Effect of reducing the area under transport ban on transmission risk and piglet surplus during a CSF epidemic in the Netherlands

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Contents

Summary

In this report, we investigate the expected effects of reducing the area in which live piglet transports are banned on transmission risk and on the piglet surplus (in the area of the transport ban) during a CSF epidemic in the Netherlands. In our analyses we consider the following effects resulting from a reduction of the area under piglet transport ban:

- the additional transmission risk
- the reduction of the piglet surplus
- the financial costs and benefits

In the present study, the area placed under animal transport ban in current contingency plans (i.e. whole regions, coloured red + yellow in Figure 1.2) is referred to as the default scenario. As a most extreme alternative scenario, we will investigate the consequences of only placing farms under the piglet transport ban which are located within a 10 km Protection and Surveillance zone (PS-zone) around a CSF-infected premise (IP). For both scenarios the risk will be expressed as the expected mean size of additional IPs in hitherto disease-free regions, caused by (1) transport of infected piglets from the red area to the green area in Figure 1.2, causing new IPs, and (2) the subsequent neighbourhood infections of these new IPs. Output of this epidemiological analysis will be used for the economic analysis of the two scenarios.

The results, based on the model used before by Backer et al. (2013), were as follows. The mean number of infected transports in the country under the alternative scenario is 0.53 per CSF epidemic, causing the same number of (finisher) farms (0.53) infected by piglet transport. The total number of additional infected farms per epidemic has a mean value of 1.01 farms (with median value 0), when the normal frequency of one piglet transport per multiplier farm per week is applied. This reduces to a mean of 0.84 farms (with median value 0) at a lower piglet transport frequency of once every three weeks.

The estimated number of additional infected farms must be compared to the mean epidemic size of CSF in the Netherlands under the default scenario, which equals 15.8 infected farms. So due to lifting the piglet transport ban in the red areas, the mean increase of the CSF epidemic size by 1.01 farms (assuming one piglet transport per week per multiplier farm) represents an increase of 6.4%.

In addition to looking at the increase in total epidemic size, we can compare the number of transmission jumps in the country during a CSF epidemic. The mean number of jumps more than 50 km away from the source farm increases from 0.21 under the default scenario to 0.74 per epidemic under the alternative scenario with a normal piglet transport frequency of once a week. In other words, this number increases by a factor 3.5 when lifting the piglet transport ban in the red areas. However, the value of 0.74 jumps can be reduced by transporting piglets from farms in red areas as much as possible to farms in the same red areas, i.e. not to green areas further away.

The number of farms with piglets located in the red areas to be screened (before their piglet transport) is very high, with mean values varying from 30-70 farms per working day during the first 8 weeks of the epidemic. This number increases to 96 farms per working day at later stages of the epidemic, if red areas are not declared free from infection.

Model simulations revealed that the average number of piglets produced in infected areas but outside the 10 km PS-zone of infected premises amounted to 2.22 million after 119 days (given an epidemic in three specific regions 8, 18 and 19). Allowing transport in affected regions will reduce piglet surplus considerably. On average supply balances demands within affected regions, however in 5% of the epidemics piglet surplus will exceed 0.28 million after 119 days. If besides allowing transport also permitted stocking density is temporarily increased (with 10% or 30%) or fattening period shortened (from 115 days to 100 days) supply will exceed demand in areas of interest.

Easing the transport ban would increase the risk of transmission (i.e., larger epidemics) thereby increasing control and enforcement costs by 6.1 million Euro. Compared to other costing components the relative impact of an increased epidemic size is less relevant. The economic losses due to reduced revenues in infected areas (i.e., channelling and suboptimal value) are offset by the foregone costs of culling and destructing valuable products (i.e., welfare slaughter programme).

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Chapter 1. Epidemiological evaluation of the extra transmission risk

1.1 Introduction

Background and research question

Given the large number of piglets that need to move from multiplier to finisher farms, transport restrictions in certain areas affected by Classical Swine Fever (CSF) or Foot-and-Mouth Disease (FMD) will lead to a piglet surplus problem (in those areas) during CSF or FMD epidemics.

In this report, we investigate the expected effects of reducing the area in which live piglet transports are banned on transmission risk and the piglet surplus during a CSF epidemic in the Netherlands. Such a strategy would potentially be a way to reduce piglet surplus, improve animal welfare and decrease financial costs during an outbreak of CSF or FMD in the Netherlands. In our analyses we consider the following effects resulting from a reduction of the area under piglet transport ban:

- the additional transmission risk
- the reduction of the piglet surplus
- the financial costs and benefits

Currently, regions under transport ban are determined using a set of 20 geographical control regions[1] as defined in the Dutch CSF contingency plan (Anon., 2013) and depicted in Figure 1.1. The region under transport ban is formed by those control regions which overlap with so-called Protection- and Surveillance-zones (PS-zones). A PS-zone is the combined area of the Surveillance zone of 10 km around an infected premise (IP) which encapsulates the Protection zone of 3 km around the same IP.

Approach to answering the research question

In the present study, this area placed under animal transport ban in current contingency plans (coloured red + yellow in Figure 1.2) is referred to as the <u>default scenario</u>. As a most extreme <u>alternative scenario</u>, we will investigate the consequences of only placing farms under the piglet transport ban which are located within a 10 km PS-zone around an IP. Thus, for the rest of that control region, extra financial costs will be prevented and the piglet surplus with its associated animal welfare problems will be reduced. As a potential consequence, IPs in a red area that are as yet undetected can in the alternative scenario unknowingly transport infected piglets to other farms (finisher farms), and thus spread the disease further. In this study, we only consider transport of live piglets, and all other types of transports (such as manure etc) remain under the transport ban according to the current contingency plans.

Figure 2.2 illustrates the difference between the default and the alternative scenario: under the default scenario the regions coloured red and yellow are subject to a piglet transport ban, whereas under the alternative scenario only farms located within 10 km PS-zones around detected IPs receive

[1] The Dutch word 'regio (van regionalisatie)' has been translated into 'control region'.

a piglet transport ban (areas coloured yellow). Figure 1.3 shows a map of commercial pig farm densities in The Netherlands in the year 2011.

