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Does Pig Density Matter for the Choice of Control Strategies in Classical Swine Fever Epidemic?

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Does pig density matter for the choice of control strategies in a Classical Swine Fever epidemic?[1]

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Does pig density matters for the choice of control strategies in a Classical Swine Fever epidemic?

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 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.

Keywords:
Classical Swine Fever epidemics; pig population density; animal transport; emergency vaccination; preventive slaughter; the Netherlands

1. Introduction

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. Mangen et al. (2001b) 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. 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, 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. Two 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?

We simulated epidemics beginning in either a SPLA or a DPLA[2], 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 Mangen et al. (2001b). 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.

2. Methodology

2.1 InterCSF and further adaptations for the current work

InterCSF, a spatial, temporal and stochastic simulation model, developed by Jalvingh et al. (1999), 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. Mangen et al. (2001a) added emergency vaccination as a control option to InterCSF with a gradual non-linear increase over time of protection from vaccination as well as constrained vaccination capacities.

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

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. 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

[2] 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.

of carrier piglets on a susceptible farm, a major within-herd outbreak will occur. Information on input parameters are available on request.

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 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.

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 Mangen et al. (2001a) 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 (information available on request). 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).

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 minor within-herd outbreak. The infectious period of vaccinated farms is 30 days (see Mangen et al., 2001a) 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 first 6 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.

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.

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. 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 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 15 replications with at least as many 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) as discussed in more detail in section 4.1. We also corrected the estimated transmission probabilities of Stegeman et al. (2002) for a 15% probability of minor within-herd outbreaks.

2.3 Contact matrix

Three contact types between pig farms are defined: (1) direct animal contact, (2) transport contact and (3) professional contact. 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 fewer 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 are compared with the simulated epidemics using the contact structure of Jalvingh et al. (1999).

2.4 Simulating epidemic control with different pig densities

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.

Stamping-out infected herds and tracing all contacts with infected herds, in addition to the setting up 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 movement standstill 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***) (Mangen et al., 2001a). 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.

2.4.2 Economic framework

Mangen et al. (2001b) developed an economic framework to calculate the impact on the Dutch economy of epidemics simulated in InterCSF, assuming different trade scenarios. 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 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. Retailers' total margins are assumed to be unchanged in all scenarios. The economic welfare changes of the different stakeholders are aggregated to determine the net welfare effect for the Dutch economy. As in Mangen et al. (2001b), 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 (Mangen et al., 2001b), 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.

3. Results

3.1 Contact reduction

The effect of adopting the new contact matrix is shown in Table 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. We note that by far the greatest source of infection in a DPLA is local spread. Fewer animal contacts has a direct effect on the spread of infection, but also an indirect effect on the potential for locally spread infection.

Table 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 farms	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 farms	254	57	197	638	112	46	98	186
# Prev. sl. farms	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

3.2 Epidemics in a SPLA compared with a DPLA

3.2.1 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 outcomes.

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 in 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 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 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.

3.2.2 Economic results

Two alternative definitions of epidemic size are used: length of the epidemic in days and the number of detected farms[3]. 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 3 and for the SPLA region in Table 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 % contribution from the EU budget towards the total extra expenditure on controlling the epidemic. However, if the EU contribution were lower, 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. Table 5 shows details of the distribution of welfare changes of piglet, finisher and breeding stock producers for two trade scenarios, whereby we distinguish for each producer category if they are inside quarantine zones (Q) or outside the quarantine zones.

Tables 3 and 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 (Table 5). For both these stakeholders, the welfare change is negative when foreign trade continues from non-quarantine zones.

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[3] 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 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

Note:

a) In the case of the intra-community trade scenario 120 days extra should be added for zones in which vaccination was used.

