse strategies as their worst-case replications are smaller in size than for the PS strategy.

5.5 Conclusions

Our analysis indicates that when a CSF epidemic remains located in a SPLA, the standard EU strategy is also economically optimal, whereas for a DPLA, the ICT strategy seems economically most attractive, assuming no export trade ban. With the ICT strategy, the changes in producer and consumer surplus are the lowest. Extra expenditure to control and eradicate the virus is also the lowest of all simulated strategies. No extra control costs for the post-vaccination zone are included, but based on the existing identification and registration system in the Netherlands, those costs are likely to be rather low.

Ethical reasons favour the ICT strategy as only infected herds are slaughtered and rendered. However, acceptance of this strategy by EU trading partners, as well as by retailers and final consumers, is highly questionable. As long as vaccinated animals are present, the country's reduced pig health status may cause the loss of some important trading markets. Moreover, although the Netherlands trades more than 70 % of reared pigs (either as live animals or as meat) mainly within the EU (Pluimers et al., 1999), a reduced health status in the Netherlands may be seen by non-European countries as a reduced health status of the EU as a whole. As a consequence, Danish pig meat that is now mainly exported outside the EU could be dumped on the European market.

During the 2001 FMD epidemic, the discussion about whether to slaughter vaccinated animals and sell them on the Dutch market was abruptly ended by reservations from major Dutch retailers about selling meat from vaccinated animals and recognition of the short-term logistic problems of guaranteeing strict separation of meat originating from vaccinated animals and from non-vaccinated animals (Jan Klaver (PVE), personal communication, October 2001). As long as the political and the public acceptance of vaccination is questionable (due to lack of a reliable diagnostic test, insufficient markets for vaccinated pig meat or tough logistic problems), the risk of an export ban on live pigs favours the option of preventive slaughter. However, in future epidemics overwhelming public and media pressure may force the adoption of the DD strategy whereby pigs are first vaccinated but are later slaughtered and rendered as there is no market available.

Regarding the specific research questions addressed in this paper, we can report that the impact of carrier piglets on the size and the length of an epidemic is rather low. Moreover, if the new Dutch pig transport legislation is applied correctly, it will certainly lead to a reduction of disease spread in future CSF epidemics.

Most important, our work shows that the pig density in the area of the initial outbreak is relevant to the evolution of the epidemic and the choice of optimal control strategy. In a SPLA, the EU strategy is in most cases sufficient to eradicate the disease, whereas in a DPLA additional control measures are necessary. The simulation evidence indicates that any control measures that lead to a total export ban of all live Dutch pigs should be avoided. Therefore, given current political and public levels of acceptance, we conclude that the PS strategy is economically the most rational if a CSF epidemic occurs in a DPLA whereas the EU strategy is sufficient in a SPLA. Accordingly, future epidemic control policy decisions should be area-specific and based on pig density.

Finally, this work shows the need for more insight into transmission probabilities and the mechanism of local spread, in order to refine the accuracy of InterCSF_v3.

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Appendix X Input parameters of InterCSF_v3

Table X-1 Probabilities used in InterCSF [a)]

Probability of minor outbreak (given infection) on a non-vaccinated farms [b)]	
Multiplier farms	0.14
Finisher farms	0.18
Mixed or breeding farms	0.16
Probability of a minor (rather than major) outbreak on a vaccinated and maximum protected farm [b)]	
All farm types	1.00
Probability of carrier piglets (given a minor outbreak) on a non-vaccinated farm [b) d)]	
Multiplier and breeding multiplier farms (only sows and piglets)	0.12
Mixed farms	0.06
Probability of detection via clinical signs on a non-vaccinated farm given a major within-herd infection [b)]	
Multiplier, mixed and breeding farms	0.85
Finisher farms	0.80
AI-station	0.75
Transmission probabilities for movement contacts (given infection) per contact type [c)]	
Direct animal contact (high risk contact)	0.277
Transport contact (medium risk contact)	0.048
Professional contact (low risk contact)	0.03
Transmission probabilities for local spread per day in a radius of: [c)]	
0 – 500 m	0.0122
501 – 1000 m	0.004
1001 – 2000 m	0.00003

a) A detailed description of all input parameters is available on request from the first author.

b) Based on calculations done by Don Klinkenberg (ID-DLO). A detailed description (in Dutch) is available from the first author on request.

c) The 95% confidence interval estimates of Stegeman et al. (2001) were multiplied by 2 and corrected for the probability of minor outbreaks (assuming a probability of minor outbreaks of 15 %) in order to reach our calibration goal.

d) The probability of carrier piglets on vaccinated farms with a minor outbreak was reduced by 50 %, according to the findings of Dewulf et al. (2001).

Appendix X Input parameters of InterCSF_v3 (suite)

Table X-2 Probability of detection in the event of vaccination, relative to the time since infection on an (undetected) infected farm

Time between infection entrance and vaccination (days)	Probability of detection related to control event vaccination (diagnosis date 2 days later) for **all three farm types** (sow, sow and finisher and finisher only)	
	Vaccination day[a]	1 week after vaccination[b]
	Minor outbreak (infection source = direct animal contact)[c]	
0 – 14 (7 – 21)[c]	0	0.5[d]
> 14 (> 21)[c]	0	0
	Major outbreak[e]	
0 – 14	0.25	0.90
15 – 28	0.90	0.95
29 – 42	0.99	1.00
> 42	0.99	1.00

a) We assume a clinical inspection prior to vaccination.

b) After-vaccination detection (1 week after vaccination) is based on clinical signs only.

c) We assume that in the case of a minor outbreak not caused by *introduced animals*, the probabilities are the same as for a direct animal contact but delayed by one week.

d) If a farm with a minor outbreak is vaccinated in the first 1-2 weeks after infection, we may expect a few infectious animals on the farm. If such an infectious animal is vaccinated as one of the first animals, infection may be spread by the vaccination team to the following animals.

e) Same as described in Chapter 2.

Table X-3 Probability of detection for various control events relative to the time since infection on an (undetected) infected farm and for a vaccinated farm, depending on the time since infection and the farm-specific vaccination status

Time since infection (days)	Probability of detection by control event (diagnosis date 7 days after event)														
	Traced contacts [a,d]			Surveillance (3 km radius) [b]			Preventive slaughter [b,c,d]			End-screening/ intermediate screening [c,d]			Welfare slaughter [c,e]		
	NV [f]	IV [g]	VI [h]	NV [f]	IV [g]	VI [h]	NV [f]	IV [g]	VI [h]	NV [f]	IV [g]	VI [h]	NV [f]	IV [g]	VI [h]
Major outbreak on multiplier, mixed and non-sow farms (as in Chapter 2) [a]															
0 – 14	0	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0
15 – 21	1	1	0	0	1	0	1	1	0	0.25	1	0	0	1	0
22 – 28	1	1	1	0	1	0	1	1	1	0.25	1	1	0	1	1
29 – 42	1	1	1	0.25	1	0	1	1	1	0.5	1	1	0	1	1
> 42	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
Minor outbreak on multiplier farms (only sows) (infection source = direct animal contact) [i]															
0 – 14	0	0.5 [b]	0	0	0.5	0	0	0.5 [b]	0	0	0.5 [b]	0	0	0.5 [b]	0
15 – 21	0	0 [c]	0	0	0	0	0	0 [c]	0	0	0 [c]	0	0	0 [c]	0
22 – 28	0.3	0.7 [c]	0.7	0	0	0	0.3	0.7 [c]	0.7	0.3	0.7 [c]	0.7	0.3	0.3 [c]	0.3
29 – 42	0.3	0.7 [c]	0.7	0	0	0	0.3	0.7 [c]	0.7	0.3	0.7 [c]	0.7	0.3	0.3 [c]	0.3
> 42	0.3	0.7 [c]	0.7	0	0	0	0.3	0.7 [c]	0.7	0.3	0.7 [c]	0.7	0.3	0.3 [c]	0.3
Minor outbreak on mixed farms (infection source = direct animal contact) [i]															
0 – 14	0	0.5 [b]	0	0	0.5	0	0	0.5 [b]	0	0	0.5 [b]	0	0	0.5 [b]	0
15 – 21	0	0 [c]	0	0	0	0	0	0 [c]	0	0	0 [c]	0	0	0 [c]	0
22 – 28	0.3	0.4 [c]	0.4	0	0	0	0.3	0.4 [c]	0.4	0.3	0.4 [c]	0.4	0.3	0.3 [c]	0.3
29 – 42	0.3	0.4 [c]	0.4	0	0	0	0.3	0.4 [c]	0.4	0.3	0.4 [c]	0.4	0.3	0.3 [c]	0.3
> 42	0.3	0.4 [c]	0.4	0	0	0	0.3	0.4 [c]	0.4	0.3	0.4 [c]	0.4	0.3	0.3 [c]	0.3
Minor outbreak on non-sow farms (infection source = direct animal contact) [i]															
0 – 14	0	0.5 [b]	0	0	0.5	0	0	0.5 [b]	0	0	0.5 [b]	0	0	0.5 [b]	0
15 – 21	0	0 [c]	0	0	0	0	0	0 [c]	0	0	0 [c]	0	0	0 [c]	0
22 – 28	0.3	0.3 [c]	0.3	0	0	0	0.3	0.3 [c]	0.3	0.3	0.3 [c]	0.3	0.3	0.3 [c]	0.3
29 – 42	0.3	0.3 [c]	0.3	0	0	0	0.3	0.3 [c]	0.3	0.3	0.3 [c]	0.3	0.3	0.3 [c]	0.3
> 42	0.3	0.3 [c]	0.3	0	0	0	0.3	0.3 [c]	0.3	0.3	0.3 [c]	0.3	0.3	0.3 [c]	0.3

a) In contrast to Chapter 2, detection from tracing is not only based on clinical inspection but also partly on serology. All other probabilities for a major within-herd outbreak are the same as in Chapter 2.
b) Based on clinical inspection.
c) Mainly based on serology, assuming 3 infected pigs for minor within-herd outbreak.
d) We assumed 100% sample size in vaccinated herds. For non-vaccinated farms we assumed a sample size of minimum 25 % of all sows and minimum 5 % of all other pigs (RVV, 2000), using standard herd-sensitivity formulae (Noordhuizen et al., 1997).
e) We assumed a sample size of 10% (RVV, 2000), using standard herd-sensitivity formulae (Noordhuizen et al., 1997).
f) NV: Control event happens on a non-vaccinated farm, already infected.
g) IV: Control event happens after vaccination on a farm already infected before vaccination.
h) VI: Control event happens after vaccination on a farm, infection after vaccination.
i) We assume that in the case of a minor outbreak not caused by introduced animals, the probabilities are the same as for a direct animal contact, but delayed by one week.

Appendix XI Calibration of InterCSF_v3

Effects of different transmission probabilities, given the contact matrix of Jalvingh et al. (1999), the epidemic starts on an infected farm in Boekel (DPLA), the EU strategy as control measure for the first 3 months, followed by the PS strategy: mean effects and effects for the simulations ranked 5, 50 and 95 according to the corresponding epidemiological outcome.

Scenario	Base				Alternatives											
					Point estimation				95% confidence interval				Reduced local spread			
Transmission probabilities [a]	Doubling of the upper limit of the 95 % confidence interval for all transmission probabilities				Point estimation values for all transmission probabilities				Upper limit of 95 % confidence interval for all transmission probabilities				Doubling of the upper limit of the 95 % confidence interval for movement contacts only; Upper limit of the 95 % confidence interval for local spread			
Mean/Percentile	mean	5%	50%	95%	mean	5%	50%	95%	mean	5%	50%	95%	mean	5%	50%	95%
# Infected	296	65	231	752	17	2	15	42	37	6	31	75	81	10	56	219
- minor	49	9	38	125	3	0	2	6	6	1	5	12	13	1	10	32
- minor and major	1	0	1	5	0	0	0	1	0	0	0	1	0	0	0	1
- major	245	55	190	617	14	1	12	36	31	5	26	66	67	9	45	185
# Detected	254	57	197	638	16	2	14	38	34	6	29	73	73	10	52	196
# Preventive slaughter	324	64	258	887	15	0	8	55	38	0	28	109	105	0	58	471
Duration (days)	245	178	239	321	141	65	150	205	167	100	172	210	189	133	187	250
Infected by:																
- local spread	244	56	189	645	13	1	11	34	28	3	25	57	53	6	39	126
- animal contact	17	2	12	43	1	0	1	5	3	0	2	10	11	0	6	32
- transport contact	15	2	13	33	1	0	1	3	3	0	2	9	10	1	7	27
- professional contact	19	2	14	54	0	0	0	2	2	0	1	6	6	0	5	18

a) The transmission probability values are based on Stegeman et al. (2002), corrected for a 15% probability of minor within-herd outbreaks.

Appendix XII Contact matrix, distance classes and destination distribution, specific to the Dutch pig sector (based on analysis of the 1999 Dutch identification and registration data by Mourits et al., 2001)

Table XII-1 Contact matrix

FarmType	Transport type	Frequency (times/52 weeks)	Contact type	
			Animal	Transport
Multiplier	Piglets off	32	1	2
	Gilts on	5	0	2
	Finishers off	10	0	1
	Sows off	13	0	3
Finisher	Piglets on	9	0	2
	Finishers off	17	0	1
Mixed	Piglets off	2	1	2
	Gilts on	3	0	2
	Finishers off	26	0	1
	Sows off	10	0	3
Breeder	Piglets off	20	1	2
	Gilts off	20	3	2
	Gilts on	2	0	2
	Finishers off	17	0	1
	Sows off	13	0	3
AI	Finishers off	13	0	4

Note:

It is determined how many animal transports occur on or off an infected farm each day by drawing from a Poisson distribution of animal transports per day whose average is the relevant frequency given in Table XII-1. If an animal transport occurs, the destination farms of the related animal and transport contacts are generated in InterCSF. It was assumed that no animal contacts between farms can occur if animals are transported to the slaughterhouse, but that the truck may be used for other transports that day resulting in transport contacts. Based on the highly structured Dutch industry, it was additionally assumed that farms do not sell animals to a random other farm type. For example, 95% of animal contacts from a multiplier go to a fattener, 1% to another multiplier and 4% to a mixed farm. Similar patterns are summarised for all farm types in Table XII-3. For transport and person contacts, a random receiving pig farm of any type within the selected distance class was drawn. Distance classes per contact type are shown in Table XII - 2. It was assumed that each day on average 0.2 professional-person contacts occurred from any pig farm to another pig farm (Nielen et al., 1996).