In this study, the additional transmission risk of a reduction of the area under piglet transport ban (i.e. a reduction of the areas coloured red or yellow in Figure 1.2 to only the yellow areas) will be quantified. For both scenarios the risk will be expressed as the expected mean size of additional IPs in hitherto disease-free regions, caused by (1) transport of infected piglets from the red area to the green area in Figure 1.2, causing new IPs and (2) the subsequent neighbourhood infections of these new IPs.

Output of this epidemiological analysis will be used for the economic analysis of the two scenarios. In this economic analysis the piglet surplus is calculated for both scenarios, as well as the financial costs and benefits difference between the two scenarios.

Figure 1.1: The 20 control regions in the Netherlands as defined in the Dutch CSF contingency plan (Anon., 2013).

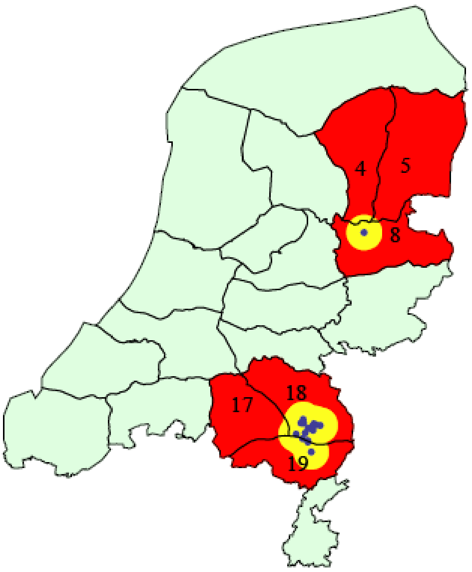

Figure 1.2: Snapshot taken during a simulated CSF epidemic (Backer et al., 2013). Blue dots are detected IPs. Yellow areas denote the 10 km PS-zones around each IP. The green regions are assumed not to be under a piglet transport ban (once the initial national standstill has ceased). In the default scenario, red areas are under a piglet transport ban. In the alternative scenario, red areas are not under a piglet transport ban.

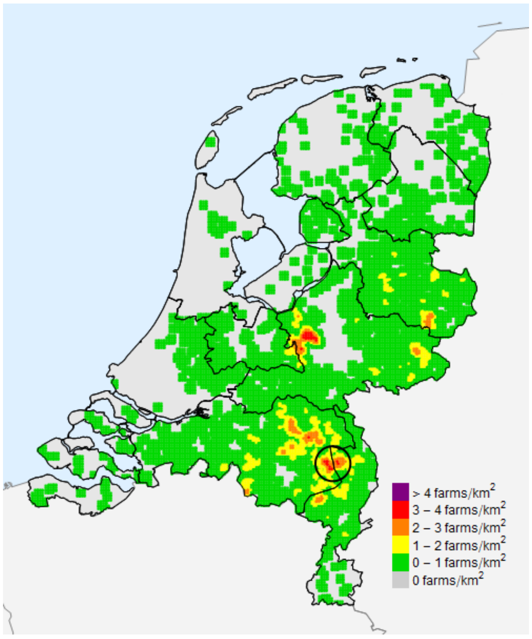

Figure 1.3: Map of pig farm densities in the Netherlands in 2011. The simulated CSF epidemics (Backer et al., 2013) all started in De Peel (black circle), a densely populated livestock area.

1.2 Material and Methods

Modelling of the transmission risks under the default scenario

Here we will employ the same epidemiological model as was used for the BO project 'C-strain vaccination against Classical Swine Fever: effects on epidemic and final screening' (Backer et al, 2013). The model of Backer et al. (2013) is a spatial and stochastic individual-based model and an extension of a previously developed model of CSF virus transmission between animals, pens and farms in the Netherlands (Bergevoet et al., 2007, Backer et al., 2009).

We will use the results of 1000 simulations where the E2-subunit vaccine was used in 2 km rings around detected IPs as control measure, and when 5 farms were infected in De Peel (control region 18, see Figure 1.2 and 1.3) at the end of the High Risk Period (HRP lasting 5 weeks). The effect of the E2-subunit vaccine on the animal-to-animal transmission of CSFV was modelled by separate effects on the susceptibility, infectiousness and infectious period of a vaccinated animal. The between-herd transmission was modelled as a function of the distance between source- and destination herd, called the transmission kernel. The transmission kernel parameters were estimated from the 1997/1998 CSF epidemic in the Netherlands (Boender et al., 2008, Backer et al., 2009, Backer et al., 2013), so they represent the between-herd transmission still occurring during a transport ban. More details such as the values of input parameters for the model can be found in Backer et al. (2013). Table 1.1 shows the number of pig farms and their size as used in the model. Location coordinates of each farm were used, based on the Dutch farm location dataset of 2011 (see Figure 1.3).

Table 1.1: Summary of herd size and number of premises in The Netherlands in 2011 as used in the simulation model (Backer et al., 2013).

	# premises	average herd size	5-95% quintiles of herd size	total # of animals
finishing herds	5688	1139	136 - 3844	6 478 796
sow sections	2425	390	77 - 1087	945 270
piglet sections	2629	1718	211 - 4980	4 517 123
total	7018	1702	156 - 5636	11 941 189

Upon detection of the first infected farm in the country, the EU measures will be applied: culling of infected premises (IP), transport regulations in protection (3 km around IP's) and surveillance (10 km around IP's) zones, as well as tracing and screening of dangerous contacts. In the model, in addition to the EU measures, pre-emptive culling in 1 km around IP's will be applied during the first 5 days. After this period, 1 km pre-emptive culling is replaced by emergency vaccination with the E2-subunit vaccine in 2 km rings around IP's. This is strategy *vacE2_2km* in the report of Backer et al (2013).