Table 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
	No trading from the quarantine zones											
a) Ranked on the length of the epidemic												
Change in PS	318	488	914	79	169	261	84	204	359	107	182	235
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												
Change in PS	276	495	869	83	288	411	96	185	275	151	242	357
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
	No trading from the quarantine zones combined with a total export ban on all Dutch live pigs											
a) Ranked on the length of the epidemic												
Change in PS	-200	-160	-167	-295	-273	-249	-283	-167	-9	-296	-262	-268
Change in CS	230	262	520	218	237	248	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												
Change in PS	-336	-119	-91	-292	-146	-12	-269	-201	-91	-306	-200	-67
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

Note:

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 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
	No trading from the quarantine zones											
a) Ranked on the length of the epidemic												
Change in PS	8	8	19	8	28	20	9	11	19	7	11	10
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												
Change in PS	7	7	49	8	9	22	9	11	26	7	9	39
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
	No trading from the quarantine zones combined with a total export ban on all Dutch live pigs											
a) Ranked on the length of the epidemic												
Change in PS	-373	-429	-547	-363	-356	-469	-363	-378	-445	-380	-403	-468
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												
Change in PS	-402	-414	-478	-363	-381	-447	-363	-372	-397	-377	-406	-411
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

Note:

a) Less than 1 million euro.

Table 5: 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

Scenario	EU strategy			PS strategy			DD strategy			ICT strategy		
Epidemic size	small	medium	large	small	medium	large	small	medium	large	small	medium	large
	No trading from the quarantine zones											
Change in PS of:												
- all producers	318	488	914	79	169	261	84	204	359	107	182	235
- piglet producers (outside Q)	110	172	268	27	59	101	32	83	138	37	61	78
- piglet producers (inside Q)	10	17	35	1 [a]	1	5	-1	-2	7	2	4	6
- hog producers (outside Q)	186	282	564	51	104	147	53	118	175	67	112	145
- hog producers (inside Q)	21	30	67	2	7	15	2	10	45	4	11	13
- breeding producers [b]	-9	-13	-20	-2	-3	-6	-2	-4	-6	-3	-5	-6
Change in CS[c] of:												
- all consumers	-198	-316	-558	- 45	-102	-171	-49	-129	-230	-63	-109	-142
- slaughterhouses	-8	-15	-30	-1 [a]	-3	-7	-2	-7	-13	-1	-2	-4
- final consumer	-190	-301	-528	- 45	-99	-164	-47	-121	-217	-32	-106	-138
	No trading from the quarantine zones combined with a total export ban on all Dutch live pigs											
Change in PS of:												
- all pig producers	-200	-160	-167	-295	-273	-249	-283	-167	-9	-296	-262	-268
- piglet producers (outside Q)	-175	-207	-416	-152	-169	-179	-144	-107	-66	-162	-168	-191
- piglet producers (inside Q)	-8	-15	-21	-2	-4	-7	-3	-7	-3	-3	-3	-6
- hog producers (outside Q)	-10	71	270	-137	-96	-60	-133	-52	31	-128	-87	-66
- hog producers (inside Q)	4	6	23	-1	1[a]	4	-1[a]	4	35	-1[a]	3	2
- breeding producers [b]	-10	-15	-23	-2	-4	-7	-2	-5	-6	-3	-6	-7
Change in CS[c] of:												
- all consumers	230	262	520	218	237	249	208	143	55	231	231	264
- slaughterhouses	76	92	176	55	66	76	52	43	37	61	67	78
- final consumer	154	170	344	163	171	173	156	100	18	170	164	186

Note:

a) Less than 1 million euro.

b) Only breeding producer inside quarantine zones are considered, because we assume no change for breeding producers outside the quarantine zones.

c) We assume that the change for retailer is equal to zero.

4. Discussion

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. The most reliable estimates of transmission probabilities (Stegeman et al., 2002) produced epidemics that were considered small. Based on additional epidemiological information, we doubled Stegeman's transmission probabilities. 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, whereas for a DPLA the simulated epidemic is larger in size and with a longer duration when the parameters for local spread are doubled (results not shown).

4.2 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.