Appendix XII Contact matrix, distance classes and destination distribution, specific to the Dutch pig sector (suite)

Table XII-2 Probability that a simulated contact happens in a specific distance class, depending on the contact type

Contact type	Distance class (in km)							
	0-5	5-10	10-15	15-20	20-30	30-60	60-100	100-150
Animal and transport	0.305	0.208	0.135	0.085	0.101	0.115	0.041	0.12
Person	0.65	0.15	0.15	0.025		0.025	0	

Table XII-3 Destinations of direct animal contacts (in percentages)

From \ To	Multiplier	Finisher	Mixed	Breed	AI-station
Multiplier	1	95	4	-	-
Finisher [a]	-	-	-	-	-
Mixed	12	75	10	3	-
Breed	31	34	21	14	-
AI-station [a]	-	-	-	-	-

a) In the case of a finisher or an AI-station all animal contacts off farms are directed to slaughterhouses.

Chapter 6

Epidemiological and economic effects of supplementary measures to reduce piglet supply during a Classical Swine Fever epidemic

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Abstract

A sector-level market and trade model and a spatial, stochastic, temporal epidemiological simulation model are used to simulate the Dutch pig market during a CSF epidemic. The effects of supplementary measures to reduce the piglet supply during an epidemic, namely an insemination ban, abortion of sows and the killing of young piglets, are studied. It is assumed that trade from non-quarantine zones continues. Changes in the economic welfare of different stakeholders are measured, as well as the net welfare effect for the Dutch economy. Economic results do not support the use of measures to reduce piglet supply. Moreover, the use of such measures is not a solution to problems of shortage of rendering capacity.

6.1 Introduction

During the 1997-8 Dutch Classical Swine Fever (CSF) epidemic (hereafter referred to as the Dutch CSF epidemic), an insemination ban and the killing of very young piglets were imposed in much of the infected area to reduce overcrowding on farms. These supplementary measures were also seen as a solution to the problem of insufficient rendering capacity, which became evident in April 1997 (Pluimers et al., 1999). Pig farming is highly specialised and intensive in the Netherlands, where breeding, multiplication, and fattening are usually carried out on separate farms. Producers do not have facilities to house animals longer than is necessary for their normal production cycle, therefore they need to deliver pigs frequently to other farms and/or to slaughterhouses. Once the transport ban was enforced, most farms became overstocked with pigs within a few weeks (Pluimers, et al, 1999). Overstocking leads to cannibalism and fighting. Furthermore, pen floors may break due to the over-weighted animals. The authorities, supported legally and financially by the European Commission, implemented a programme to buy out pigs from overstocked farms (hereafter referred to as welfare slaughter). Because regulations prevent the marketing of these animals for human consumption, the carcasses were rendered (Pluimers, et al, 1999).

After the Dutch CSF epidemic, these supplementary measures were the subject of on-going discussion. The Dutch authorities favoured the measures, and offered them to farmers again, on a ‘voluntary’ basis, during the Dutch 2001 FMD epidemic (LNV, 2001). In this case, farmers could participate in welfare slaughter schemes only if they stopped insemination for four months and aborted their pregnant sows. By contrast, farmers were hostile to the insemination ban, preferring the killing of young piglets, which was seen as having a less disruptive impact on herd management. However, veterinarians opposed the killing of young piglets for ethical reasons, preferring an insemination ban. In a court action brought by farmers, the court concluded that the insemination ban imposed during the Dutch CSF epidemic was illegal (Agrarisch Dagblad, 2001). Moreover, the European Union (EU, 2000) concluded that the insemination ban applied by the Dutch authorities should not be repeated in the future, because large-scale synchronised insemination of sows at the end of the ban led to a disturbance of the piglet market in 1998.

Until now, the epidemiological and economic effects of an insemination ban, abortion and/or the killing of young piglets have not been studied. Here we analyse these effects, comparing the use of one, two or all three supplementary measures with a situation where none is used. The goal of the paper is to describe the epidemiological consequences, particularly in terms of disease spread, and the economic consequences as measured by direct programme costs and the extent of disruption to the piglet market.

6.2 Modelling framework and sensitivity analysis

6.2.1 Modelling framework

6.2.1.1 General

The modelling framework comprises a spatial, stochastic, dynamic epidemiological model (InterCSF_v3), developed by Jalvingh et al. (1999) and further adapted in Chapter 5[1], and a four-part economic model described in detail in Chapter 4.

InterCSF_v3 simulates the daily spread of the disease from infected farms through three contact types (animals, vehicles and persons) and through local spread up to 2000 m. All Dutch pig farms are known by their geographical co-ordinates, their farm type and their stock numbers. Control measures such as diagnosis of infected farms, slaughter of infected farms, movement control areas, tracing, preventive slaughter and emergency vaccination may also be simulated on a daily basis.

A micro-economic model (EpiPigFlow) converts the daily output from InterCSF_v3 into a weekly flow of piglets, which becomes an input into DUPIMA, a partial equilibrium model of the Dutch pig market. DUPIMA simulates weekly market behaviour and trade flows at sector level. A second micro-economic model (EpiCosts) uses output from InterCSF_v3 and

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[1] In 1997 Jalvingh et al. (1999) developed InterCSF, based on InterSpread (Sanson, 1993; Jalvingh et al., 1995), to analyze the Dutch CSF epidemic. In Chapter 5 we adapted InterCSF towards a generic CSF model.

the simulated market prices from DUPIMA to calculate the expenditure incurred by the Dutch authorities in controlling the epidemic. Furthermore, EpiCosts calculates the changes in producer surplus of pig producers inside the quarantine zones. An Excel worksheet integrates the results of EpiCosts and DUPIMA to calculate the economic welfare changes of producers and consumers (slaughterhouses, the processing industry, retailers and final consumers), and the extra expenditure of the Dutch health authorities. The economic welfare changes of the different stakeholders aggregate to the net economic welfare change for the Dutch economy.

6.2.1.2 The three supplementary animal welfare measures

The adoption of an insemination ban will stop the birth of piglets on sow farms 115 days after the start of the measure and will stop the supply of growers (25-kg-piglets) 185 days after the start of the measure. Aborting pregnant sows from day 0 until day 40 of pregnancy (LNV, 2001) will stop the birth of piglets 75 days after implementation and will stop the supply of growers 145 days after implementation. By contrast, the killing of young piglets at around 10 days of age will not interrupt the flow of newborn piglets on a farm, but will stop the supply of growers 2 months after implementation.

If all three measures are implemented together, the killing of young piglets can be applied only as long as newborn piglets are born and the abortion of sows will take place only as long as there are inseminated sows. Moreover, we assume that the abortion of sows is always combined with an insemination ban, resulting in at most a single abortion event per sow until the ban is lifted.

We assume that the three supplementary measures are lifted at the same moment as the quarantine zone and that sows are re-inseminated gradually, leading to a normal supply of growers after 185 days (115 days pregnancy and 70 days for rearing). If only the killing of very young piglets is used, a normal supply of growers from the farms involved is restored after 60 days.

An insemination ban and the abortion of sows also prevent the possible birth of carrier piglets (piglets infected as a foetus that spread the CSF virus throughout their lives). The absence of carrier piglets, due to one or more of these measures, effectively eliminates all routes of spread related to carrier piglets.

We assume that slaughtered 10-day-old-piglets are compensated at the rate of 61% of the weekly piglet price, as in the Dutch CSF epidemic. Compensation payments for sows under an insemination ban are also based on those paid during the Dutch CSF epidemic (Meuwissen et al., 1999). For simplicity we assume the same compensation payments for aborted sows. The variable costs saved by not producing piglets or not raising growers, as well as the compensation payments paid, are included when calculating the economic welfare change for piglet producers inside a quarantine zone.

6.2.1.3 Simulated scenarios

In our simulations, the first infected farm is always situated in a densely populated livestock area (DPLA)[2]. In Chapter 5 we found that a larger epidemic will occur in a DPLA than in a sparsely populated pig area. In all simulations, control measures are adopted comprising stamping-out infected herds, tracing all contacts, setting up quarantine zones (protection and surveillance zones) around infected herds with movement restrictions and preventive slaughter on all farms in a radius of 750 to 1000 m around a detected herd. This corresponds to the PS (preventive slaughter) strategy described in Chapter 5. Inside the quarantine zone, the frequency of different control events (surveillance and serological screening) is based on the Dutch animal health authorities contingency plan for a future epidemic (RVV, 2000). In the case of a long-lasting movement standstill, welfare slaughter of hogs and growers to avoid overcrowding is always assumed.

The PS strategy serves as the Base strategy for our comparative evaluations. Three alternative scenarios are simulated. In Alternative 1 (favoured by the Dutch government) we assume that insemination prohibition, sow abortion and the killing of young piglets are all adopted within movement standstill areas. In Alternative 2 (favoured by the veterinarians) only an insemination ban and sow abortion are used in addition to the base strategy. In Alternative 3 (favoured by the Dutch farmers), the only measure adopted to reduce stock numbers within quarantine areas is the killing of young piglets. For all simulations, a partial trade ban (imposed on quarantine zones only) is assumed (Chapter 4 and 5).

6.2.2 Sensitivity analyses

6.2.2.1 Destruction capacity

Killing very young piglets was seen in the Dutch CSF epidemic as a solution to the shortage of rendering capacity (Pluimers et al., 1999). Pigs were slaughtered on the farm, in the case of control measures (infected and preventively slaughtered farms), and in designated

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[2] In this study the only livestock species considered are pigs.

slaughterhouses, in the case of welfare slaughter. In the first months of the Dutch CSF epidemic, *all* carcasses were rendered. Hence, the rendering capacity rather than the slaughtering capacity was the limiting factor. Our simulations assume that welfare slaughter of "healthy" pigs (hogs and growers) always takes places in specific slaughterhouses and welfare slaughtered pigs are rendered only when capacity is available. Control measures have priority over available destruction capacity (killing and rendering), assuming maximum capacity of 5 farms per day in the first week rising to 15 farms per day from the third week onwards (Capacity-base). If limited destruction capacity were used for both control measures and welfare slaughter, less capacity would be available for control measures possibly resulting in larger epidemics. Therefore, we perform two sensitivity analyses: the destruction capacity for control measures was held at a maximum of 5 farms per day (Capacity-low A) and alternatively the adoption of the three supplementary measures increases destruction capacity available for control measures from 5 to 10 farms per day from approximately 4 months into the epidemic (Capacity-low B).

6.2.2.2 High risk period

The period between the first farm in a region becoming infected and the first detected case in that region is called the high-risk period (HRP). The HRP is one of the most important parameters for determining the size of an outbreak because it defines the period in which the virus can circulate freely and is able to infect pig herds (Horst et al., 1998). For all scenarios we randomly draw a HRP from a truncated lognormal curve (21-100), with 49 days as mean (HRP-base). For sensitivity analyses we displaced the whole curve left (HRP-short) and right (HRP-long) by 14 days to obtain shorter and longer HRPs with, as possible consequences, smaller or larger epidemics. The Base and three Alternative scenarios are simulated with the shorter and longer HRPs.

6.2.2.3 Clinical signs

The probability of detection based on clinical signs is decreased by 10% for all farms and for the whole epidemic.

6.2.2.4 When to decide to implement such measures?

Our hypothesis is that using supplementary measures to reduce pig numbers would only make sense when a large epidemic is expected. Therefore, we use the epidemics simulated under the PS strategy to see if and when a large epidemic might be predicted, based on the number of detected farms to date. InterCSF_v3 output provides the daily number of detected farms. The cumulative detected cases by the end of the first week and the sixth week after detection are calculated. We examine the correlation between those two criteria and the length of the epidemic. We checked, for each replication, whether a threshold level of 5, 10 or 15 detected farms within the first week, or of 40, 50 or 60 detected farms within the first 6 weeks, was met. We repeated this procedure for all 100 replications of PS (HRP-base), as well as for PS (HRP-short) and PS (HRP-long). All 100 replications were ranked according to the epidemic length and divided into quarters. For each quarter the number of replications that met the threshold is reported. We further reported the number of replications that met the threshold and that were ranked according to the epidemic length to be among the 5 or 10 longest.

6.2.2.5 Cyclical variation

We calculated the economic net welfare effects using a *high* pig price year (model calibrated to produce 1996 price levels in a non-epidemic situation) and a *low* pig price year (model calibrated to produce 1999/2000 price levels).

6.3 Results

6.3.1 Epidemiological results

InterCSF_v3 was used to perform 100 replications of each scenario. All replications began with the same infected multiplier farm in an area with the highest pig density in the Netherlands (see figure 6.1), but thereafter the epidemics developed differently because of the stochastic nature of the model.

When comparing the base scenario with Alternatives 1, 2 and 3, assuming the base HRP, we find no difference in the size and/or the length of the simulated epidemics. Insemination prohibition, abortion and/or the killing of young piglets thus have no influence on disease spread.

6.3.2 Economic results

6.3.2.1 General

To summarise the economic results according to size of epidemic all replications are ranked according to length of the epidemic in the base scenario. The averages of the three replications centred on the 5th, 50th and 95th percentile represent "small", "medium" and "large" epidemics respectively. The mean of the last 5 ranked replications represents the "worst case" epidemic. Since the epidemiological outcomes are exactly the same for all four scenarios, so too are the rankings of the replications.

Figure 6.1 Pig and pig farm density in the Netherlands in an area with a radius of 10 km around each pig farm, whereby the arrow points at the index farm.