Additional modelling steps for the transmission risks under the alternative scenario

For the default scenario we can directly use the output of the 1000 simulated CSF epidemics as a basis for evaluating the risks. For the alternative scenario this output is also used, but now as input for further modelling to estimate the risks arising from live piglet transports occurring in this scenario that are not allowed in the default scenario. Below we describe this further modelling in three steps. Output variables of interest are listed in Table 1.2, and their values are given in the Results section.

Step 1: Infected farms in the red areas

First, we use the 1000 simulated epidemics to calculate the number $N_{\mathrm{farmsinfpiglets}}$ of IPs with infected piglets located in red areas. For an example of the red areas, see Figure 1.2. In the default scenario, the IPs with piglets and located in red areas are subject to a piglet transport ban. In the alternative scenario, these IPs are not subject to a piglet transport ban up until they become detected or become part of a PS zone around another IP. Thus these IPs pose a risk by potentially transporting infected piglets to other (finishers) farms. A related measure of risk is the cumulative number $N_{\mathrm{cuminfdays}}$ of infectious days of these IPs until becoming detected or becoming part of a PS-zone.

Step 2: Transmission by piglet transport from IPs in red areas to farms elsewhere

Just after weaning on multiplier farms, piglets are often sorted by weight to make pens of piglets with a uniform starting weight. By law, piglets are allowed to be mixed, but only once. After that they stay together. In addition, when piglets are transported, they are all sent to the same finisher farm. This makes it likely that infected piglets from one multiplier farm stay grouped, and therefore it becomes relevant to consider the destination of the whole group of infected piglets. Thus, in our model we assume that in the period before the IP becomes detected or becomes part of a PS-zone, such a group of piglets will either be transported as a whole, thereby infecting one single finisher farm, or not be transported, thereby infecting none.

The probability p_{inf} that transport of the group of infected piglets takes place can be calculated from the cumulative number $\overline{N}_{\mathrm{infdaysperfarm}}$ of infectious days per IP in a red area and the average residence time D_{piglets} of a piglet in the weaned piglet section of a multiplier farm (i.e. the time between weaning and transport to a finisher farm), which is around 5 weeks. Note that if the frequency in which piglets are transported to finisher farms would be set to once per three weeks in crisis time (instead of the normal value of once a week) and all pigs would be kept on the multiplier farm for a minimum of 5 weeks, then the value for $D_{piglets}$ increases with 1 week to 6 weeks. Due to this longer average residence time, the value of the probability p_{inf} would be lowered by 20%.

The total number $N_{\mathrm{inftransports}}$ of infected piglet transports from red areas (and thus of new IPs infected via piglet transport) arises from a binomial distribution with a probability of success equal to p_{inf} and number of draws equal to the number $N_{\mathrm{farmsinfpiglets}}$ of IPs with infected piglets in red areas.

Step 3: Total number of newly infected farms outside already affected regions

As a worst-case scenario we assume that all infected piglet transports go over long distances, infecting finisher farms located in areas outside the control regions already affected. We note that whether such a scenario is relevant depends on the question whether or not the piglet surplus could already be addressed by allowing piglet transports only within the red areas. This question is studied in Chapter 2 of this report (economic evaluation), and is important because allowing piglet transports from red to green areas goes against the general purpose of regionalisation.

As a result of the worst-case scenario assumption, the number of distant infected finisher farms is equal to $N_{\text{inftransports}}$. Before detection of these infected finisher farms, they can subsequently infect their neighbouring farms, a process which was modelled by the between-herd transmission kernel discussed above, describing all unknown transmission routes in the presence of an animal transport ban. We therefore call these newly infected finisher farms ‘distant seeders’. The distribution of the number of subsequent neighbourhood infections per distant seeder was obtained also from the 1000 simulated epidemics, by identifying all long jumps (of 50 km or more) in these epidemics and counting their subsequent neighbourhood infections.

The total number of additional infected IPs per epidemic (N_{add}) resulting from lifting the piglet transport ban in the red areas is the sum of the number of infected transports (i.e. distant seeders) and their number of subsequent infections. From the simulated distribution of N_{add} we calculate the mean, the median and the 5% and 95% quantiles.

Table 1.2: List of one parameter ($\boldsymbol{D_{\text{piglets}}}$) and seven output variables of interest.

Symbol	Origin	Units	Description
D_{piglets}	Expert knowledge	days	Average residence time of a weaned piglet on a multiplier farm.
$N_{\text{farmsinfpiglets}}$	Simulated epidemics	farms	Number of farms with infected piglets in the red areas.
$N_{\text{cuminfdays}}$	Simulated epidemics	days	Cumulative number of days of all farms with infected piglets in the red areas per epidemic.
$\bar{N}_{\text{infdaysperfarm}}$	Simulated epidemics	days/farm	Average period that a farm contains infectious piglets in red areas.
p_{inf}	Simulated epidemics + further modelling	-/-	Probability that transport of the group of infected piglets takes place from an IP with infected piglets in a red area.
$N_{\text{inftransports}}$	Simulated epidemics + further modelling	# transports	Number of infected transports leaving the red areas (not the yellow PS zones) per epidemic.
$N_{\text{subseqcases}}$	Simulated epidemics	farms/farm	Number of subsequent infections per ‘distant seeder’.
N_{add}	Simulated epidemics + further modelling	# farms	Number of additional infected IPs per epidemic.

1.3 Results

Epidemiological analysis of the default scenario

Table 1.3 shows the results of 1000 simulated CSF epidemics, where the epidemic started in De Peel with 5 infected farms at the end of the HRP (Backer et al., 2013). The size of the epidemics controlled by 2-km ring vaccination with the E2subunit vaccine (*vacE2_2km*) is relevant for the present study. The size for the other scenarios of EU measures only (*EU*) and 1-km ring culling (*cul_1km*) are given as comparison. The median epidemic size for *vacE2_2km* is 14 detected farms, with range of 5 to 32. The mean size is 15.8 detected farms.