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

The probability of transmission by local spread has an impact on the size and the length of an epidemic in a DPLA, 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.

4.4 Policy implications

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 programme 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.

Moreover, 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, the Netherlands trades more than 70 % of reared pigs (either as live animals or as meat), most of them 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 and all EU exports may be banned by third importing countries. 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.

5. Conclusions

Regarding the specific research questions addressed in this paper, we can report that, if the new Dutch pig transport legislation is applied correctly, it will lead to a reduction of disease spread in future CSF epidemics.

More 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.

References

Dewulf, J., Laevens, H., Koenen, F., Mintiens, K., de Kruif, A., 2001. An E2 sub-unit Marker Vaccine does not prevent horizontal or vertical transmission of Classical Swine Fever Virus. Vaccine, 20 (1-2) 86-91.

Elbers, A.R.W., Stegeman, A., Moser, H., Ekker, H.M., Smak, J.A., Pluimers, F.H., 1999. The classical swine fever epidemic 1997-1998 in the Netherlands. Preventive Veterinary Medicine 42: 157-184.

Fritzmeier, J., Teuffert, J., Greiser-Wilke, I., Staubach, C., Schlüter, H., Moennig, V., 2000. Epidemiology of classical swine fever in Germany in the 1990s. Veterinary Microbiology 77: 29-41.

Houlder, V., 2001. Foot-and-mouth to damage economy by up to $5.9 bn. *Financial Times, 29-August 2001 (http://ft.com).*

Jalvingh, A.R.W., Nielen, M, Maurice, H., Stegeman, A.J., Elbers, A.R.W., Dijkhuizen, A.A., 1999. Spatial and stochastic simulation to evaluate the impact of events and control measures on the 1997-1998 classical swine fever epidemic in the Netherlands. I. Description of simulation model. Preventive Veterinary Medicine 42: 271-295.

Law, A.W. and Kelton, W.D., 1991. Simulation modeling and analysis. McGraw-Hill Inc, 2nd edition, Singapore.

LNV, 2000. Regeling varkensleveringen, Ministerie van landbouw, natuurbeheer en visserij, Den Haag (http://www.minlnv.nl/thema/dier/varken/levering); In Dutch.

Mangen, M.-J.J., Jalvingh, A.W., Nielen, M., Mourits, M.C.M, Klinkenberg, D., Dijkhuizen, A.A., 2001 a. Spatial and stochastic simulation to compare two emergency-vaccination strategies with a marker vaccine in the 1997/98 Dutch Classical Swine Fever epidemic. Preventive Veterinary Medicine 48 (3): 177-200.

Mangen, M.-J.J., Burrell, A.M., Mourits, M.C.M., 2001b. Welfare effects of controlling a Classical Swine Fever epidemic in the Netherlands. Paper presented at the annual meeting of the American Association of Agricultural Economist; Chicago, USA, 5- 8 August.

Mourits, M.C.M., Nielen, M., Léon, C.D., 2001. Quantification of high-risk contacts between Dutch pig farms. Poster presented at the annual meeting of the Society for Veterinary Epidemiology and Preventive Medicine; Noordwijkerhout, Netherlands, 28-30 March.

Nielen, M., Jalvingh, A.W., Meuwissen, M.P.M., Horst, S.H., Dijkhuizen, A.A., 1999. Spatial and stochastic simulation to evaluate the impact of events and control measures on the 1997-1998 classical swine fever epidemic in the Netherlands. II. Comparison of control strategies. Preventive Veterinary Medicine, 42: 297-317.

Pluimers, F.H., de Leeuw, P.W., Smak, J.A., Elbers, A.R.W., Stegeman, J.A., 1999. Classical swine fever in The Netherlands 1997-1998: a description of organisation and measures to eradicate the disease. Preventive Veterinary Medicine, 42: 139-155.

RVV, 2000. Draaiboek – Klassieke varkenspest, version 3.0. Rijksdienst voor de keuring van vee en vlees (RVV), Voorburg; (In Dutch).