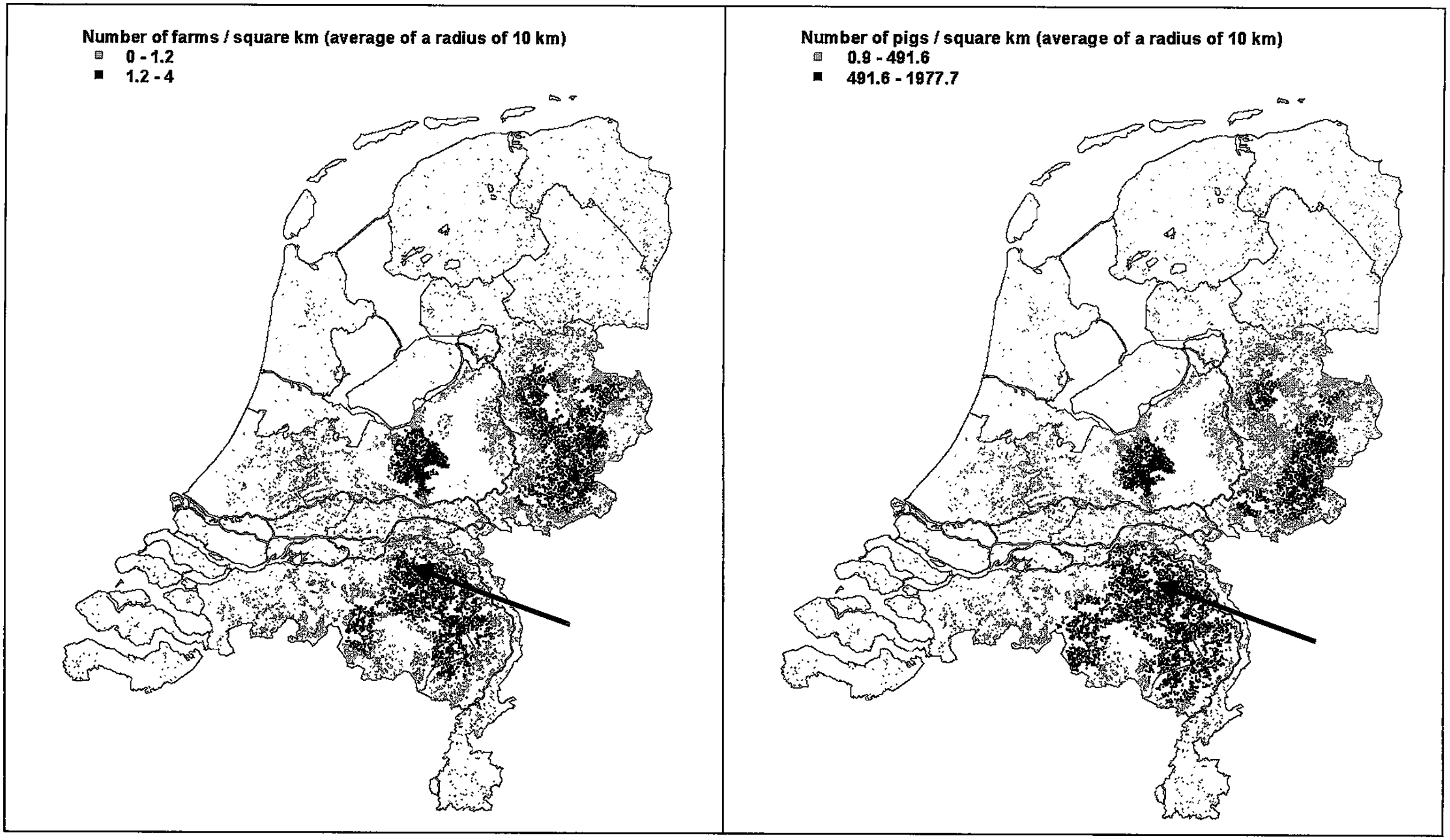

Table 6.1 summarises the economic welfare effects for the different stakeholders (pig producers, consumers[3] and public funds) and the net economic welfare effect for the Dutch economy, relative to a non-epidemic situation. These effects are calculated for a low and a high pig price year. Although there are some small differences in the different economic welfare effects between a low and a high pig price year the general conclusion is the same. Therefore, only the results for the low pig price year are shown.

For all four scenarios (PS strategy, Alternative 1, 2 and 3) we observe that in general the reduction in national supply is not matched by a fall in total demand. Therefore, pig prices outside quarantine zones rise. Hence, as found in Chapter 4, consumers lose and producers gain collectively, although the overall gain to pig producers hides the fact that producers inside quarantine zones lose. Moreover, pig producers inside a quarantine zone are not a homogeneous group, being either piglet, hog or breeding stock producers. If piglet producers are not destocked, they may continue in production and sell their ready-to-deliver piglets for welfare slaughter. In this case, they may gain as well. Piglet farms that are destocked because of control measures receive no compensation for their idle capacity. However, when production on piglet farms is interrupted because of measures to reduce livestock numbers for welfare reasons, we assume that they receive compensation to cover part of their losses. For specialised fattening farms (hog producers), welfare slaughter leads to empty stables after approximately 4 months under quarantine restrictions. Idle capacity; whether due to depopulation after detection, preventive slaughter or welfare slaughter may cost some pig farmers their business.

6.3.2.2 Piglet supply disruption

All three supplementary measures were lifted at the same moment as the quarantine zone. Depopulated infected and preventively slaughtered farms were assumed to restock gradually after the lifting of the quarantine zones regardless of the scenario simulated. However, piglet farms where production was interrupted by measures under Alternatives 1, 2 or 3 need some additional time after the lifting of the quarantine zone before being able to supply the market again with growers. Hence, larger welfare changes for producers and consumers result due to a longer-lasting disruption of the piglet supply. Alternative 3 (killing of young piglets) showed the smallest decrease in net economic welfare and the least additional time before normal supply was restored. After the end of the epidemic Alternative 1 needed the most additional time before supply was normalised.

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[3] Under consumer we group slaughterhouses/processing industry; retailers and final consumers.

Table 6.1 Changes (in million Euro) in producer surplus (PS), consumer surplus (CS), Dutch public funds and the net welfare of small, medium, large and worst case epidemics (ranked according to the length of the epidemic) for four scenarios, assuming a trade ban imposed on the quarantine zones only and a low pig price year.

Scenario	PS-strategy (Base)				Alternative 1				Alternative 2				Alternative 3			
Epidemic size	small	med.	large	worst	small	med.	large	worst	small	med.	large	worst	small	med.	large	worst
- Low pig price year																
Welfare change in PS	79	169	261	313	99	224	322	374	87	203	320	374	91	196	283	339
Welfare change in CS	-45	-102	-171	-203	-62	-175	-312	-362	-45	-136	-270	-318	-62	-145	-237	-274
Dutch public funds	-25	-61	-102	-125	-30	-74	-117	-139	-27	-67	-112	-135	-28	-68	-111	-133
Net welfare effect	9	6	-12	-15	6	-24	-108	-127	14	-1	-62	-79	1	-16	-65	-68

6.3.2.3 *Direct costs*

Table 6.1 shows the Dutch share of the programme expenditure, which was equal to 50 % of the total programme costs. Total expenditure increases with the size of the epidemic. Compensation payments for welfare slaughter schemes are always the largest share of all costs. These payments are highly related to the length of the epidemic and the number of farms in quarantine zones. With the use of supplementary measures to reduce piglet supply the total programme costs are higher than with the PS strategy, even for the worst-case epidemics. This is because the slight fall in compensation payments for destocked infected and preventively slaughtered farms, and in organisation costs, is outweighed by additional compensation payments for the supplementary measures for reducing piglet supply.

6.3.3 Sensitivity analyses

6.3.3.1 *Destruction capacity*

When the destruction capacity allocated to control measures is reduced by competition from welfare slaughter carcasses, we obtain larger epidemics (Table 6.2). Allowing the three supplementary measures for reducing piglet supply to increase the destruction capacity available for control measures from 4 months onwards (Capacity- low B) has an effect relative to the Capacity-low A scenario only for the worst case epidemics, but still results in larger epidemics than in the base scenario. Table 6.2 shows the mean, the 95 and the 100 percentiles for several output parameters based on 100 replications of InterCSF_v3.

Table 6.2 Effects of varying destruction capacity (farms/day) available for control measures: average effects, and effects for the simulations ranked 95 and 100 according to the corresponding epidemiological outcome. Base: week 1 = 5 farms/day; week 2 = 10 farms/day and from week 3 = 15 farms/day. Scenario A: 5 farms/day; Scenario B: week 1 – 17 = 5 farms/day and from week 17 = 10 farms/day.

Scenario	Base			Reduced destruction capacity					
				Capacity-low A			Capacity-low B		
Mean/ Percentile	mean	95%	100%	mean	95%	100%	mean	95%	100%
# Infected	46	92	244	62	95	1031	57	95	750
# Detected	29	65	150	45	70	962	39	70	619
Duration (days)	134	210	280	138	226	444	136	219	331

Figure 6.2, based on the longest epidemic from our 100 replications, illustrates that welfare slaughter can cause a huge logistic problem. The large number of pigs slaughtered in the first weeks, regardless of the scenario simulated, is greatly in excess of our calculated reduction in destruction capacity of approximately 10 farms/day. Consequently, if carcasses of pigs slaughtered due to control measures are not given priority over those arising from welfare slaughter, even larger epidemics than simulated under scenarios A and B would result.

Figure 6.2 shows that Alternative 1 begins to reduce the total number of pigs slaughtered for welfare reasons in week 10 compared with the PS strategy. But in Alternative 1 a huge number of young piglets is also killed. Even more young piglets are killed under Alternative 3 (killing of young piglets only). Alternative 2 involves no killing of young piglets, but the insemination ban plus abortion reduces the number of pigs welfare slaughtered compared to the PS strategy only from week 20-21 onwards. In all the alternative scenarios, the highest weekly incidence of welfare slaughter occurs before any of the supplementary measures for reducing piglet supply show an effect. In other words, the duration of the simulated epidemics is too short to allow any benefits from these measures.

6.3.3.2 HRP

Changing the average HRP has the predicted impacts on epidemic size and length (Table 6.3). All results show the mean, the 5th, 50th and 95th percentiles for several output parameters based on 100 replications of InterCSF_v3. Results are exactly the same for the PS-strategy as well as for Alternative 1, 2 and 3.[4]

6.3.3.3 Clinical signs

A 10 % lower probability of detection based on clinical signs throughout the epidemic results in a slightly higher average number of infected farms, 48 versus 46 (base PS strategy), and a slightly longer average epidemic, 141 versus 134. Because serological screening is used monthly on farms situated in a quarantine zone, the reduced clinical detection rate is probably covered by detection based on serology.

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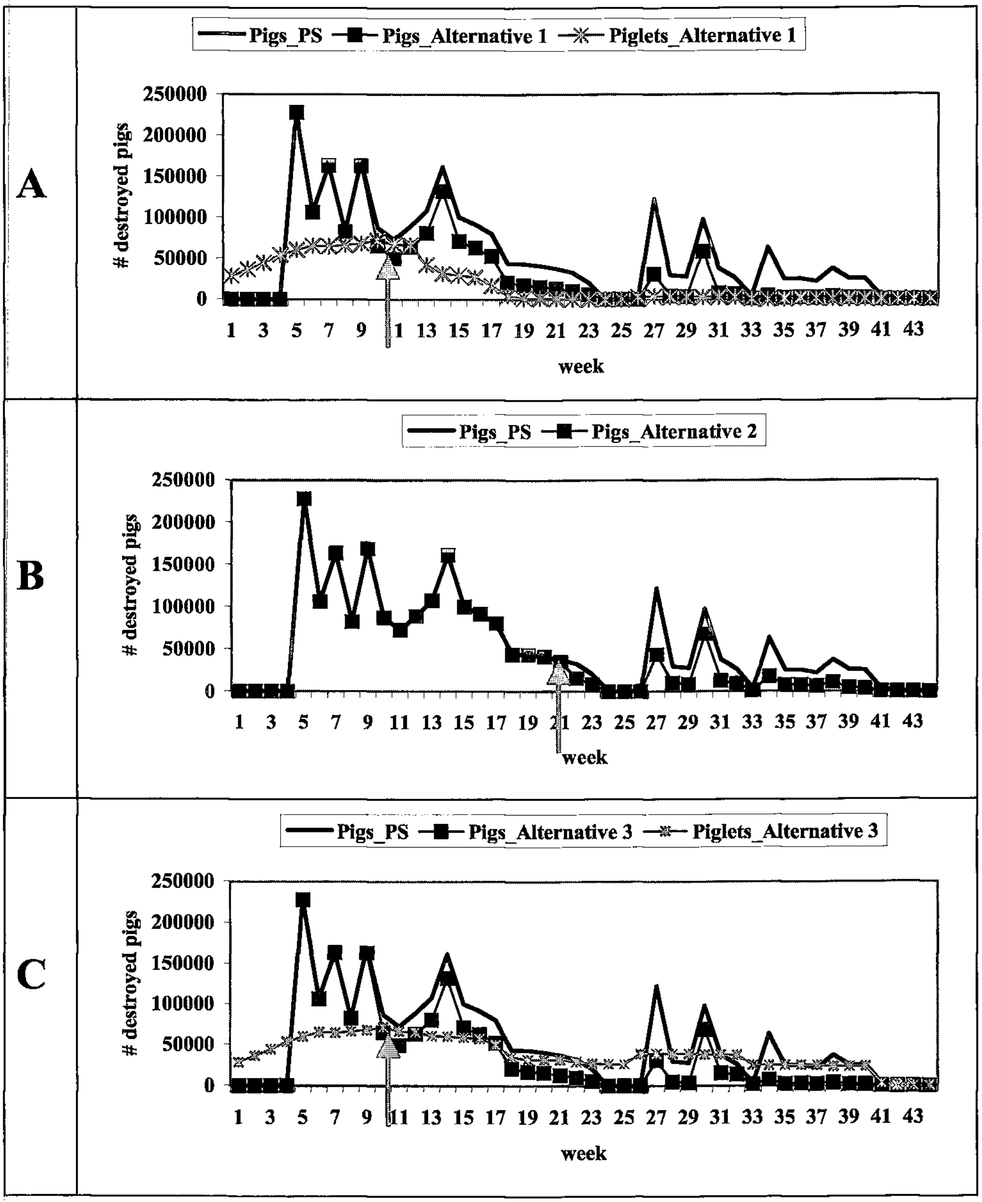
[4] When we forced the model to simulate really large epidemics (for example, by increasing transmission probabilities by a factor of 1.5), we found a slight impact of the supplementary measures for the largest replications only. The effect was a slightly smaller epidemic. Alternatives 1 and 3 had a slightly larger impact than Alternative 2.

Figure 6.2 Number of pigs and of young piglets welfare-slaughtered and rendered per week for the longest epidemic of the base scenario. The arrow indicates the first week in which the number of welfare slaughter pigs is lower with the Alternative than with the PS strategy. Panel A: PS strategy versus Alternative 1; B: PS strategy versus Alternative 2; C: PS strategy versus Alternative 3.



6.3.3.4 Detected cases as a prediction for epidemic length?

Results are exactly similar for the PS strategy as well as for Alternative 1, 2 and 3, therefore we show only results for the PS strategy. For the scenario with the base HRP we find a significant positive correlation between the two criteria and the length (in days) of an epidemic, with the number of detected cases after 6 weeks having a higher correlation coefficient (0.54) than the number of detected cases within 1 week (0.45). A higher positive correlation (0.72 and 0.89) is found between the two criteria and the size of an epidemic measured in terms of the number of detected farms. Table 6.4 shows that the overall probability at least 5 cases in the first week is 0.37. This probability is, however, 0.7 for the 10 largest epidemics and 1 for the 5 largest epidemics. For a long HRP, these indicators are less decisive. When a short HRP is assumed, none of the replications reach these thresholds.