Table 1.3. Simulation results of 3 control strategies EU, cul_1km and vacE2_2km: epidemic duration, number of detected, pre-emptively culled and vaccinated farms per CSF epidemic; median values and (5% - 95%) interval between brackets.

control strategy	duration* (days)		number of detected farms		number of preemptively culled farms		number of vaccinated farms	
EU	202	(65 - 475)	40	(10 - 128)	0	(0 - 0)	0	(0 - 0)
cul_1km	93	(35 - 199)	13	(5 - 27)	79	(26 - 173)	0	(0 - 0)
vacE2_2km	113	(37 - 236)	14	(5 - 32)	8	(2 - 20)	191	(56 - 414)

*Duration of the epidemic is defined as the time between the first and the last detection.

Epidemiological analysis of the alternative scenario

Also derived from the *vacE2_2km* simulations is the number of farms with infected piglets in the red areas: $N_{\text{farmsinfpiglets}}$. Table 1.4 shows the Probability Density Function (PDF), i.e. the distribution of $N_{\text{farmsinfpiglets}}$ in the 1000 simulated epidemics. According to this table, 52.1 % of the CSF epidemics in the Netherlands had no IPs with infected piglets located in the red areas at all. So in half of the epidemics there is no risk at all of lifting the piglet transport ban in these (red) areas. But in the other 47.9 % of the epidemics, 1 to 6 infected farms were located in the red areas at their moment of infection. These farms can cause a risk. Overall, $\mathrm{N}_{\text{farmsinfpiglets}}$ has a mean of 0.848 farms.

Table 1.4: Distribution of $\mathrm{N_{farmsinfpiglets}}$ over 1000 simulated CSF epidemics. $\mathrm{N_{farmsinfpiglets}}$ is the number of farms with infected piglets in the red areas at their moment of infection.

Distribution for $\mathrm{N_{farmsinfpiglets}}$

value	probability
0	0.521
1	0.268
2	0.109
3	0.067
4	0.019
5	0.011
6	0.005

mean = 0.848

The cumulative number of infectious days of all the IPs with infected piglets in the red areas, denoted by $N_{\mathrm{cuminfdays}}$, is the total number of days that those farms present a risk of CSF spread via piglet transport. As shown in Table 1.5A, the mean value of $N_{\mathrm{cuminfdays}}$ based on the 1000 *vacE2_2km* simulations is 18.4 days. To put this number into perspective, Table 1.5A also gives the mean cumulative number of infectious days of all IPs with infected piglets in the yellow and in the green areas (see Figure 1.2) in the Netherlands, as well as the corresponding quantities for IPs with infected finisher pigs and for IPs with infected sows. The mean value for $N_{\mathrm{cuminfdays}}$ of 18.4 days is small compared with the much higher number of 120.9 days of IPs with infected piglets located in yellow areas (i.e. PS-zones) at their moment of infection. According to Table 1.5A, the mean total number of infectious days of IPs with infected piglets is 143.4 days, to which the PS-zones contribute 84.3%, the red areas 12.9%, and the green areas 2.8%. The IPs in green areas correspond to long-distance between-herd transmission events that are already present in the default scenario.

Table 1.5A: Cumulative number of infectious days of farms with infected finishers, infected sows or infected piglets per epidemic: mean values in different areas.

	Area		
Herd type	PS-zone[1]	Red[1]	Green[1]
Finishers	209.2	29.9	7.1
Sows	158.1	17.5	3.6
Piglets	120.9	18.4	4.1
Any	481.3	65.3	14.7

[1] for these areas, see Figure 1.2

When considering number of infected farms (IPs, all herd types combined) instead of the number of infectious days of IPs with infected piglets, a comparable contribution of 85%, 12% and 2.8% is found for IPs located in the PS-zones, the red areas and the green areas, respectively. Data are shown in Table 1.5B. The first detected farm of the epidemic (first case) is not located in a PS-zone yet at the moment of detection.

Table 1.5B: Location of detected farms (at the moment of their detection) in 1000 simulated CSF epidemics.

Type	Mean	Median	5%-quantile	95%-quantile
First case	1.00	1	1	1
PS-zone[1]	12.64	11	3	27
Red[1]	1.74	2	0	4
Green[1]	0.42	0	0	2
Whole of NL (total)	15.80	14	5	32

[1] for these areas, see Figure 1.2

From Table 1.4 and Table 1.5A it was calculated that the mean number of infectious days per farm with infected piglets in a red area ($\overline{N}_{\mathrm{infdaysperfarm}}$) is 21.7 days. Using this number and a value for D_{piglets} (the average residence time of weaned piglets on a multiplier farm), the probability p_{inf} that a given IP with infected piglets, and located in a red area at its moment of infection, infects a finisher farm via piglet transport is equal to 0.62 when D_{piglets} is 5 weeks and 0.52 when D_{piglets} is 6 weeks. These residence times of 5 and 6 weeks correspond with a piglet transport frequency of once a week (normal value) and once per three weeks, respectively.

As explained in the Materials and Methods section, the number of infected piglet transports ($N_{\mathrm{inftransports}}$) leaving from IPs in red areas is binomially distributed, with probability of success denoted by p_{inf}. The results for $N_{\mathrm{inftransports}}$ are shown in Table 1.6. According to this table, in 64.7% of the CSF epidemics there is no infected piglet transport from a red area at all under the alternative scenario, with a normal value for the piglet transport frequency of once a week. In the other 35.3% of the epidemics, 1 to 6 infected transports occur. The mean number of infected piglet transports from red areas is 0.53 per epidemic (Table 1.6).

If all these transports are to distant (say >50 km away) finisher farms, this corresponds to a mean additional number of transmission jumps of more than 50 km away from the source farm of 0.53. For the default scenario (of a piglet transport ban in the red areas) the mean number of such long jumps is approximately 0.21 per epidemic (see Appendix A for details). Therefore, under the alternative scenario this increases from 0.21 to 0.74 per epidemic for a normal piglet transport frequency of once a week.

Table 1.6. The total number of infected transports per epidemic for different piglet transport frequencies.