Snoek, H., Hemmer, H., Kuunders, L., Ellen, H., 1999. Kwantitatieve Informatie veehouderij 1999-2000. Praktijkonderzoek Rundvee, Schapen en Paarden, Lelystad, 443 pp (In Dutch).

Stegeman, A., Elbers, A.R.W., Moser, H., De Smit, H., Bouma, A., De Jong, M.C.M., 1998. Rate of transmission of classical swine fever virus between herds by various routes. Proceedings of the 15th IPVS Congress, Birmingham, England, 5-9 July; 269.

Stegeman. A., Elbers, A.R.W., Bouma, A., de Jong, M.C.M., 2002. Rate of inter-herd transmission of Classical Swine Fever virus by different types of contact during the 1997-1998 epidemic in the Netherlands. Epidemiology and Infection (in press).

Appendix for referees

In the following tables we show some of the most important input parameters that are used in InterCSF_v3. More information are available on request from the first author. Furthermore, figure A-1 fives an overview of the overall framework.

Input parameters of InterCSF_v3

Table A-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

Note:

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. (2002) 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).

Table A-2.- 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 (from Mangen et al. 2001a) [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

Note

a) In contrast to Mangen et al. (2001a) 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 Mangen et al. (2001a).
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.

Table A-3. - 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 Mangen et al. (2001a).

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 A-4. 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 III-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 III-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 III - 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).

Table A-5. Probability that a simulated contact happens in a specific distance class, depending on the contact type

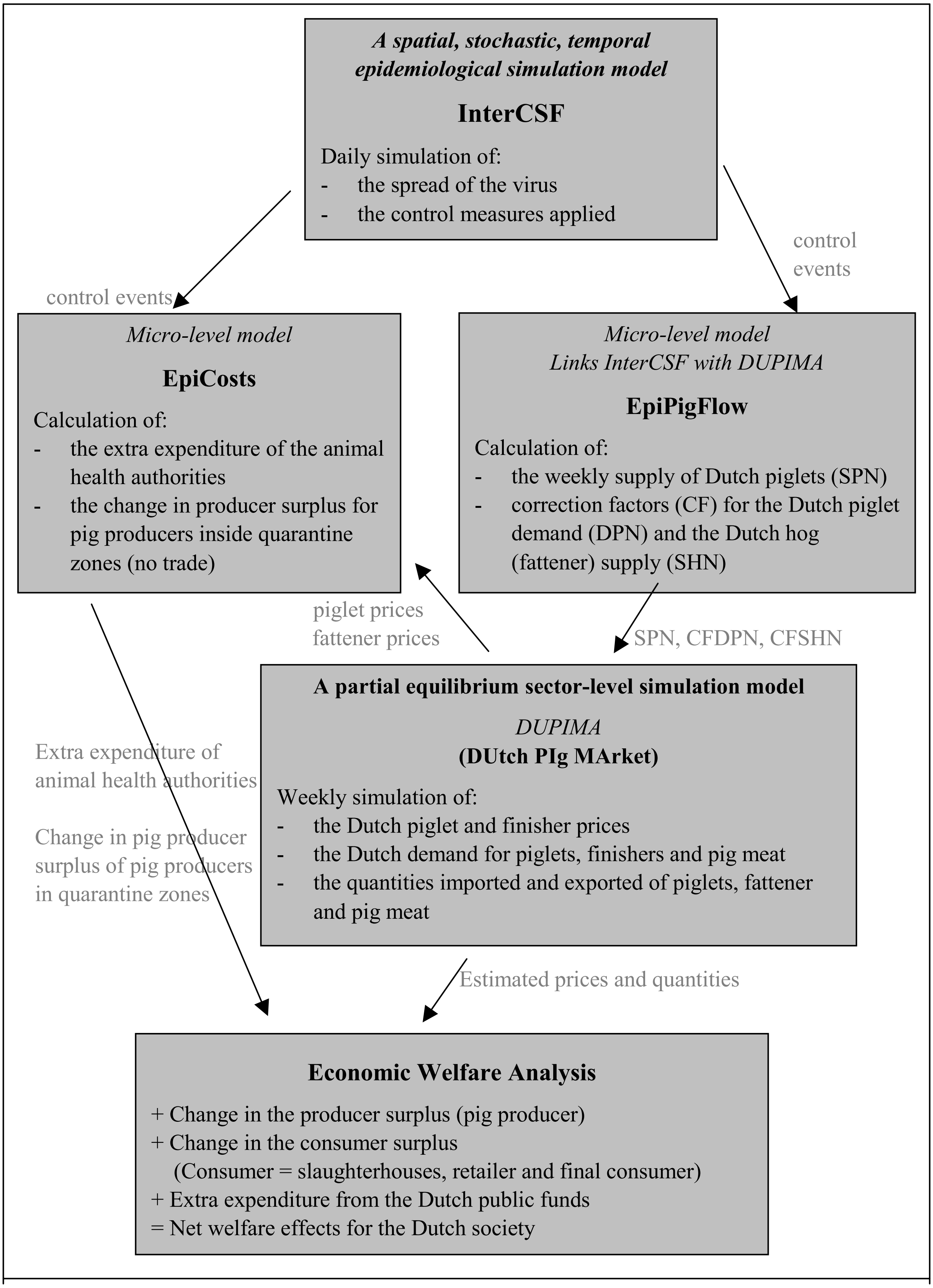
Contact type	Distance class (in km)							
	0-5	5-10	10-15	15-20	20-30	30-60	60-100	100-150
Animal and transport	0.305	0.208	0.135	0.085	0.101	0.115	0.041	0.12
Person	0.65	0.15	0.15	0.025		0.025	0	