6.4 Discussion

6.4.1 Epidemiological effects

Adult pigs show less clear clinical signs than young pigs (Depner et al., 1996). If measures are used to interrupt the flow of piglets, the number of young piglets on the farm will decrease and therewith the probability of clinical detection. And yet, assuming a lower probability of clinical detection for the whole epidemic led to only a slight increase in the number of infected farms and in the length of the epidemic. Moreover, these measures decrease the number of young animals only over time, so clinical detection remains high at the beginning of the epidemic. Combined with the monthly serological screening, we conclude that these strategies do not seriously hamper the detection of infected farms.

6.4.2 Economic effects

The use of one, two or all three supplementary measures had a more negative economic impact on the Dutch pig sector than the PS strategy alone. All measures raised the number of piglet producers out of production for a longer period and caused a longer disruption of the Dutch piglet supply beyond the end of the epidemic. Our assumption of gradual restocking and re-insemination probably results in an underestimation of the likely piglet supply disruption. Furthermore, at the end of an epidemic the restrictions are lifted from a huge number of farms (figure 6.3), which together may have a significant market effect, resulting in a long-lasting cycle of market disruption. However, with the framework used here, we are not able to reproduce such long-lasting market disruption effects.

Table 6.3 Effects of varying the length of the HRP, given the PS strategy: average effects, and effects for the simulations ranked 5, 50 and 95 according to the corresponding epidemiological outcome.

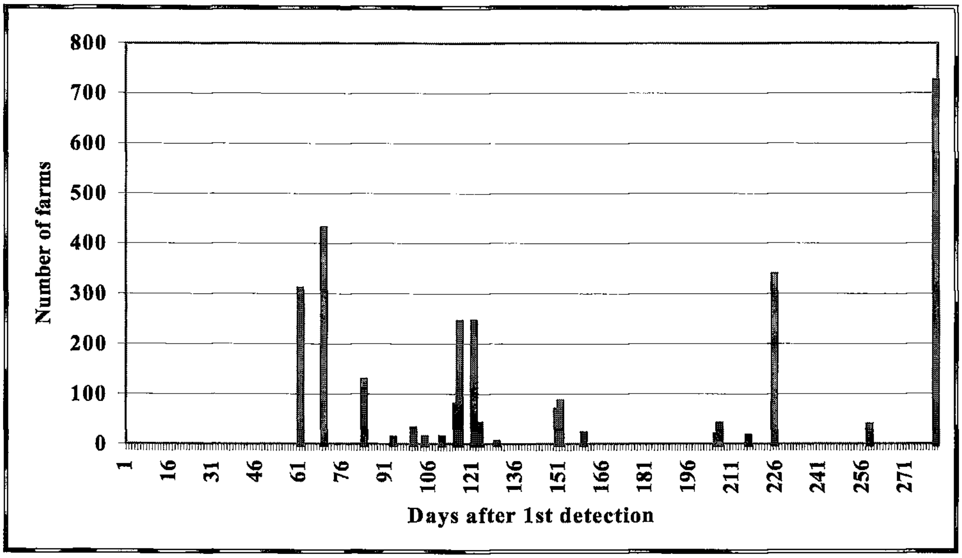
Scenario	Base HRP				Shorter HRP				Longer HRP			
Mean/Percentile	Mean	5%	50%	95%	Mean	5%	50%	95%	Mean	5%	50%	95%
# Infected farms	46	9	38	92	22	2	18	53	83	25	68	192
# Detected farms	29	4	25	65	13	1	11	32	56	14	46	142
# Preventive slaughtered	136	40	113	281	72	27	58	154	246	80	203	575
Duration (days)	134	65	127	210	109	50	104	176	145	93	138	213

Table 6.4 Number of replications for HRP-base and HRP-long, given the PS strategy, that meet various thresholds regarding number of detected farms 1 week and 6 weeks after the first detection.

Scenario	Base HRP				Long HRP					
Criterion	After 1 week		After 6 weeks		After 1 week			After 6 weeks		
Threshold	≥ 5	≥ 10	≥ 40	≥ 50	≥ 5	≥ 10	≥ 15	≥ 40	≥ 50	≥ 60
1-25 ranked replications	3	0	0	0	16	7	0	4	2	0
26-50 ranked replications	7	0	0	0	22	9	2	9	6	2
51-75 ranked replications	13	2	2	0	22	13	6	14	9	6
76-100 ranked replications	14	5	5	2	20	15	8	14	10	6
Total	37	7	7	2	80	44	16	41	27	14
10 largest replications	7	3	3	1	8	6	5	6	5	2
5 largest replications	5	2	2	0	4	2	1	2	1	1

All three measures are intended to stop the supply of growers during the epidemic and as such also the supply of hogs. However, this effect shows up only late in time and hence can be of no, or only minor importance, in reducing the number of welfare slaughtered healthy pigs. Thus, the compensation payments for regular welfare measures are hardly reduced. These compensation payments comprise the biggest share of public expenditure occasioned by the epidemic. The extra compensation paid for very young piglets killed and/or for sows under an insemination ban or aborted just increase total compensation paid. Thus, using these supplementary measures increases the total programme costs of an epidemic.

Figure 6.3 Number of farms per day becoming free of restrictions (longest simulated epidemic).



6.4.3 Welfare slaughter and limited destruction capacities

Logistic and ethical reasons may favour the combined insemination ban and the abortion of sows, since it avoids later killing of piglets or hogs. In contrast, killing young piglets will not reduce the number of animals killed but will reduce only the total tonnage of killed pigs. However, this measure does not disrupt the sow herd management. Therefore, the killing of young piglets, as favoured by farmers, may solve some logistic problems as well as later animal welfare problems, although it may raise ethical objections.

However, a lower piglet supply inside quarantine zones due to the use of these supplementary measures shows up at the earliest 2-3 months after adoption. The often acute shortage of destruction capacity at the beginning of an epidemic, due to competition for rendering between carcasses slaughtered due to control measures and those due to welfare slaughter schemes, will not be solved by using such additional measures. Therefore, other options are needed to solve the capacity problem. Designation of specific slaughterhouses inside quarantine zones for welfare slaughter and storage of welfare slaughtered carcasses until rendering capacity is available, from the beginning of an epidemic, is probably the best option for overcoming a shortage in destruction capacity exacerbated by welfare slaughter. On-farm killing capacity and rendering capacity would then be reserved in priority for destruction due to control measures. In the Dutch CSF epidemic, specific slaughterhouses were designated for welfare slaughter but as welfare slaughtered pigs were rendered simultaneously with slaughtered pigs due to control measures, rendering capacity was insufficient. Only later during the epidemic was the problem partly solved by storing the welfare slaughtered carcasses in cold stores (Pluimers, et al., 1999).

Other options that might reduce the number of pigs slaughtered and rendered under the welfare slaughter option are: a smaller radius for quarantine zones, a shorter quarantine zone period, or, as applied first in Belgium in the 1994 CSF epidemic (Vanthemsche, 1995), controlled slaughter of pigs in the 3-10 km zone for market outlets. Controlled slaughter means slaughtering in designated slaughterhouses where the meat is marked and can be sold afterwards as fresh meat inside the EU. The first two options may be risky as they could favour the spread of the disease, especially as long as the epidemic is not under control. However, the commercialisation as fresh meat of meat from controlled slaughter, assuming strict sanitary controls, involves only minimum risk as the probability that an infected farm will not be detected is rather small. Although this option requires some complicated logistics, it would reduce the number of carcasses to be rendered as well as compensation expenditure. Furthermore, it may reduce the short-run market disruption due to imposition of quarantine zones, since fewer pigs will be taken out of the market.

6.4.4 Timing of the implementation decision

This study supports our hypothesis that additional measures should only be implemented when an extremely large epidemic is expected. In Chapter 5 we showed that the pig density around the first detected outbreaks is a good indicator of whether a large epidemic might be expected (figure 6.1). In this study, where all outbreaks begin in a high density area, we found a positive correlation between the number of detected farms in the early weeks and epidemic size. The more cases detected in the first 6 weeks, the more likely the epidemic is to be large. Besides pig density and number of early detections, other indicators are needed to give a better forecast of epidemic size. The length of the HRP could be a good indicator. Certain indicators may be more reliable than others for predicting a particular dimension of epidemic "size".

6.5 Conclusions

The use of an insemination ban, the abortion of sows and the killing of very young piglets had no impact on the size and the length of the epidemic. Whether pig prices were high or low, these measures resulted in higher direct costs and greater disruption to piglet supply on farms after the lifting of all restrictions. However, ethical and logistic reasons may favour some of the measures. Our study gives an indication of the overall cost to society of these measures, so that decision-makers can weigh these costs against public acceptance. In any case, an insemination ban is recommended for ethical reasons in the case of an emergency vaccination campaign when all vaccinated herds have to be ultimately slaughtered and rendered (Chapter 2).

Our study indicates that, on economic grounds, these additional measures should be used only when an extremely large epidemic is expected, and they should also be implemented from the very start of the epidemic. Future research is needed to help find indicators of the expected size of an epidemic at a very early stage.

Finally, our study shows that control measures (stamping-out infected herds and preventively slaughtering neighbouring farms) should have a priority claim on destruction capacity. Decision-makers should be aware of the need for alternative solutions to dispose of animals that are killed and rendered for welfare reasons.

Acknowledgement

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Chapter 7

General discussion

7.1 Introduction

This final chapter is devoted to a general discussion of the results obtained in this thesis and the methods used. The objectives of the thesis were: 1) to further develop an available epidemiological model that simulates the spread of the virus between farms and permits a comparison of control measures of interest; 2) to develop an economic model that calculates not only the direct control costs of the animal health authorities but also the indirect costs for Dutch society as a whole, whereby different market scenarios are considered; and 3) with the help of these models, to analyse possible control strategies that might be applied in an epidemic and to give recommendations, on epidemiological and economic grounds, on which control strategies to apply in future epidemics. Objective 3 was the most important part of this study, whereas the development of an epidemiological and an economical framework was necessary in order to be able to fulfil this purpose. This chapter, therefore, discusses the results reported in previous chapters in relation to policy-making for the control of classical swine fever (CSF) epidemics (hereafter referred to as "policy-making"), section 7.2. In section 7.3 the applied modelling framework and its main restraints are briefly discussed. Finally, the main conclusions of this thesis are summarised in section 7.4.

The current EU policy to eradicate CSF virus from its territory was taken as standard situation. In this thesis various measures to control CSF epidemics were analysed, whereby eradication was the main goal. Ethical and animal welfare reasons were not considered as it was and is nearly impossible to impute a monetary or other measurable value due to different moral judgements concerning ethical and animal welfare problems. Therefore, only the epidemiological and economic aspects of various control measures were analysed. The Dutch contingency plan for future CSF epidemics foresees the use of additional preventive slaughter from the very beginning (RVV, 2000). Therefore, when comparing the various control strategies in this thesis, additional preventive slaughter was always considered as part of the base control strategy.

7.2 Discussion of results with special attention to policy making

7.2.1 Economic considerations

Results of Chapters 4 and 5 allowed the conclusion that as long as trade continued from non-quarantine zones[1] Dutch producers collectively gained from the epidemic. This result was

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[1] By a "quarantine zone", we understand the protection zone (0-3 km) plus the surveillance zone (3-10 km), since movement restrictions are installed inside those zones

independent of the size of the epidemic. It occurred because producers outside quarantine zones benefited from the higher prices caused by lower supply, and because the loss of some producers inside a quarantine zone was moderated by compensation payments for welfare slaughter. With a trade ban on live pigs and no increase in exports of pig meat, market price was weaker and so the gain of non-quarantined producers no longer outweighed the losses of other producers; collectively, producers lost. However, the total producer loss in this situation was inversely related to the size of the epidemic: the larger the epidemic, the greater the shortfall in marketable supply and hence the smaller the downward pressure on market price.

Policy makers should always be aware of the welfare changes of all stakeholders involved when making a decision. In this study, the welfare changes for producers were generally found to be in the opposite direction to the welfare changes for consumers (slaughterhouses / processing industry, retailer and final consumer). Furthermore, the size of welfare changes depends partly on when the epidemic occurs in relation to the pig cycle. At the top of the pig cycle, when prices are high, welfare losses are more pronounced. This can be seen by comparing the welfare effects reported in Chapter 4 (measured against a non-epidemic scenario with high pig prices, as anticipated for 1997-98) and those given in Chapter 5, which are measured against a non-epidemic scenario with low (1999) prices. The smaller welfare changes for all stakeholders calculated in Chapter 5 are also due to the smaller size of the simulated epidemics, which is mainly due to the newly incorporated contact matrix.

Compensation payments for animal welfare slaughter schemes formed the major share of the total programme costs, and vaccination costs, if applied, were only marginal. It is worth noting that without the assumption of a significant contribution from the EU budget (50% or more), the net welfare losses for the Netherlands would have been much greater. Furthermore we assumed for simplification that the Dutch public funds came entirely from Dutch taxpayers, whereas in reality the Dutch pig sector was and is partly involved in financing control costs. In the 1997/1998 Dutch CSF epidemic (hereafter referred as the Dutch CSF epidemic) the contribution by the sector was only marginal in comparison to the total animal health expenditures for controlling the epidemic. However, in future epidemics the sector's contribution will be larger (Meuwissen et al., 2002). As a consequence, the animal health expenditures, which were now considered to come entirely from Dutch public funds, will have to be partly considered as a change in economic welfare of producers. Nevertheless, the net economic welfare effect will stay the same.

7.2.2 Geographic based control strategies

The main conclusion from Chapter 5 was that policy decisions should always be based on geographic areas that were defined with respect to pig and/or pig farm density. Berentsen et al. (1990), Garner et al. (1995b) and Mahul and Durand (2000), found similar conclusions for the case of foot-and-mouth disease (FMD) epidemics. As long as a CSF epidemic remained located in a sparsely populated livestock[2] area (SPLA) stamping-out infected herds combined with quarantine zones (EU-strategy) was sufficient to control and eradicate the epidemic and was also economically feasible (Chapter 5). In a densely populated livestock area (DPLA), however, additional control measures were necessary and economically feasible. This is similar to the findings of Mahul and Durand (2000), who found that the implementation of emergency vaccination in a region with a high livestock density might be optimal in the case of an FMD epidemic. Such additional control measures reduced the number of susceptible herds, resulting in smaller epidemics in both size and length (Chapters 2 and 5).