	Piglet transport frequency once per week, i.e. $D_{\text{piglets}} = 5$ weeks	Piglet transport frequency once per 3 weeks, i.e. $D_{\text{piglets}} = 6$ weeks
Number of infected transports	Probability [1]	Probability [2]
0	0.6470	0.6841
1	0.2338	0.2267
2	0.0803	0.0632
3	0.0282	0.0197
4	0.0082	0.0042
5	0.0021	0.0020
6	0.0004	0.0001

[1] Mean number of infected transports (and thus distant seeders): 0.525
[2] Mean number of infected transports (and thus distant seeders): 0.440

Each infected piglet transport leads to a new IP, which is called a 'distant seeder'. The number of subsequent cases per 'distant seeder', $N_{\text{subseqcases}}$, is given in Appendix A, with mean 0.94 farms per 'distant seeder'. The distribution of the total number of additional infected farms per epidemic N_{add} obtained from the distribution of $N_{\text{inftransports}}$ and that of $N_{\text{subseqcases}}$, is characterized in Table 1.7**.** For $D_{\text{piglets}} = 5$ weeks, the mean total number of additional IPs per epidemic equals 1.01, with 5% and 95% quantiles being 0 and 5, respectively. In 64.7% of the CSF epidemics there is no additional infected farm at all when lifting the piglet transport ban in the red areas. In another 16.5 % of the epidemics 1 additional infected farm occurs and in the other 18.8 % more than 1 additional infected farm occurs. For $D_{\text{piglets}} = 6$ weeks, the mean total number of additional IPs per epidemic equals 0.84, with 5% and 95% quantiles being 0 and 4, respectively. (The fact that the value of $N_{\text{farmsinfpiglets}}$ in Table 1.3 is also 0.84 is a pure coincidence).

As a summary, Table 1.8 shows the mean estimates of all relevant output variables. Table 1.9 shows a summary of results comparing the default transport ban scenario to the alternative scenario, for a piglet transport frequency of once a week.

Table 1.7. Distribution of the total number of additional infected farms (IPs) per epidemic, resulting from lifting the piglet transport ban in the red areas, at different piglet transport frequencies.

	Piglet transport frequency once per week, i.e. $D_{\text{piglets}} = 5$ weeks	Piglet transport frequency once per 3 weeks, i.e. $D_{\text{piglets}} = 6$ weeks
Total number N_{add} of additional IPs (distant seeders + subsequent IPs)	Probability [1]	Probability [2]
0	0.647	0.684
1	0.165	0.160
2	0.068	0.059
3	0.038	0.032
4	0.024	0.020
5	0.015	0.012
>5	0.042	0.033

[1] Mean number of additional IPs: 1.01
[2] Mean number of additional IPs: 0.84

Table 1.8: Mean estimates of relevant output variables. When two values are given, the first value corresponds to a piglet transport frequency of once per week, and the second to a piglet transport frequency of once per 3 weeks.

Symbol	Origin	Mean value	Units	Description
$N_{\text{farmsinfpiglets}}$	Simulated epidemics	0.848	days	Average residence time of a weaned piglet on a multiplier farm.
$N_{\text{cuminfdays}}$	Simulated epidemics	18.4	farms	Number of farms with infected piglets in the red areas.
$\bar{N}_{\text{infdaysperfarm}}$	Simulated epidemics	21.7	days	Cumulative number of days of all farms with infected piglets in the red areas per epidemic.
p_{inf}	Simulated epidemics + further modelling	0.62 or 0.52	days/farm	Average period that a farm contains infectious piglets in red areas.
$N_{\text{inftransports}}$	Simulated epidemics + further modelling	0.53 or 0.44	-/-	Probability that transport of the group of infected piglets takes place from an IP with infected piglets in a red area.
$N_{\text{subseqcases}}$	Simulated epidemics	0.94	# transports	Number of infected transports leaving the red areas (not the yellow PS zones) per epidemic.
N_{add}	Simulated epidemics + further modelling	1.01 or 0.84	farms/farm	Number of subsequent infections per 'distant seeder'.

Table 1.9: Summary of results comparing the default transport ban scenario to the alternative scenario. Only results for a piglet transport frequency of once per week are given.

Symbol	**Default:** no transport of piglets in red areas Mean value	**Alternative:** piglet transports allowed in red areas Mean value	Units	Description
$N_{inftransports}$	0	0.53	# transports	Number of infected piglet transports leaving the red areas per epidemic (=number of distant seeders).
# jumps (>50 km)	0.21 [1]	0.74 [2]	farms	Farms infected by source farms > 50 km away per epidemic
N_{add}	0	1.01	farms	Number of additional infected farms per epidemic, due to piglet transport in red areas.
Total epidemic size	15.8	16.8	farms	Number of detected farms per epidemic

[1] See Table A in Appendix A: 208 jumps of >50 km were observed in 1000 simulated epidemics.
[2] Calculated as the sum of 0.21 (default number of jumps) and 0.53 (number of distant seeders due to piglet transport in red areas).

Extra control measure: screening of all multiplier farms in the red areas, before piglet transport takes place to finisher farms.

To reduce the probability that an infected piglet transport takes place (i.e. to reduce p_{inf}), each multiplier farm can be screened shortly before transport of the piglets to another farm. Screening can take place (shortly before piglet transport) by visual inspection of piglets, or by a PCR test. Table 1.10 shows the number of farms with piglets located in the red areas during a CSF epidemic, according to simulations of Backer et al. (2013), and the corresponding number of farms to be screened per working day, when all farms with piglets located in the red areas (second column of Table 1.10) are screened within a period of one week.

Table 1.10: Number of farms with piglets located in the red areas in 1000 simulated CSF epidemics; mean values and (5% - 95%) interval between brackets.

