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Welfare effects of controlling a 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[1] without export restrictions, although producers within quarantine areas lose. Consumer surplus falls by EUR 465 mn. With a ban on live pig exports, pig producers' collective loss is EUR 251 mn whereas consumers gain EUR 116 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 –299 mn and EUR –390 mn respectively, without and with an export ban.

Keywords: Sector-level trade model, economic welfare analysis, export restrictions, Classical Swine Fever, epidemiological simulation model;

JEL Classification: Q12, Q13

[1] EUR 1 = $ 0.87 (approx) on 14/5/2001.

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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).

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. 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).

Various studies have looked at the costs related to an incidental outbreak of a contagious animal disease. Garner and Lack, and Mahul and Gohin, calculated the economy-wide costs, whereas Berentsen et al. used a partial equilibrium approach to estimate only a subset of the indirect costs. Other studies have evaluated eradication programs for endemic animal diseases (Ellis, Ebel et al., Miller et al., Andersson et al.).

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.

The 1997-8 Dutch CSF epidemic

EU minimum measures in the case of CSF

After the detection of CSF on a pig farm, all pigs on the farm are destroyed. 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. Repopulation 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.

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 repopulation of the farm is not allowed until the quarantine zone is lifted. Under EU legislation, preventive slaughter is an optional control measure. In the Dutch 1997-8 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).

Market support measures

In the 1997-8 epidemic, the prolonged duration of quarantine zones led to animal welfare problems. To avoid overcrowding and to reduce the risk of illegal animal movements, welfare slaughter was used for 25-kg-ready-to-deliver piglets and for 120-kg-ready-to-deliver pigs. These healthy pigs were bought at current market price and were destroyed. As no animal transport or repopulation were allowed inside a quarantine zone, fattening farms remained empty if the quarantine zone lasted for longer than 4 months.

Methodology

Model structure and content

The modelling framework comprises five parts. 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.

Epidemiological simulation model (InterCSF)

InterCSF (Jalvingh et al.) 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 1997-8 Dutch CSF epidemic (Jalvingh et al.). 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 1997-8 epidemic.

EpiPigFlow

EpiPigFlow is written in C++ and links InterCSF and DUPIMA. InterCSF works at farm level and on a daily basis, whereas DUPIMA requires weekly market supplies as input.

To calculate the piglet flow during an epidemic, EpiPigFlow begins with the average weekly supply in 1996. 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, are subtracted from this figure. 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 (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 restriction. 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.

DUPIMA

DUPIMA (**Du**tch **Pig** **Ma**rket) is a sector-level partial equilibrium simulation model written in GAMS. Dupima models the Dutch piglet and hog markets using the same approach as Buijtels and Burrell. 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, 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 welfare slaughter compensation on the basis of the actual weekly pig market prices, will all encourage farmers to continue in production.

The model DUPIMA

The structure of the Dutch piglet market is described by 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.

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.

The structure of the Dutch hog market is as follows:

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

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

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

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

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

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

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

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

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

where SHN = supply of hogs from within the Netherlands, SHI = import of hogs, SCI = import of pig meat (converted to pig carcasses[2]), 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

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

export destination.

Equation (14) is the equilibrium condition for the hog market. The link between the two markets is modelled *as if* all piglets pass to fatteners via a market decision. 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).

Estimated demand relationships

The behavioural equations were econometrically estimated with monthly data[3] from 1992-1996. 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 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.

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

Calibration of DUPIMA

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.

Simulated scenarios and assumptions

In 1998 we surveyed 10 "experts" from the Dutch pig sector on the likely trade policy reactions to a CSF epidemic in the Netherlands with and without emergency vaccination as an extra control measure. 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 is used, an export ban on pig meat originating from vaccinated pigs would certainly be added. The experts did not believe that the Dutch government would adopt any control measures, such as emergency vaccination, that conflict with EU policy, in order to avoid a total export ban on all Dutch live pigs and pig products.

Therefore, we assume that there will be either 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 1997-8, 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).

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, Hueth and Schmitz, 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 average simulated (non-epidemic) market situation in 1996.

In 1997-8, the EU budget financed 50 % of organisation costs and veterinary compensation payments and 70 % of compensation payments for welfare slaughter measures (LNV). Other payments are funded partly by the Dutch government and partly by the Dutch farm sector via contributions. In the 1997-8 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, which is an adapted version of EpiLoss (Meuwissen et al.). The compensation payments for welfare slaughter are calculated using the simulated weekly prices obtained from DUPIMA. Further details on EpiCosts are available on request.

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 the margin is equal to average cost per pig slaughtered and processed (PVE). A further assumption is that the slaughterhouses are distributed over the Netherlands in proportion to pig density.