7.2.3 Additional control measures

Emergency vaccination and/or preventive slaughter (PS-strategy) in the neighbourhood of an infected farm were such additional control measures. Two emergency vaccination strategies were simulated, the delayed destruction strategy (DD), whereby all pigs on vaccinated farms will be destroyed but later in time, and the intra-community trade strategy (ICT), which assumes intra-community trade of vaccinated pig meat. Both simulated emergency vaccination strategies were at least as effective as the PS-strategy (Chapters 2 and 5), assuming a reliable diagnostic test and no relaxation of other control measures. The largest simulated epidemics for both emergency vaccination strategies were not as large as the largest simulated epidemics under the PS-strategy. However, the large number of preventively slaughtered farms in the DD-strategy was a negative aspect of the DD-strategy compared to the PS-strategy. In the ICT-strategy on the other hand, no farms were preventively slaughtered. ICT avoided the destruction (slaughtering and rendering) of a large number of healthy pigs. In addition, ICT would avoid also some ethical and animal welfare objections. Nevertheless, political factors, third countries' reactions and public opinion might change policy-makers' preferences.

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[2] In the case of CSF, only one livestock species is considered, namely pigs

7.2.4 Supplementary measures to reduce later animal welfare problems

An insemination prohibition, forced abortion of sows and/or the killing of very young piglets, used as supplementary measures to reduce later animal welfare problems (hereafter referred as supplementary animal welfare measures) in combination with the PS-strategy, had no impact on the size and the length of the epidemic (Chapter 6). Moreover, the effects of such supplementary animal welfare measures showed up only far behind the simulated epidemics, resulting in a longer lasting and larger disruption of the piglet supply after the end of the epidemic. Consequently, their use was economically irrational, although political and ethical reasons might still favour such measures. Only in the case of an extremely large epidemic and when supplementary measures are adopted from the very beginning, may some economic effect be expected.

Additionally, the use of supplementary animal welfare measures did not reduce the number of pigs slaughtered and destroyed via animal welfare slaughter schemes in the beginning of an epidemic, although, this was one of the arguments for their use (Pluimers et al., 1999). The effects of such supplementary measures showed up too late in time, and as such did not help to overcome a potential shortage in rendering capacities at the start of the epidemic.

7.2.5 Destruction capacities and animal welfare slaughter

Results of Chapter 6 showed that the available rendering capacities should be reserved for pig carcasses of infected premises and preventively slaughtered farms. A shortage in killing and rendering capacities triggered by the simultaneous destruction of a large number of "healthy" pigs for animal welfare reasons should be avoided. Those pigs should be slaughtered elsewhere, for example in specifically defined slaughterhouses, and after slaughter they might be stored and later rendered.

Additionally, ethical, animal welfare and public acceptance as well as economic reasons require new solutions in order to decrease the number of slaughtered and destroyed healthy pigs for animal welfare reasons. Options that might reduce the number of slaughtered and rendered pigs are a reduction in the quarantine zone radius or a shortening of the time period over which restrictions are imposed. However, these two options are risky as they may favour the spread of the disease, whereas the commercialisation of meat from controlled slaughter as fresh meat on the community market (Vanthemsche, 1995), assuming strict conditions of sanitary control measures, involves only a minimum risk. Serological screening and surveillance applied before slaughter should reduce the probability of slaughter from an infected but not yet detected farm. Besides, infected but undetected pig meat could lead to infection of other pigs only if fed to pigs via swill. Controlled slaughter presumes some heavy logistic requirements but on the other hand would reduce the number of pigs rendered as well as the animal health authority expenditure (fewer compensation payments). Furthermore, it may weaken the market disruption, as a smaller number of pigs will be taken out of the market. More research is needed here to gain better insight into 1) the risk of spreading the disease by the measures listed here and 2) the economic effects of such measures.

7.2.6 When to implement stricter measures?

Especially in densely populated pig areas, a good forecast of the epidemic size at the beginning of an epidemic would help policy makers to chose the most accurate and appropriate control measures. If necessary, the addition of control measures, such as emergency vaccination and preventive slaughter, or even the use of supplementary animal welfare measures should be implemented right from the very beginning of an epidemic. Mahul and Durand (2000) also found that the earlier additional "emergency vaccination" was applied in the case of an FMD epidemic in Brittany, the less expensive this strategy was predicted to be. Consequently, a continued tendency towards stricter control measures during the on-going epidemic could be avoided, leading to more clearly defined management tasks and less confusion between the different partners involved in the control. Quick and adequately applied control measures might help to convince farmers, traders, slaughterhouses and other partners to co-operate and thereby to reduce frauds. In contrast, less strict control measures at the end of an epidemic might allow farmers to restock gradually before the last restrictions are lifted, possibly resulting in fewer market disruptions. Results of Chapter 5 show that the pig density around the first detected outbreak was a good indicator of whether a large epidemic might be expected. In Chapter 6, a positive correlation between the number of detected farms in the early weeks and the epidemic size was found. Another indicator could be the estimated length of the high-risk period (Chapter 6). Certain indicators may be more reliable than others. Therefore more research is needed 1) to predict at the very beginning of an epidemic the possible size; and 2) to forecast the future course and the possible end of the on-going epidemic.

7.2.7 Financial appraisal or economic welfare analysis?

In Chapter 2 we applied a financial analysis, similar to those of Meuwissen et al. (1999) and Nielen et al. (1999). This financial analysis included only direct control costs and consequential losses of farmers and related industries within quarantine zones, but ignored losses further down the chain. Moreover, no trade reactions were considered. On the other hand, the economic welfare analysis performed in Chapters 4, 5 and 6 considered all the main stakeholders involved in the Netherlands, and involved simulating different possible trade scenarios. By comparing results of Chapter 2 and Chapter 5, we demonstrate for the PS, the DD and the ICT-strategies the shortcomings of such a financial appraisal. From Chapter 2 it was concluded that the ICT-strategy was economically the most attractive in a DPLA. However, a total trade ban on live pigs might be a possible consequence when applying an emergency vaccination strategy. Without any economic analysis of such a possible trade restriction and without a consideration of all stakeholders affected, the possible consequences for society as a whole will remain only best guesses. Therefore, in the economic welfare analysis in Chapter 5, we simulated two trade scenarios: a partial trade ban imposed only on quarantine zones; and a national export ban on live pigs. Only with a partial trade ban imposed on quarantine zones was the ICT-strategy economically the most attractive in a DPLA, similar to Chapter 2. However, the current political and public acceptance of this strategy raises the risk of a total export ban on live pigs, resulting in much larger negative net welfare effects for the Dutch economy (Chapter 5). As a consequence, all control measures that lead to a total export ban of all live Dutch pigs should be avoided. From Chapter 5 we therefore concluded that as long as political and public acceptance of vaccination are questionable, the risk of an export ban on live pigs would favour preventive slaughter (PS-strategy).

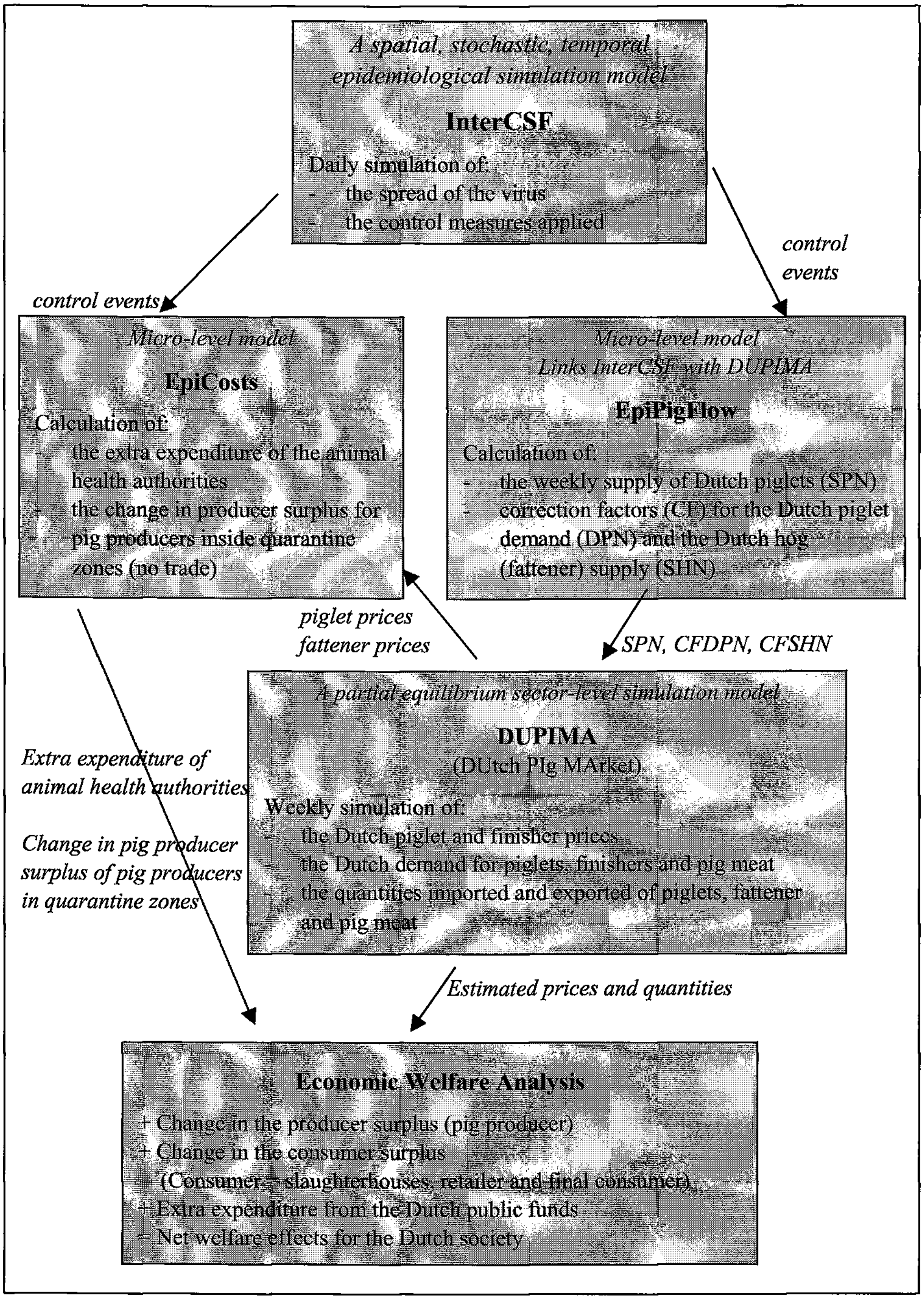
Thus, simulating different trade scenarios and considering the welfare changes of all affected stakeholders, economic welfare analysis allowed us to make recommendations that were based on economic as well as on epidemiological grounds. Showing separately the net welfare effects for the whole national economy, as well as the welfare effects for each individual stakeholder (producers, consumers and the public funds) provided detailed information upon which policy makers can base their own value judgement.

7.3 The applied models

7.3.1 General

The modelling framework comprises a spatial, dynamic, stochastic, epidemiological model, as well as an economic framework, including a partial equilibrium market and trade simulation model. Figure 7.1 gives an overview of the overall framework (as was also done in Chapter 4).

Figure 7.1 The modelling framework



A spatial, stochastic, temporal epidemiological simulation model

InterCSF

Daily simulation of:
- the spread of the virus
- the control measures applied

Micro-level model

EpiCosts

Calculation of:
- the extra expenditure of the animal health authorities
- the change in producer surplus for pig producers inside quarantine zones (no trade)

Micro-level model
Links InterCSF with DUPIMA

EpiPigFlow

Calculation of:
- the weekly supply of Dutch piglets (SPN)
- correction factors (CF) for the Dutch piglet demand (DPN) and the Dutch hog (fattener) supply (SHN)

A partial equilibrium sector-level simulation model

DUPIMA
(DUtch PIg MArket)

Weekly simulation of:
- the Dutch piglet and finisher prices
- the Dutch demand for piglets, finishers and pig meat
- the quantities imported and exported of piglets, fattener and pig meat

Economic Welfare Analysis

\+ Change in the producer surplus (pig producer)
\+ Change in the consumer surplus
\+ (Consumer = slaughterhouses, retailer and final consumer)
\+ Extra expenditure from the Dutch public funds
= Net welfare effects for the Dutch society

The modelling framework presented here can be a useful tool for the Dutch policy makers. This modelling framework could help them to prepare during CSF-free times for "war" (epidemic) times. During an epidemic, the modelling framework might also be used for advice. Yet the actual version, which consists of 5 individual parts, is not very user-friendly and is also time demanding. However, the modelling framework could help policy makers: 1) to gain better insight into the development of possible CSF epidemics; 2) to gain better insight into the direct and indirect costs, including the possible net welfare effect for the whole Dutch economy, depending on the trade restrictions imposed; 3) to draw up geographically dependent contingency plans.

7.3.2 Epidemiological model

The aim of the epidemiological model was to simulate the spread of the virus between farms and to compare the epidemiological effects of the different control measures. A further requirement was to model spatial heterogeneity, allowing us to model control measures with effects on specific herds in a population.

InterCSF, a spatial, stochastic, dynamic simulation model that was developed by Jalvingh et al. (1999), seemed to fulfil the desired requirements. However, the modelling aim of InterCSF was to simulate the specific Dutch CSF epidemic. To get a more generic epidemiological model, InterCSF was adapted. The adaptations to InterCSF_v3 were described in Chapter 5. Consulting literature and asking people from the field was a first step of model validation, according to Law and Kelton (1991). After verification of the newly incorporated mechanisms, InterCSF_v3 had to be validated anew as well as calibrated (Chapter 5). However, the simulated output could not be compared with real data as there was only one recent epidemic in the Netherlands. Therefore, sensitivity analysis was performed. According to Law and Kelton (1991) sensitivity analysis is one of the most useful tools of validation. Sensitivity analysis was applied, before and after calibration, to the different input parameters by increasing and/or decreasing their values. The impact of the different parameter changes was rather small except for the parameters describing contact and local spread transmission. When calibrating, the calibration goal could only be obtained by doubling the recently estimated transmission probabilities of Stegeman et al. (2002), without any further manipulation of the other input parameters. Therefore, the transmission probabilities were the most uncertain point in the whole validation process of this simulation model and more research is needed here. Furthermore, the frequency of routine non-epidemic movement contacts also had a large impact on the simulated epidemics (Chapter 5). Reducing the frequency of routine non-epidemic movement contacts also decreased the simulated epidemics in size and length. However, forcing farmers to reduce their routine non-epidemic contacts will constrain farmers in their entrepreneurial independence.