Week since first detection	Number of farms with piglets located in the red areas		Number of farms with piglets to be screened per working day	
0	163	(139-181)	32.6	(27.8-36.2)
2	194	(143-291)	38.9	(28.6-58.2)
4	261	(172-401)	52.2	(34.4-80.2)
8	359	(211-542)	71.8	(42.2-108.6)
16	449	(242-689)	89.8	(48.4-137.9)
32	480	(245-754)	96.0	(49.0-150.8)
48	482	(245-758)	96.4	(49.0-151.6)
54	482	(245-758)	96.4	(49.0-151.6)

Table 1.10 shows that the number of farms with piglets in the red areas continues to increase during the epidemic. This is due to the fact that red areas remain their red status during the epidemic, and they are not declared free from infection (i.e. become green) until the final screening, which in the model takes place at the end of the epidemic. In reality, red areas can be declared free from infection earlier during the epidemic, 42 days after the last detection in that region. This decision is, however, a political one, which cannot be simulated by the model. Furthermore, the figures of Table 1.10 during the first 8 weeks of the epidemic are not affected by this, as that is too early for declaring areas free from infection.

Nevertheless, Table 1.10 shows that the number of farms to be screened (before their piglet transport) is very high, with mean values varying from 30-70 farms per working day during the first 8 weeks of the epidemic.

1.4 Discussion and Conclusions

Infected farms in the red areas

According to our model simulations, about half of the CSF epidemics in the Netherlands have no farm with infected piglets located in the red areas at all. But in the other half of the epidemics, 1 to 6 farms with infected piglets were located in the red areas at their moment of infection. These farms can cause a risk when the piglet transport ban in these areas is lifted. Overall, the mean number of farms with infected piglets in the red areas is 0.85 farms per epidemic. This number of infected farms (0.85) causes 18.4 emission-days in the red areas, which is 13% of the total number of emission-days caused by farms with infected piglets before detection in the whole country. Most of the emission-days (84%) are caused by farms located in the PS-zones, where a standstill was already implemented.

Transmission by piglet transport from IPs in red areas to farms outside these regions

With a normal value for piglet transport frequency of once a week, in 65% of the CSF epidemics there is no infected transport at all, when lifting the piglet transport ban in the red areas. In the other 35% of the epidemics, 1 to 6 infected transports occur in the country. The mean number of infected transports in the country is 0.53 per epidemic, causing the same number of farms (0.53) infected by piglet transport.

Total number of newly infected farms outside the red areas

With a normal piglet transport frequency of once a week, in 65% of the CSF epidemics there is no additional infected farm at all, when lifting the piglet transport ban in the red areas. In another 16.5% of the epidemics, 1 additional infected farm occurs and in the other 18.8% more than 1 additional infected farm occurs. The total number of additional infected farms per epidemic has a mean value of 1.01 farms (with median value 0), when the normal frequency of one piglet transport per week is applied. This reduces to a mean of 0.84 farms (with median value 0) at a lower frequency of one per three weeks.

The estimated numbers of additional infected farms must be compared to the mean epidemic size of CSF in the Netherlands under the default scenario, which is 15.8 infected farms according to Backer et al. (2013). So due to lifting the piglet transport ban in the red areas, the mean increase of the CSF epidemic size by 1.01 farms (at one piglet transport per week) represents an increase of 6.4%. This reduces to 5.3% at a lower piglet transport frequency of one per three weeks.

Additional to looking at the increase in total epidemic size, we can compare the number of transmission jumps in the country during an epidemic. The mean number of jumps more than 50 km away from the source farm increases from 0.21 under the default scenario to 0.74 per epidemic under the alternative scenario (with a normal piglet transport frequency of one per week). In other words, this number increases by a factor 3.5 when lifting the piglet transport ban in the red areas. However, the value of 0.74 jumps can be reduced by transporting piglets from farms in red areas as much as possible to farms in the same red areas (i.e. not to green areas further away).

Screening of all multiplier farms in the red areas before piglet transport takes place to finisher farms.

The number of farms with piglets located in the red areas to be screened (before their piglet transport) is very high, with mean values varying from 30-70 farms per working day during the first 8 weeks of the epidemic. This number increases to 96 farms per working day at later stages of the epidemic, if red areas are not declared free from infection.

Appendix A. The number of subsequent IPs per distant seeder

The number of subsequent IPs per distant seeder is given in Table A, and was obtained from the simulated epidemics of Backer et al. (2013). In 1000 simulated epidemics, 208 long jumps were observed (i.e. long distance jumps of between-herd transmission of 50 km or more), corresponding to a mean number of 0.208 long jumps per epidemic. These long jumps in CSF transmission are possible because of the tail of the between-herd transmission kernel: there is still a small (but not 0) probability of getting infected at long distances from a source farm. Of these 208 distant seeders, 147 farms (being 70.7 %) did not infect any of their neighbouring farms, so their number of secondary cases was 0. The other 29.3% of the distant seeders did infect neighbouring farms, the number varying between 1 and 14 (see Table A).

Table A: Distribution of $\mathbf{N_{subseqcases}}$. $\mathbf{N_{subseqcases}}$ is the total number of subsequent infected farms per distant seeder. A long jump is a between-herd transmission jump of 50 km or more.

Number of secondary cases per long jump	Absolute number of jumps	Probability
0	147	0.706731
1	25	0.120192
2	13	0.062500
3	8	0.038462
4	4	0.019231
5	2	0.009615
6	0	0.000000
7	1	0.004808
8	2	0.009615
9	1	0.004808
10	1	0.004808
11	1	0.004808
12	0	0.000000
13	1	0.004808
14	2	0.009615
	208	1.000000

Mean number of subsequent IPs caused per distant seeder (long distance infection) is 0.9375.

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Chapter 2. Economic analysis of the piglet surplus

2.1 Introduction

Pig farming is a highly specialized in the Netherlands. Breeding, multiplication and fattening are usually carried out on separate farms. Only a relatively small fraction of farms combine different phases on one location (i.e., closed farms). Movement of animals between different farms is an often occurring event because of this highly specialized production. Furthermore, a large number of piglets are exported from the Netherlands to other EU Member States since fattening of slaughter pigs is an activity increasingly performed outside the Netherlands.