Table A-6. 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]	-	-	-	-	-

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

Figure A-1. The modelling framework



References

Dewulf, J., Laevens, H., Koenen, F., Mintiens, K., de Kruif, A., 2001. An E2 sub-unit Marker Vaccine does not prevent horizontal or vertical transmission of Classical Swine Fever Virus. Vaccine, 20 (1-2) 86-91.

Mangen, M.-J.J., Jalvingh, A.W., Nielen, M., Mourits, M.C.M, Klinkenberg, D., Dijkhuizen, A.A., 2001. Spatial and stochastic simulation to compare two emergency-vaccination strategies with a marker vaccine in the 1997/98 Dutch Classical Swine Fever epidemic. Preventive Veterinary Medicine 48 (3): 177-200.

Mourits, M.C.M., Nielen, M., Léon, C.D., 2001. Quantification of high-risk contacts between Dutch pig farms. Poster presented at the annual meeting of the Society for Veterinary Epidemiology and Preventive Medicine; Noordwijkerhout, Netherlands, 28-30 March.

Nielen, M., Jalvingh, A.W., Horst, H.S., Dijkhuizen, A.A., Maurice, H., Schut, B.H., van Wuijkhuise, L.A., de Jong, M.F., 1996. Quantification of contacts between Dutch farms to assess the potential risk of foot-and-mouth disease spread. Preventive Veterinary Medicine, 28, 143-158.

Noordhuizen, J.P.T.M., Frankena, K., van der Hoofd, C.M., Graat, E.A.M., 1997. Application of Quantitative Methods in Veterinary Epidemiology. Wageningen Pers, Wageningen.

RVV, 2000. Draaiboek – Klassieke varkenspest, version 3.0. Rijksdienst voor de keuring van vee en vlees (RVV), Voorburg. (In Dutch)

Stegeman. A., Elbers, A.R.W., Bouma, A., de Jong, M.C.M., 2002. Rate of inter-herd transmission of Classical Swine Fever virus by different types of contact during the 1997-1998 epidemic in the Netherlands. Epidemiology and Infection (in press).