Spatial, stochastic and dynamic simulation models, such as InterCSF_v3, are suitable for simulating other diseases. Similar models were developed, for example, to simulate FMD epidemics (Morris et al., 2001; Mourits et al., 2002) and bovine herpesvirus type I epidemics (Vonk Noordegraaf et al. (2000)). Alternatives to our spatial, stochastic and dynamic simulation model are mathematical models and state-transition simulation models. The state-transition simulation model approach was used by e.g. Berentsen et al. (1992) on FMD without stochastic elements, whereas implementing stochastic elements in the state-transition models, Durand and Mahul (2000) simulated FMD epidemics, and Garner and Lack (1995a) simulated FMD, sheep pox and CSF. Garner and Lack (1995a) simulated only one strategy: stamping-out of infected herds and installing quarantine zones, in the case of a CSF epidemic occurring in Australia. Mathematical modelling was used by e.g. Ferguson et al. (2001) for FMD and Klinkenberg et al. (2001) for CSF. Klinkenberg et al. (2001) simulated different control strategies for a densely populated pig area. The general conclusion of Klinkenberg et al. (2001), that transmission through transport should be avoided and a sufficient number of susceptible herds should be removed, is consistent with our findings. However, mathematical models and state-transition simulation models do not consider spatial heterogeneity. Consequently, neither model approach is suitable to compare different control measures with effects on specific herd situations in a population.

7.3.3 Economic modelling framework

The second objective of this thesis was to develop an economic model to calculate the direct control costs for the animal health authorities as well as the indirect costs for Dutch society as a whole in relation to a non-epidemic situation, by considering different market scenarios.

In contrast to the epidemiological model, no model was available in our group. Financial analysis was not considered, except for Chapter 2, because this kind of analysis constitutes only partial analyses at the national level and may therefore, according to Bennett (1992), be inappropriate as a basis for national disease-control programme decisions. The shortcomings of such a financial analysis in the case of CSF policy making was already discussed in section 7.2.7. When looking at a national level, three modelling approaches are mainly of interest: general equilibrium model, partial equilibrium model and an input-output matrix. Economic welfare analysis was used, for example by Ebel et al. (1992), Miller et al. (1996) and Andersson et al. (1997). All three used a partial equilibrium based welfare analysis to analyse the social benefits of eradication programmes of diseases (Pseudorabies or Aujeszky's disease) in pigs. Buijtels and Burrell (2000), on which Dupima, a partial equilibrium sector-level simulation model, was based, used a partial equilibrium sector trade model to simulate pig producers' surplus changes in the Netherlands, assuming different trade scenarios. On the other hand, Garner and Lack (1995b) and Mahul and Gohin (1999) used an input-output matrix to analyse the indirect losses of an FMD epidemic on a national economy as a whole through the interaction between the economic sectors, simulating different trade restrictions. Buhr et al. (1993) and Crooks et al. (1994) analysed the macro-economic implications of improved animal health (no contagious diseases) using multi-sector models, in which they focused on long-run improvements.

Input-output analysis assumes fixed input-output coefficients, perfectly elastic factor supplies, and exogenously determined final demands. The main limitation of the input-output analysis is that it does not include price effects. For a partial equilibrium based welfare analysis the main limitation is that it only considers price changes in a single market (i.e. pig production chain) and does not include effects on other sectors of the economy. General equilibrium or multi-sector models analyse the economy-wide effects and the interactions between the different markets. A problem shared by all three methodologies is that they require large amounts of data. More sophisticated models, such as general equilibrium models, require much more data and time than partial equilibrium models.

In this research project we assumed that in the case of a CSF epidemic, welfare changes outside the meat production chains, if occurring, would be rather small and of minor importance. This is not the case in an FMD epidemic, where the recreation and tourist sector, for example, might be badly affected by imposed movement restrictions. On the meat production chains, however, more knowledge was needed. 1) Are there likely to be adverse consumer reactions due to a disease outbreak? 2) Which market(s), i.e. meat production chain(s), will be affected and are there important spillovers onto other markets? This was essential knowledge for us as model builders but it is also important for policy makers before taking any decision. Results of Chapter 3 showed that there was no adverse consumer reaction due to the Dutch CSF epidemic. Further, no significant substitution between pork and other meat was found, allowing the consideration of the pig market only. In addition, during the Dutch CSF epidemic large pig price fluctuations were observed in a short-run period. Therefore, an economic welfare analysis seemed to be the appropriate method to use, using a sector-level partial framework.

The estimation of the behavioural equations for Dupima, the verification, validation and calibration of Dupima were described in full detail in Chapter 4, as well as the assumptions made on the different stakeholders involved for the economic welfare analysis. Nevertheless, there are three important assumptions, which fit in this Chapter: the Dutch public funds (section 7.2.1), restocking of depopulated farms and the non-Dutch stakeholders.

A gradual restocking of empty farms was the main assumption made about the aftermath of our epidemics. This assumption may be unrealistic. Small fattening pig producers in particular tend to restock their fattening farms all at once (all-in all-out system), although larger farms tend to have a more continuous flow of tradable pigs. Sow farms are more limited by expensive farrowing places. Consequently, in the case of simultaneous non-gradual restocking of a huge number of empty farms after the quarantine zones were lifted, greater temporary market disruption than simulated might be expected.

In this research project we do not consider economic welfare changes outside the Netherlands. However, in the case of a CSF epidemic in the Netherlands and with only trade restrictions imposed on the Dutch pig market, the pig supply outside the Netherlands is reduced, resulting in economic welfare changes for non-Dutch pig producers and non-Dutch consumers. Moreover, a country specific decision might lead to trade restrictions also being imposed on other countries, e.g. the whole European Union (EU). For example, if regionalisation is not fully recognised world-wide, or especially if emergency vaccination has been used, a reduced health status in the Netherlands may be seen by non-European countries as a reduced health status for the whole EU. Consequently, other European pigs (mainly Danish) may also be excluded from the world-wide trade and may therefore be mainly sold only within the intra-European market. If these changes on the European pig market were also to have an important spillover effect on the Dutch pig market, pig prices would be lower than predicted by our model. Therefore, in the field of contagious animal diseases, future economic analyses might need to focus also, in addition to the country concerned, on a supra-national level, such as the EU.

Nevertheless, the economic modelling framework described here is a useful tool for an economic evaluation of a CSF epidemic and might also be used for other contagious diseases, assuming a short-run effect and that only one market would be affected. In the case of more markets being affected, such as for FMD, the partial sector approach might be too simplified and other economic modelling approaches might be more appropriate

7.4 Main conclusions of this thesis in brief

- Ignoring the economic welfare changes of consumers, which are usually in the opposite direction to the economic welfare changes of producers, might be misleading. Therefore indirect costs of all stakeholders should be considered when policy decisions to control a contagious disease are taken.
- If trade continues from non-quarantine zones during a CSF epidemic, producers collectively gain and consumers collectively lose. Where there is a trade ban on live pigs and no increase in exports of pig meat, market price is weaker and so the gain of non-quarantined producers no longer outweighs the losses of other producers; collectively, producers lose and consumers gain.
- All control measures that lead to a total export ban of live Dutch pigs should be avoided. Therefore, as long as vaccination is not officially accepted in the market, the PS-strategy is economically the most rational if a CSF epidemic occurs in a DPLA whereas the EU-strategy remains appropriate in an SPLA.
- Policy decisions to eradicate CSF epidemics should be made according to geographical circumstances, i.e. the pig density in the infected area.
- A reduction of the regular, non-epidemic frequency and number of animal contacts between farms reduces the simulated epidemics in size and length.
- Rendering and on-farm killing capacities should be prioritised for the killing and rendering of pigs on infected premises and preventive slaughtered farms during an epidemic.
- The implementation of supplementary measures to reduce later animal welfare problems, such as insemination prohibition, forced abortion of sows, and killing of very young piglets, has no impact on the size and the length of an epidemic.
- Better knowledge of CSF transmission mechanisms is crucial for epidemiological modelling and is desired for economic modelling, to analyse and compare the effect of various control measures.
- The combination of epidemiological and economic models was and is a useful tool to give decision-makers insight into the epidemiological as well as the economic effects of the various measures for controlling a contagious disease like CSF.

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Summary

Introduction

Classical swine fever (CSF) is a viral disease of pigs. In countries where CSF is endemic, it is common practice to vaccinate pigs against the disease to avoid serious losses. However, pigs vaccinated with the conventional vaccine cannot be distinguished from infected pigs and therefore importing countries do not usually allow the import of live pigs or fresh pig products from countries that vaccinate against CSF.

In the EU, CSF has been largely eradicated from the pig population and preventive vaccination was banned in the 1990s. In the case of an epidemic, current EU policy requires stamping-out of animals on infected premises and the installation of quarantine zones (protection and surveillance zones). Trading partners may close their borders on sanitary grounds depending on the control measures used. Recent epidemics in Belgium, Germany and the Netherlands have demonstrated that these control measures might not be sufficient to eradicate the disease quickly. Therefore other approaches are required for future epidemics.

The objectives of this research are: 1) to develop a generic epidemiological model that is able to simulate spread of the virus from farm to farm and permits a comparison of control measures of interest; 2) to develop an economic model that calculates not only the direct control costs of the animal health authorities but also the indirect costs for Dutch society as a whole, whereby different market scenarios are considered; and 3) with the help of these two models, to analyse possible control strategies that might be applied in an epidemic and to give some recommendations, on epidemiological and economic grounds, about which control strategies to apply in future epidemics.

Emergency vaccination strategies

As a result of current public sector debate and requests from private industry, this study starts with an evaluation of two alternative emergency-vaccination strategies with a marker vaccine that could have been applied in the 1997/98 Dutch CSF epidemic (Chapter 2). In strategy 1, vaccination would only be applied to overcome a shortage in destruction (killing and rendering) capacities. Destruction of all pigs on vaccinated farms distinguishes this strategy from strategy 2, which assumes intra-community trade of vaccinated pig meat.

The spread of CSF between farms through local spread and 3 contact types (animal, transport and person contacts) is simulated in a modified spatial, temporal and stochastic simulation model, InterCSF. Disease spread is affected by control measures implemented through different mechanisms. Economic results are generated by a separate model that calculates the direct costs (including the vaccination costs) and consequential losses for farmers and related industries subjected to control measures.

The comparison (using epidemiological and economic results) between the different emergency-vaccination strategies with an earlier simulated preventive-slaughter strategy leads to the conclusion that both emergency-vaccination strategies are scarcely more efficient than the non-vaccination strategy for the Dutch CSF-epidemic. Vaccination strategy 2 (involving the continuation of intra-community trade) is the least costly of all three strategies.

Preferences shifts for meat and fish

Although pig production takes place in specialised units that generally do not share any fixed factors with other types of livestock production, there may be interaction between pork and other meats at consumer level. Before being able to build an economic model to calculate the direct and the indirect costs of developments in the pig sector for Dutch society as a whole, it is important to investigate whether changes in retail supply of pork will have indirect effects on demand and profitability of other meats. Hence some knowledge of Dutch consumer behaviour regarding demand for meat and fish is needed. Therefore, in Chapter 3 the preferences of Dutch consumers for meat and fish are investigated. The 1990s were marked by several crises of confidence in beef due to BSE. The empirical investigation of consumers' preferences takes account of changing tastes among meats due to BSE by using a switching almost ideal demand system. Structural changes in demand between January 1994 and May 1998 are separated out into underlying trends, irreversible preference shifts triggered by the BSE crisis of March 1996, and a 'panic' reaction against beef in the month of the crisis itself. However, no evidence is found for an adverse consumer reaction to pork due to the 1997/98 Dutch CSF epidemic in the Netherlands. Furthermore, no evidence on substitution between pork and other meat is found.

Welfare effects of controlling the 1997/98 Classical Swine Fever epidemic

In Chapter 4 the 1997/98 Dutch CSF epidemic is simulated, using a spatial, stochastic epidemiological simulation model that implements the control measures as applied in the 1997/98 Dutch CSF epidemic. Using a newly developed sector-level market and trade model, the Dutch pig market is simulated, assuming different trade scenarios. Economic welfare changes of producers and consumers, and government costs are calculated. In a medium-sized epidemic, Dutch pig producers' surplus increases by EUR 454 million without an export ban, although producers within quarantine areas lose. Consumer surplus falls by EUR 463 million. With a ban on live pig exports, pig producers' collective loss is EUR 251 million whereas consumers gain EUR 111 million. Government costs are also lower when exports are banned. The economic net welfare effects for the Dutch economy relative to a non-epidemic situation are EUR –297 million without an export ban and EUR –394 million with an export ban.

Effect of pig population density

In Chapter 5, CSF epidemic scenarios that might occur in the Netherlands are simulated, starting in different regions, using an adapted and more generic, spatial, stochastic and temporal epidemiological simulation model, InterCSF_v3. Different control measures, current EU legislation, and preventive slaughter or an emergency vaccination strategy (delayed destruction and intra-community trade) as additional control measures are considered for controlling these CSF epidemics. Dutch pig market reactions are simulated for CSF epidemic circumstances in the Netherlands using a sector-level market and trade model. For all strategies we consider two different trade scenarios: partial trade ban for the quarantine zones only or a total export ban on all Dutch live pigs. Adding up the economic welfare changes for the different stakeholders (pig producers, consumers and government) results in the economic net welfare effect for the Dutch economy.

Economic and epidemiological results suggest that current EU legislation is enough to eradicate an epidemic in a sparsely populated pig area. By contrast, additional control measures are necessary if the outbreak begins in an area with high pig population density. The economic consequences of using preventive slaughter rather than emergency vaccination as additional control measures depend strongly on the expected reactions of the trading partners. Furthermore, reducing the number of animal movements reduces the size and length of epidemics in areas with a dense pig population.

Supplementary measures to reduce piglet supply

In Chapter 6, a sector-level market model and a generic, spatial, stochastic, epidemiological simulation model are used to simulate the epidemiological and economic effects of the use of supplementary measures to reduce later animal welfare problems. Such supplementary measures are insemination prohibition, forced abortion for pregnant sows and the killing of young piglets. Adding up the economic welfare changes of the different stakeholders (pig producers, consumers and government) results in the net economic welfare effect for the Dutch economy.

Economic results reject the use of such supplementary measures. Besides, the use of these supplementary measures is no real solution to overcoming a shortage in rendering capacities.

Discussion and conclusions

Chapter 7 discusses the general insights obtained by this research project. The main focus is on the contribution of the conclusions to future policy decisions. Model assumptions and limitations are additional subjects discussed.