At retail level, we assume a flexible marketing margin. Dynamic margin adjustment was estimated econometrically using monthly data for 1992-1999. The change in the surplus of the final consumer is calculated using the consumer price per kg pig meat derived from the hog price per kg pig carcass and the margins of the slaughterhouses and the retailer.

We assume further that a CSF epidemic does not change consumer tastes for pork. This assumption is reinforced by the study by Mangen and Burrell (2001), which found no evidence of a taste shift that might have been due to the 1997-8 CSF epidemic.

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 destroyed by welfare slaughter; b) those whose pigs are slaughtered and destroyed 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 welfare slaughter and repopulation is forbidden. These sub-categories are summarised in Table 1. The changes in their surpluses are calculated separately.

Table 1 here

Results

Presentation of results

InterCSF was used to perform 100 replications of the Dutch 1997-8 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 10^{th}, 50^{th} and 90^{th} represent "small", "medium" and "large" epidemics respectively. Table 2 summarises the key parameters for small, medium or large epidemics according to each criterion.

Table 2 here

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 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.

Table 3 here

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 movement restrictions 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.

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). 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 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), welfare slaughter leads to empty stables after a few months. Idle capacity, whether due to depopulation of detection, preventive slaughter or welfare slaughter may cost some hog farmers their business.

Table 4 here

In our calculations, welfare slaughter on breeding stock farms caused costs to the farmers as their pigs were compensated at the same rate as fattening pigs. So, as in the 1997-8 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 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.

Government expenditure

Table 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 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 under movement restrictions, since the cost per pig in these categories are independent of the simulated market price.

Table 5 here

Welfare slaughter compensation is the biggest part of all government expenditure on control programmes. These payments are highly 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 welfare slaughter compensation due to higher weekly market pig prices. Reducing the compensation paid per pig under 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 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 welfare slaughter, but those two measures may increase then the risk of spreading the virus. More epidemiological research is needed here.

The marketing chain and final consumers (not shown)

When exports are banned, slaughterhouses gain as more animals are slaughtered domestically. This matches the reality of the 1997-8 Dutch CSF epidemic. Retailers gain in all scenarios, 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.

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 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 welfare slaughter). In particular, the major share of 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 633 million whereas that of a medium epidemic is just EUR 390 million. If the Dutch authorities had used additional measures costing less than EUR 243 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. show that immediate preventive slaughter reduces the median length of the epidemic by half. Another extra control measure might be emergency vaccination. Mangen et al. 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.

Table 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)	Continues production: Welfare slaughter (with or without delay) of ready-to-market animals; weekly pig market prices are paid for pigs slaughtered and destroyed 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.

Note:

a) Farms may switch weekly from one to another category. 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 in a) or b) and only if they were in I.b) they may directly switch to II.c).

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

Table 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

Note:

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

Table 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	-388	-247	-223
Q + Exp	-226	119	-218	-325
Q + Exp + switch	42	-8	-228	-194
Medium epidemic				
Q	502	-550	-358	-405
Q + Exp	-73	-76	-318	-466
Q + Exp + switch	204	-201	-330	-327
Large epidemic				
Q	529	-798	-577	-846
Q + Exp	-50	-258	-515	-822
Q + Exp + switch	276	-398	-532	-654
Size of epidemic defined by the number of infected and detected farms				
Small epidemic				
Q	415	-405	-251	-240
Q + Exp	-277	156	-220	-341
Q + Exp + switch	12	16	-229	-201
Medium epidemic				
Q	454	-465	-289	-299
Q + Exp	-251	116	-254	-390
Q + Exp + switch	52	-29	-265	-243
Large epidemic				
Q	506	-658	-450	-602
Q + Exp	-100	-134	-400	-633
Q + Exp + switch	208	-271	-415	-478

Table 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	-[1]	-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

Note: 1) 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 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						579	726	247	479
Q + Exp	7	18	67	21	34	483	630	218	412
Q + Exp + switch						514	661	228	433
Medium epidemic									
Q						813	1042	358	684
Q + Exp	13	23	90	34	69	678	907	318	589
Q + Exp + switch						719	948	330	618
Large epidemic									
Q						1319	1681	577	1104
Q + Exp	21	38	133	58	112	1110	1472	514	958
Q + Exp + switch						1169	1531	532	999
Size of the epidemic defined by the length of epidemic (days)									
Small epidemic									
Q						597	740	251	489
Q + Exp	6	18	70	19	30	493	636	219	417
Q + Exp + switch						525	668	229	439
Medium epidemic									
Q						674	847	289	558
Q + Exp	8	21	78	23	43	559	735	254	478
Q + Exp + switch						594	767	265	502
Large epidemic									
Q						1035	1314	450	864
Q + Exp	15	30	108	40	86	869	1148	400	748
Q + Exp + switch						917	1196	415	781

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