Movement restrictions are a vital part of contingency plans. The spread of CSF or FMD after introduction in a country is reduced by implementing severe movement restrictions for farms that might be at risk of being infected. However, transport restrictions during CSF or FMD epidemics will likely lead to overstocking since pig farmers only have limited possibilities to house extra animals as may be necessary during movement bans. Moreover, movement restriction will also lead to a piglet surplus problem, not only on affected farms, but also on other farms given the relative large number of piglets produced in the Netherlands .

Reducing the area under transport ban is likely to ease the surplus problem, improve animal welfare and decrease financial costs during an outbreak of CSF or FMD in the Netherlands. Easing transport bans in affected regions is expected to reduce specific costing components of an outbreak since density of sow farms and fattening pig farms are highly correlated (Figure 2.1).

However reducing the area under transport ban might have consequences for the course of the epidemic as well. In the previous section the epidemiological impact of easing transport bans during an CSF epidemic in the Netherlands is quantified. The risk assessment focused on the transmission of the virus via piglet transport from infected piglets to other farms and regions.

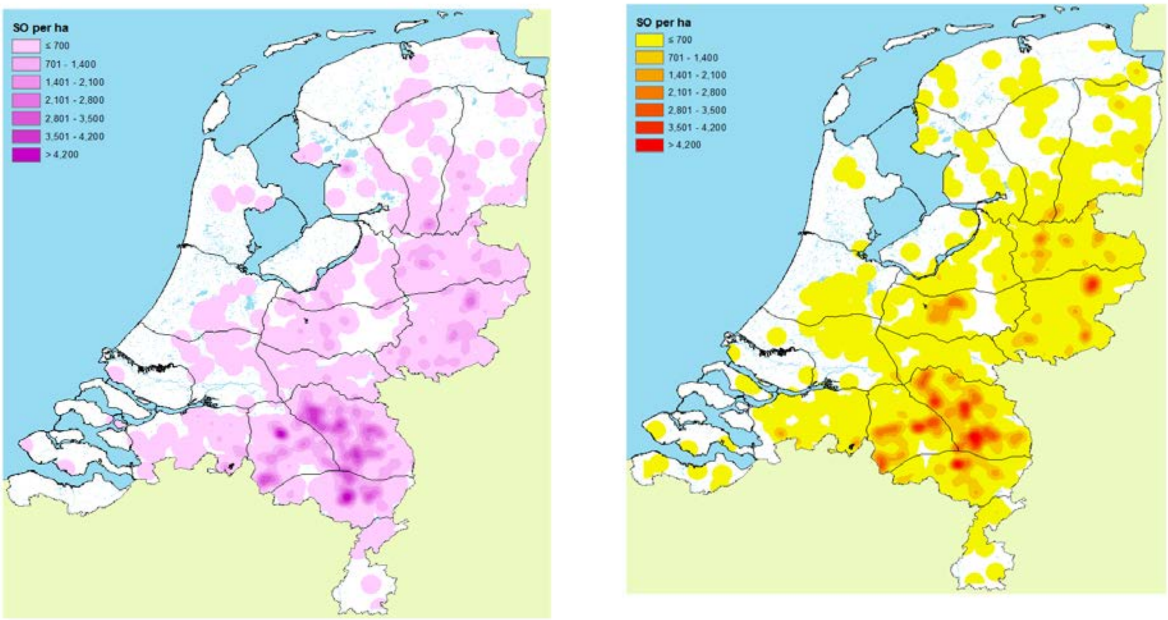


Figure 2.1: Density of sow farms (left) and fattening pig farms (right). Borders of 20 control regions are depicted and units are in SO [2].

In this section the potential impact of reducing the area under transport ban is quantified in terms of costs (e.g., incurred costs because of increased transmission risk) and benefits (e.g., reduction of piglet surplus). Therefore the objective of this part of the research was to evaluate the economic impact of different transport ban strategies. This can contribute to the decision making process of policy makers in government and sector. The following three sub-objectives are identified:

1. Determining the extent of piglet surplus in the different areas during a CSF outbreak;
2. Evaluating strategies to manage the surplus of piglets;
3. Economic evaluation of reducing the area under transport ban.

[2] SO is the standard revenue in euro's used as an indicator of farm size. Average SO for sow farms in the Netherlands amounts 704,000 euro (BINternet, raming 2012) ad 390,000 euro per fattening pig farm (BINternet, raming 2012). Corresponding herd size amounts 555 sows and 1545 fattening pigs respectively.

2.2 Material and Methods

Movement restrictions

The Dutch contingency plan prescribes a movement ban of all livestock for a period of 72 hours in the whole country after the first notification of CSF. All susceptible animals on Infected Premises (IP) are culled. A PS-zone is established in the combined area of the Surveillance zone (“Toezichtsgebied”) of 10 km around an IP, which encapsulates the Protection zone (“Beschermingsgebied”) of 3 km around the same IP. The rest of the country will be divided into infected areas and free areas. For the present study, two areas that are distinguished during an outbreak are of interest, namely:

A) Areas in infected regions but outside the 10 km PS-zone of an IP (hence referred to as infected areas); and

B) Not affected areas.

Infected areas are those areas/regions in which a PS is present. The rest is considered to be a free area. In principle no movement of pigs is allowed in both infected and free areas. However movement bans of pigs might be lifted after permission by the Competent Authorities. This permission will be given only after careful evaluation of the outbreak situation. In free areas restrictive measures will most likely be lifted earlier than in infected areas. In our calculations we assume that transport in the **free areas** from fattening farms to slaughter houses and from breeding farms to fattening farms is allowed rather soon after the onset of the outbreak. For infected areas we consider two situations: a) in the default situation we assume that in the **infected areas** no transport is allowed; and b) in the alternative situation in **the infected areas (except PS**) transport from fattening farms to slaughter houses and from breeding farms to fattening farms of piglets is allowed. In the contingency plan it is foreseen that within infected areas slaughtering of infected animals is possible. However it is not clear at which stage this is allowed and if and when transport from breeding to fattening farms is allowed. Hence the two alternative scenarios.