The main conclusions of this thesis are:

- Ignoring the economic welfare changes of consumers, which are usually in the opposite direction to the economic welfare changes of producers, might be misleading. Therefore indirect costs of all stakeholders should be considered when policy decisions to control a contagious disease are taken.
- If trade continues from non-quarantine zones during a CSF epidemic, producers collectively gain and consumers collectively lose. Where there is a trade ban on live pigs and no increase in exports of pig meat, market price is weaker and so the gain of non-quarantined producers no longer outweighs the losses of other producers; collectively, producers lose and consumers gain.
- All control measures that lead to a total export ban of live Dutch pigs should be avoided. Therefore, as long as vaccination is not officially accepted in the market, the PS-strategy is economically the most rational if a CSF epidemic occurs in a DPLA whereas the EU-strategy remains appropriate in an SPLA.
- Policy decisions to eradicate CSF epidemics should be made according to geographical circumstances, i.e. the pig density in the infected area.
- A reduction of the regular, non-epidemic frequency and number of animal contacts between farms reduces the simulated epidemics in size and length.
- Rendering and on-farm killing capacities should be prioritised for the killing and rendering of pigs on infected premises and preventive slaughtered farms during an epidemic.
- The implementation of supplementary measures to reduce later animal welfare problems, such as insemination prohibition, forced abortion of sows, and killing of very young piglets, has no impact on the size and the length of an epidemic.
- Better knowledge of CSF transmission mechanisms is crucial for epidemiological modelling and is desired for economic modelling, to analyse and compare the effect of various control measures.

- The combination of epidemiological and economic models was and is a useful tool to give decision-makers insight into the epidemiological as well as the economic effects of the various measures for controlling a contagious disease like CSF.

Samenvatting

Inleiding

Klassieke varkenspest (KVP) is een virusziekte bij varkens en wilde zwijnen. Om grote verliezen te voorkomen, worden in landen waar KVP endemisch is de varkens preventief ingeënt. Echter, met het conventionele vaccin zijn ingeënte varkens serologisch niet van besmette varkens te onderscheiden. Om die reden weigeren veel landen de invoer van varkens en varkensvlees uit landen waar tegen KVP ingeënt wordt.

Binnen de EU is KVP grotendeels uitgeroeid in de varkenspopulatie en is sinds begin negentiger jaren het preventieve enten verboden. In het geval van een KVP epidemie zijn de EU richtlijnen als volgt: het doden en vernietigen van de besmette veestapels ("stamping-out") en het instellen van quarantainegebieden (beschermingsgebied en toezichtsgebied). Handelspartners kunnen uit zootechnische overwegingen hun grenzen sluiten, afhankelijk van de besloten maatregelen. Recente KVP epidemieën in België, Duitsland en in Nederland hebben aangetoond dat deze basis EU maatregelen niet voldoende zijn om de ziekte snel uit te roeien. Daarom zou in toekomstige epidemieën een andere benadering nodig kunnen zijn.

De doelstellingen van dit promotie onderzoek waren: 1) het ontwikkelen van een generiek epidemiologisch model, dat zowel de verspreiding als de bestrijding van het virus simuleert; 2) het ontwikkelen van een economisch model dat de bestrijdingskosten berekent, maar ook de indirecte kosten voor de Nederlandse maatschappij, rekening houdend met verschillende markt scenario's; en 3) met behulp van deze twee modellen verschillende maatregelen ter bestrijding van een KVP epidemie analyseren om aan de hand daarvan aanbevelingen voor toekomstige KVP epidemieën te kunnen doen.

Noodentingsstrategieën

De publieke discussie en een aanvraag van de farmaceutische industrie maakten dat dit onderzoek begint met een evaluatie van twee noodentingsstrategieën met een marker vaccin, uitgewerkt voor de 1997/98 Nederlandse KVP epidemie (Hoofstuk 2). In de eerste strategie ("delayed destruction") wordt vaccinatie alleen toegepast om een tekort aan ruimingscapaciteit te voorkomen. Destructie van alle varkens van gevaccineerde bedrijven onderscheidt deze strategie van de tweede strategie. In de tweede strategie ("intra-community trade") wordt verondersteld dat het vlees van de geënte varkens binnen de EU gewoon verhandeld kan worden.

Met behulp van aanpassingen in een temporeel, ruimtelijk en stochastisch simulatie model, InterCSF, is de verspreiding van KVP gesimuleerd via 3 contact typen (dieren, transport en personen) en via lokale verspreiding. De verspreiding van de ziekte wordt beïnvloed door de gesimuleerde bestrijdingsmaatregelen. Economische resultaten zijn vervolgens in een apart model berekend. Dit model berekende de bestrijdingskosten (inclusief de vaccinatiekosten), maar ook de verliezen van boeren en van toeleverende en verwerkende bedrijven in het quarantainegebied.

Beide gesimuleerde strategieën zouden niet veel sneller tot het uitdoven van de Nederlandse KVP epidemie geleid hebben, vergeleken met een eerder gesimuleerde preventief ruimen strategie. Bij deze preventief ruimen strategie werden direct alle varkensbedrijven binnen een straal van één kilometer rondom elk getroffen bedrijf geruimd. De "intra-community trade-strategie" was uiteindelijk het goedkoopste alternatief.

Preferentie verschuiving voor vlees en vis

Terwijl de varkensproductie in gespecialiseerde bedrijven plaatsvindt waardoor de vaste productiefactoren bijna uitsluitend in de varkensproductie benut kunnen worden, kan er bij de consumenten wel een wisselwerking tussen varkensvlees en ander vlees bestaan. Voor het ontwikkelen van een economisch model om de directe en indirecte kosten van ontwikkelingen in de varkenssector in Nederland te berekenen was het belangrijk om effecten van veranderingen in vraag en aanbod van varkensvlees in de detailhandel te bestuderen. Kennis over het koopgedrag met betrekking tot vlees en vis van de Nederlandse consument is hiervoor noodzakelijk. In hoofdstuk 3 zijn de preferenties van de Nederlandse consumenten voor vlees en vis onderzocht. De negentiger jaren waren gekenmerkt door een aantal vertrouwenscrises in rundvlees door BSE. Met behulp van een "switching almost ideal demand" systeem zijn in empirisch onderzoek de consumenten preferenties berekend. Structurele verandering in de vraag tussen januari 1994 en mei 1998 is uitgesplitst in een trendeffect, een onomkeerbare verschuiving in preferentie veroorzaakt door de BSE crisis vanaf maart 1996 en een "paniek" reactie tegen rundvlees in de maand van de crisis. Er is geen bewijs gevonden voor een negatieve consument reactie op varkensvlees door de 1997/98 KVP epidemie in Nederland. Bovendien kon ook geen bewijs voor substitutie van varkensvlees aangetoond worden.

Welvaartseffecten van de bestrijding van de 1997/98 KVP epidemie

Met behulp van een temporeel, ruimtelijk en stochastisch simulatie model, is in hoofstuk 4 de 1997/98 Nederlandse KVP epidemie gesimuleerd, inclusief de werkelijk toegepaste maatregelen. De economische welvaartseffecten voor producenten, consumenten en de overheid zijn berekend met een nieuw simulatiemodel voor de structuur van de varkenssector, de handelsstromen en verschillende markt scenario's. In een middelgrote epidemie waarbij de varkensproducenten buiten het quarantaine gebied met productie en handel door kunnen gaan, neemt de gezamenlijke welvaart van de producenten met 454 Miljoen EURO toe, hoewel binnen de quarantaine gebieden verschillende producenten verliezen lijden. De welvaart van de consumenten daalt met 463 Miljoen EURO. In het geval dat de export van levende varkens stopt, verliezen de producenten gezamenlijk rond de 251 Miljoen EURO, terwijl de consument er globaal 111 Miljoen EURO op vooruit gaat. Ook zijn in dit geval de uitgaven voor de staatskas lager. Voor de Nederlandse samenleving als geheel bedraagt het economisch netto welvaartseffect van een KVP epidemie een verlies van 297 Miljoen EURO als enkel de handel in de quarantaine gebieden vervalt en, in het geval van een compleet export verbod voor levende dieren, een verlies van 394 Miljoen EURO.

Invloed van de varkensdichtheid

In hoofdstuk 5 worden, met behulp van een verbeterd temporeel, ruimtelijk en stochastisch epidemiologisch simulatie model, InterCSF_v3, KVP epidemieën gesimuleerd die beginnen in verschillende varkensdichte gebieden in Nederland. Diverse bestrijdingsmaatregelen, zoals de huidige EU richtlijn, de preventieve ruiming strategie en de noodentingsstrategie ("delayed destruction" en "intra-community trade") zijn hiermee gesimuleerd. De economische welvaartsveranderingen op de Nederlandse varkensmarkt zijn weer door een sector simulatiemodel in kaart gebracht. Twee verschillende marktscenarios zijn gesimuleerd: in het eerste scenario gaan bedrijven buiten het quarantaine gebied door met handel; in het tweede scenario stopt de export in levende varkens vanuit heel Nederland. De economische welvaartseffecten van de verschillende getroffen partijen (producenten, consumenten en overheid) tellen samen op tot het netto welvaartseffect voor de Nederlandse samenleving.

Economische en epidemiologische resultaten suggereren dat de huidige EU richtlijn voldoende is om een KVP epidemie in een gebied met weinig varkensbedrijven uit te roeien. In een varkensdicht gebied zijn er zeker additionele maatregelen nodig. De rentabiliteit van preventief ruimen ten opzichte van een noodentingsstrategie is zeer sterk afhankelijk van de te verwachten marktreacties van de handelspartners.

Aanvullende maatregelen ter reductie van latere dierwelzijn problemen

In hoofdstuk 6 wordt een varkenssector marktmodel en een stochastisch, temporeel, ruimtelijk simulatiemodel gebruikt om de epidemiologische en de economische gevolgen van aanvullende maatregelen ter reductie van latere dierwelzijn problemen te analyseren. Zulke aanvullende maatregelen zijn: een inseminatie verbod; het aborteren van drachtige zeugen; en het doodspuiten van jonge biggen.

Zulke aanvullende maatregelen bleken geen economisch voordeel op te leveren en hadden ook geen effect op het epidemiologische verloop van een epidemie. Bovendien reduceerden deze aanvullende maatregelen de enorme aantallen op te kopen dieren niet of nauwelijks.

Discussie en conclusies

In hoofdstuk 7 worden de algemene conclusies uit dit onderzoek besproken. De nadruk ligt daarbij op de mogelijke toepassing en ondersteuning van beslissingen bij toekomstige KVP uitbraken. Model aannames en model beperkingen zijn verdere discussie punten.

De belangrijkste conclusies uit dit proefschrift zijn:

- Als de economische welvaartsverandering van de consument, die meestal tegengesteld is aan de welvaartsverandering van de producent, niet in overweging wordt genomen, kan dat tot foute conclusies leiden. Daarom moeten bij beslissingen met betrekking tot KVP bestrijding welvaartseffecten van alle getroffen partijen (producenten, consumenten, overheid) in beschouwing genomen worden.
- Wanneer tijdens een KVP epidemie de export doorgaat buiten de quarantaine gebieden, dan gaan de producenten er economisch op vooruit en de consumenten verliezen. Wanneer er een totaal export verbod voor levende varkens is zonder een extra toename van de varkensvlees export, dalen de binnenlandse varkensprijzen. De consequentie is dat varkensproducenten buiten de quarantaine gebieden de verliezen van de varkensproducenten binnen de quarantaine gebieden niet meer goed kunnen maken. Producenten verliezen en consumenten gaan er op vooruit.
- Alle bestrijdingsmaatregelen die tot een totale export stop voor levende varkens leiden moeten vermeden worden. Met de huidige politieke en publieke acceptatie is daarom preventief ruimen de meest economische optie in een dichtbevolkt varkensgebied, maar voor een dunbevolkt varkensgebied zijn de huidige EU richtlijnen voldoende.

- Politieke beslissingen met betrekking tot bestrijding van KVP epidemieën zouden afhankelijk moeten zijn van geografische kenmerken zoals varkens- of varkensbedrijven-dichtheid in het besmette gebied.
- Een reductie van de dier- en de transportbewegingen in periodes zonder epidemie zou tot kleinere en kortere epidemieën leiden.
- Tijdens een epidemie mogen de dodings- en vernietigings-capaciteiten pas met laagste prioriteit benut worden voor de opkoop van varkens wegens dierwelzijn problemen.
- Aanvullende maatregelen ter reductie van latere dierwelzijn problemen, zoals een inseminatie verbod, aborteren van drachtige zeugen en het doodspuiten van jonge biggen, hebben geen invloed op het epidemiologische verloop van een KVP epidemie.
- Betere kennis over de transmissiemechanismen van KVP is noodzakelijk voor epidemiologische modellen en wenselijk voor economische modellen, zodat de effecten van de verschillende bestrijdingsmaatregelen beter geanalyseerd en vergeleken kunnen worden.
- De koppeling van epidemiologische modellen aan economische modellen is nuttig om een beter inzicht te krijgen in de effecten van de verschillende bestrijdingsmaatregelen bij een KVP epidemie en zo de besluitvorming te ondersteunen.

Zusammenfassung

Einleitung

Die Europäische Schweinepest (ESP) ist eine bedeutende Viruskrankheit bei Schweinen. In Ländern, in denen ESP endemisch ist, wird die Schweinepopulation in der Regel flächendeckend prophylaktisch geimpft, um größere Ausfälle zu vermeiden. Mit dem konventionellen Impfstoff lassen sich jedoch geimpfte Schweine nicht von infizierten Schweinen unterscheiden. Aus diesem Grunde verweigern die meisten Länder den Import von lebenden Schweinen und Schweinefleisch aus solchen Ländern, in denen gegen ESP geimpft wird.

ESP ist in der Hausschweinepopulation der EU weitgehend ausgerottet und prophylaktisches Impfen ist seit Anfang der 90iger Jahren untersagt. Im Falle eines ESP-Seuchenausbruches verlangt die derzeitige europäische Seuchenpolitik das Keulen und Vernichten der infizierten Herde, sowie die Ausweisung von speziellen Quarantänegebieten (Sperr- und Beobachtungsgebiet). Handelspartner könnten aus hygienischen Gründen abhängig von den getroffenen Bekämpfungsmethoden ihre Grenzen schließen. Die jüngsten ESP-Seuchengeschehen in Belgien, Deutschland und den Niederlanden gezeigt, dass die derzeitigen Bekämpfungsmethoden nicht immer ausreichend sind, um die Epidemie möglichst schnell zum Erlöschen zu bringen. Bei zukünftigen Epidemien werden deshalb wohl andere Vorgehensweisen erforderlich sein.

Die Zielsetzungen dieser Arbeit sind: 1) Die Entwicklung eines allgemeinen epidemiologischen Modells, das die Verschleppung des Virus von Betrieb zu Betrieb simuliert und es ermöglicht, verschiedene Bekämpfungsmethoden zu vergleichen; 2) die Entwicklung eines ökonomischen Modells, das unter Berücksichtigung von verschiedener Marktszenearien die anfallenden Kosten der Bekämpfungsmaßnahmen berechnet, sowie auch die indirekten volkswirtschaftlichen Kosten ausweist; 3) mit Hilfe dieser beiden Modelle sollen verschiedene Bekämpfungsmethoden analysiert werden und anhand von epidemiologischen und ökonomischen Erkenntnissen Empfehlungen zur Bekämpfung zukünftiger ESP-Seuchen abgeleitet werden.

Notimpfungsstrategien

Am Anfang dieser Studie stand – bedingt durch die öffentliche Diskussion und Nachfragen von Seiten der Privatwirtschaft - die Simulation von zwei möglichen Notimpfungsstrategien mit einem markierten Impfstoff, der 1997/98 bei Ausbruch von ESP in den Niederlanden zur Anwendung hätte kommen können (Kapitel 2). Die erste Notimpfungsstrategie, „delayed destruction“, hat zum Ziel, ein Defizit an verfügbaren Tötungs- und Vernichtungskapazitäten zu verhindern, indem die geimpften und nicht nachweislich erkrankten Bestände erst zu einem späteren Zeitpunkt per „stamping-out“ vertilgt werden. Die Tötung und Vernichtung aller Schweine aus geimpften Beständen unterscheidet diese Strategie im wesentlichen von der zweiten Strategie, der „intra-community-trade-Strategie“. In dieser wird angenommen, dass das Fleisch geimpfter Tiere auf dem europäischen Markt vermarktet werden kann.

Mit Hilfe des modifizierten, räumlichen, zeitlichen und stochastischen Simulationsmodells, InterCSF, wird die Verschleppung des ESP-Erregers zwischen den Betrieben simuliert. Die Verschleppung des ESP-Erregers kann örtlich bis zu einem Radius von 1 km erfolgen, sowie über längere Abstände via Tier-, Fahrzeug- und Personenverkehr. Die getroffenen Bekämpfungsmethoden beeinflussen die Verbreitung der Krankheit. Sämtliche Kosten der Bekämpfungsmaßnahmen, einschließlich aller Impfkosten, sowie etwaige Verluste der Schweineproduzenten und der nachgelagerten Industrie in den Quarantänegebieten, wurden in einem separaten Model errechnet.

Der Vergleich der beiden Bekämpfungsstrategien zeigt, dass beide Notimpfungsstrategien kaum effizienter gewesen wären, als die zuvor simulierte „preventive slaughter-Strategie“ (d.h. zusätzliches Keulen aller Schweinebeständen im Umkreis von 1 km um eine infizierte Herde). Von allen drei ist die „intra-community-trade-Strategie“ jedoch die kostengünstigste Alternative.

Veränderungen der Konsumentenpräferenzen von Fleisch und Fisch

Obwohl die Schweineproduktion in spezialisierten Betrieben stattfindet, und die fixen Produktionsfaktoren fast ausschließlich in der Schweineproduktion eingesetzt werden, so könnte auf der Konsumentenebene doch eine Wechselwirkung zwischen Schweinefleisch und anderem Fleisch bestehen. Bevor jedoch ein ökonomisches Modell, das die direkten und indirekten Kosten von Entwicklungen im Schweinesektor für die ganze niederländische Gesellschaft berücksichtigt, entwickelt werden kann, ist es wichtig zu untersuchen, ob Veränderungen im Schweinefleischangebot des Einzelhandels indirekte Effekte auf die Nachfrage und die Wirtschaftlichkeit von anderen Fleischarten haben können. Kenntnisse über das Kaufverhalten der niederländischen Verbraucher im Bezug auf Fleisch und Fisch sind dazu notwendig. Deshalb wurden in Kapitel 3 die Präferenzen für Fleisch und Fisch der niederländischen Verbraucher untersucht. Die neunziger Jahre waren, bedingt durch BSE, durch Vertrauenskrisen im Hinblick auf Rindfleisch gekennzeichnet. Die empirische Untersuchung der Konsumentenpräferenz berücksichtigt die teilweise durch die BSE-Krise entstandenen Geschmacksveränderungen für die einzelnen Fleischsorten durch die Verwendung eines „switching almost ideal demand (AID)“ Systems. Strukturelle Veränderungen der Konsumentenpräferenzen zwischen Januar 1994 und Mai 1998 werden unterschieden in einen zu Grunde liegenden Trend, eine irreversible Präferenzenverlagerung, ausgelöst durch die BSE Krise im März 1996, und eine „Panikreaktion“ auf Kosten der Rindfleischnachfrage im Monat der Krise. Wir konnten keinen Beweis für eine gehemmte Schweinefleischnachfrage erbringen, der auf den ESP-Seuchenausbruch in den Niederlanden in den Jahren 1997/98 zurückzuführen wäre. Darüber hinaus fanden wir keinerlei Beweise für die Substitution von Schweinefleisch durch andere Fleischsorten.

Wohlfahrtseffekte durch die ESP-Seuche von 1997/98

Im Kapitel 4 simulieren wir die ESP-Seuche in den Niederlanden von 1997/98 einschließlich der angewandten Bekämpfungsmethoden mit einem dynamischen, räumlichen und stochastischen epidemiologischen Simulationsmodell. Mit Hilfe eines neu entwickelten sektoralen Handels- und Marktmodells wurde das Geschehen auf dem niederländischen Schweinemarkt unter Annahme verschiedener Marktszenarien simuliert. Ökonomische Wohlfahrtveränderungen bei Produzenten, Konsumenten und dem Staat wurden berechnet. Im Falle einer mittelschweren ESP-Seuche und einer begrenzten Handelssperre stieg der Produzentenüberschuss auf 454 Millionen EURO, obwohl innerhalb der Quarantänegebiete einige Produzenten Verluste erlitten. Der Konsumentenüberschuss dagegen fiel um 463 Millionen EURO. Im Falle eines Exportstopps von lebenden Schweinen ging den Schweineproduzenten ein Überschuss von insgesamt 251 Millionen EURO verloren, wohingegen der Konsumentenüberschuss um 111 Millionen EURO stieg. Im Falle eines Exportverbotes für lebende Schweine sind die Staatskosten niedriger. Für die niederländische Wirtschaft beträgt der ökonomische Wohlfahrtsverlust gegenüber einer ESP-seuchenfreien Situation im Falle der begrenzten Handelssperre 297 Millionen EURO, und im Falle eines Exportverbotes für lebende Schweine 394 Millionen EURO.

Einfluss der Schweinedichtheit

Mit Hilfe eines verbesserten räumlichen, dynamischen und stochastischen epidemiologischen Models, InterCSF_v3, wurden in Kapitel 5 ESP-Seuchen in Gebieten mit unterschiedlicher Schweinedichte simuliert. Die Anwendung von verschiedenen Bekämpfungsmethoden, wie der derzeitigen EU-Seuchenpolitik, der „preventive slaughter“ Strategie und/oder einer Notimpfung („delayed destruction“ und „intra-community-trade-Strategien“) wurden für den Fall einer ESP-Seuche simuliert. Des weiteren wurde mit Hilfe des sektoralen Handels- und

Marktmodells das Geschehen auf dem niederländischen Schweinemarkt simuliert. Zwei unterschiedliche Handelsszenarien wurden simuliert: Ein Handelsverbot allein in den Quarantänegebieten, sowie ein Exportverbot für lebende Schweine. Die ökonomischen Wohlfahrtsveränderungen auf Seiten der verschiedenen betroffenen Parteien (Schweineproduzenten, Konsumenten und Staat) zusammen ergeben den gesamten ökonomischen Nettowohlfahrtseffekt für die Niederlande.

Ökonomische und epidemiologische Ergebnisse suggerieren, dass die aktuelle EU-Seuchenpolitik ausreicht, um eine ESP-Epidemie in einem Gebiet mit geringer Schweinedichte auszulöschen. In einem Gebiet mit hoher Schweinedichte hingegen sind jedoch zusätzliche Maßnahmen erforderlich. Die Wirtschaftlichkeit der „preventive slaughter-Strategie“ gegenüber einer Notimpfungsstrategie ist sehr stark abhängig von der zu erwartenden Handelsreaktion. Außerdem führt in Gebieten mit hoher Viehbesatzdichte eine allgemeine Reduktion des Tier- und Fahrzeugverkehrs zu kleineren und kürzeren Seuchenausbrüchen.

Ergänzungsmaßnahmen zur Reduzierung des Ferkelangebotes

In Kapitel 6 wurden ein sektorales Handels- und Marktmodell, sowie ein räumliches, stochastisches und dynamisches epidemiologisches Simulationsmodell benutzt, um die epidemiologischen und ökonomischen Folgen von begleitenden Maßnahmen zur Vermeidung von späteren Problemen des Wohlbefindens der Tiere zu untersuchen. Solche Ergänzungsmaßnahmen waren ein Besamungsverbot, die Abtreibung bei trächtigen Sauen, sowie das Töten von sehr jungen Ferkeln. Die Aufsummierung der ökonomischen Wohlfahrtsveränderungen der betroffenen Parteien (Schweineproduzenten, Konsumenten und Staat) führte zum Nettowohlfahrtseffekt für die niederländische Volkswirtschaft.

Wirtschaftlich ist die Anwendung solch begleitender Maßnahmen nicht. Außerdem reduzieren diese die enorme Anzahl an Schlachtungen, welche aus Problemen des Wohlbefindens der Tiere erfolgen, kaum oder gar nicht.

Diskussion und Schlussfolgerung

In Kapitel 7 werden allgemeine Schlussfolgerungen, die aus der Studie gewonnen werden konnten, diskutiert. Im Mittelpunkt steht die Ausrichtung der Seuchenpolitik bei zukünftigen ESP-Seuchenausbrüchen. Notwendige Modellannahmen, sowie Modelleinschränkungen, sind weitere Diskussionspunkte.

Die wichtigsten Schlussfolgerungen dieser Studie sind:

- Werden Wohlfahrtsveränderungen auf Seiten der Konsumenten, die sich gewöhnlich entgegengesetzt zu den Wohlfahrtsveränderungen der Produzenten verhalten, nicht berücksichtigt, so könnte dieses zu falschen Schlussfolgerungen führen. Deshalb sollten im Falle einer Entscheidung über die Bekämpfung einer Seuche Wohlfahrtsveränderungen aller betroffenen Parteien (Produzenten, Konsumenten, Staat) beachtet werden.
- Wenn der Handel im Falle eines ESP-Seuchenausbruches, außerhalb der Quarantänegebiete keinen Beschränkungen unterliegt, dann erwirtschaften Schweineproduzenten in der Summe einen Überschuss, wohingegen die Konsumenten verlieren. Im Falle eines Exportverbotes von lebenden Schweinen werden ohne eine gleichzeitige Erhöhung der Exportmengen von Schweinefleisch niedrige Marktpreise erzielt. Die Konsequenz ist, dass die Schweineproduzenten außerhalb der Quarantänegebiete die Verluste der betroffenen Schweineproduzenten nicht wettmachen können; Produzenten erleiden einen kollektiven Verlust und Konsumenten gewinnen.
- Alle Bekämpfungsmethoden, die zu einem Exportverbot von lebenden Schweinen führen, sollten vermieden werden. Die derzeitige politische und öffentliche Akzeptanz lässt den Schluss zu, dass in einem Gebiet mit einer hohen Schweinedichte im Falle eines Seuchenausbruchs die „preventive slaughter“-Strategie die wirtschaftlichere Strategie ist. Dahingegen ist in einem Gebiet mit geringerer Schweinedichte die derzeitige EU-Seuchenpolitik ausreichend.
- ESP-Seuchenpolitik sollte an geographische Gegebenheiten, d.h. Schweinedichte oder Schweinebetriebsdichte, gebunden sein.
- Eine allgemeine Reduzierung des Tier- und Fahrzeugverkehrs in seuchenfreien Zeiten führt zu kürzeren Seuchenausbrüchen, sowie eine geringere Anzahl infizierter Betriebe.
- Im Falle einer Seuche sollten die Tötungs- und Vernichtungskapazitäten in aller erster Linie zur Schlachtung und Vernichtung von Schweinen aus infizierten und präventiv geschlachteten Betrieben benutzt werden.
- Begleitende Maßnahmen zur Vermeidung von späteren Problemen des Wohlbefindens der Tiere, wie z.B. ein Besamungsverbot und die Abtreibung bei trächtigen Sauen, sowie die Tötung junger Ferkel, haben keinen Einfluss auf das Seuchengeschehen.

- Für die epidemiologischen Modelle sind bessere Kenntnisse über verschiedene ESP-Verschleppungsmechanismen notwendig, und im Falle der ökonomischen Modelle wünschenswert, um die Folgen der verschiedenen Bekämpfungsmethoden besser analysieren und vergleichen zu können.
- Die Koppelung von epidemiologischen an ökonomische Modelle war und ist nützlich, um einen besseren Einblick in die Wirkungsweise von den verschiedenen Bekämpfungsmethoden bei Seuchen zu erhalten und somit den Entscheidungsprozess zu erleichtern.

Related publications

Scientific papers

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Curriculum vitae

Marie-José Justine Mangen was born on 3 January 1970 in Luxembourg-ville, Luxembourg. In 1989 she obtained her secondary high school degree (Téchnicien en agriculture) at the "Lycée Technique Agricole" in Ettelbruck, Luxembourg. The same year she began her studies at the "Rheinische-Friederich-Wilhelm-Universität zu Bonn" in Germany, where she graduated in 1993 with the degree of Dipl.-Ing. agr. (equivalent to MSc) having specialised in animal science. From February 1994 until August 1994 she worked at the "Musée d'Histoire Naturelle" in Luxembourg as a temporary employee in the mammal section. In September 1994 she started studying for a second MSc degree, at Wageningen University in the Netherlands. At the end of this study she went for about 3 months as an Erasmus exchange student to the University of Aberdeen in Scotland. In 1996 she obtained her MSc degree in Agricultural Economics and Marketing at Wageningen University, with specialisation in Farm Management. From February 1996 until December 1997 she was working at the "Service d'Economie Rurale" of the Agriculture Ministry in Luxembourg in the market department.

From January 1998 until March 2002 she was employed as a PhD fellow at the Department of Social Sciences of Wageningen University whereby she carried out the research resulting in this thesis. This thesis was part of a larger research project that is entitled "Development and application of a decision support system for contagious disease control in livestock" and financed by the Technology Foundation (STW) in Utrecht. During her time as PhD fellow she joined the education program of the Mansholt Graduation School and participated in national and international courses, seminars and congresses in the Netherlands and abroad.

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