Figure 2.2A illustrates the default scenario of regions which are confronted with an animal transport ban (coloured red and yellow) when outbreaks are detected in three specific control regions 8, 18 and 19. Figure 2.2B illustrates the alternative scenario where only farms located within 10 km PS-zones around detected IPs are confronted with a transport ban (coloured yellow) and the absence of a transport ban for the rest of the regions. In both the default and alternative scenario all farms within a PS-zone are under the transport ban.

In this study, the additional transmission risk of a reduction of the area under transport ban (a reduction of the area coloured red + yellow in Figure 2.2A to only yellow in Figure 2.2B) will be quantified. The risk will be expressed as the expected mean size of additional IPs in formerly disease-free regions, caused by (1) unknown transport of infected piglets from the red area to the green area in Figure 2.2 and (2) the subsequent neighbourhood infections of these new IPs. Per area the number of farms with piglets, sows, and fattening pigs are summarised on a weekly basis until the end of outbreak (Backer et al., 2013). For this, we will use the output of 10.000 simulated CSF epidemics in the Netherlands of Backer et al. (2013), where 2 km ring vaccination with the E2 subunit vaccine was used as control measure.

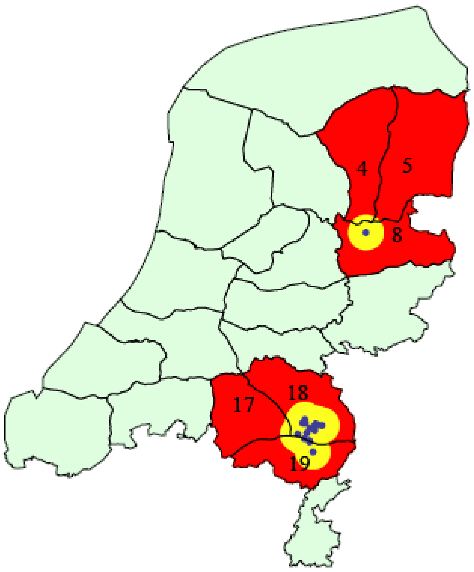


Figure 2.2A: Default scenario. Blue dots are detected IPs. Yellow disks denote the 10 km PS-zones around each IP. Outbreaks in control regions 8, 18 and 19 cause a transport ban in the northern control regions 4, 5 and 8 and in the southern regions 17, 18 and 19. The green regions are not under a transport ban.

Figure 2.2B: Alternative scenario. Blue dots are detected IPs. Yellow disks denote the 10 km PS-zones around each IP. Only the yellow regions (PS-zones) are placed under a transport ban. The green regions are not placed under a transport ban.

Extent of piglet surplus in the different areas and management strategies

In the present study, the extent of piglet surplus during a CSF outbreak is determined per investigated area. This surplus is based on weekly difference in piglet production and fattening pigs delivered for slaughtering. Average herd size is 390 sows. The average number of piglets produced per sow per year is set at 25 and this results in a piglet production of 188 piglets/week/sow farm. The average herd size on a fattening farm is 1136 and with a fattening period is 115 days (3.18 production cycles per fattening pig place of $1m^2$) there are 69.5 pigs/week ready for slaughter . These input values together with the number of breeding and fattening farms in the different areas were used to calculate on a weekly basis piglet production in a region and the number of slaughter pigs that are ready for slaughter.

To manage the surplus of piglets three options are analysed:

a. Allowing transport within areas (i.e., within infected areas);

b. Additional measures:

b1. Higher stocking density by reducing the space per fattening pig (10% or 30% increased stocking density instead of 0.8m2 (default);

b2. More pigs fattened per year per place by lowering slaughter weight by reducing the fattening period to 100 days instead of 115 days (default).

Note that the maximum allowed stocking density is depending on average weight of a pen; for the range of 30-50 kg, 50-85 kg, 85-110 kg and above 110 kg the area per pig should be at least 0.5m^2, 0.65m^2, 0.80m^2 and 1.00m^2 respectively.

Economic evaluation of reducing the area under transport ban

Given the objective of the study only the differences in economic consequences between the different strategies were evaluated. To evaluate the economic consequences of the different strategies an existing economic model is used (Backer et al., 2009). This model is based on partial budgeting. In partial budgeting only those costs and benefits that are expected to differ substantially between alternatives are included. Given the main objective of this research, to compare the effects of different strategies, this evaluation method is appropriate. Price data of 2012 were used. In case no recent data are available (e.g. because some cost can only be determined after an outbreak) they are based on historical data indexed for a price level of 2012. For this indexation price indexes of CBS were used. Bergevoet and van Asseldonk (2013) estimated that the average cost of an outbreak of CSF in the Netherlands in which vaccination with a E2 subunit vaccine in an area of 2 km around an infected farms will cost around 45 million Euro (excluding enforcement, welfare culling and export losses) given an average of 14 infected farms as estimated by Backer et al. (2013).

Additional costs and **cost foregone** are the two main additional components in the current partial budget to evaluate differences between a strategy with a transport ban and a strategy without an transport ban in infected areas (outside PS area).

The first component of additional cost stems from the risk of <u>increased control</u> costs because of larger expected outbreaks. Increased control costs comprise culling and the potential risk of establishing new PS's and vaccination areas. The average costs per (extra) infected farm will amount 3.4 million Euro (Bergevoet and van Asseldonk, 2012).

The second component of additional costs comprises <u>extra enforcement costs.</u> Enforcement costs are costs related to police involvement and other control agencies to ensure compliance with the movement restrictions an execution of regulations. The enforcement costs are likely to be different between the strategies since it affects the risk that an area outside the PS zone might become infected. However, they are difficult to estimate, since they depend on the location of the outbreaks, enforcement deemed necessary by the competent authorities and the expected cooperation of farmers in the affected areas. Enforcement costs are mainly affected by the duration of the outbreak and are often substantial. In previous outbreaks enforcement costs were estimated to be as high as 335,000 Euro per day (Bergevoet et al, 2012). Although less precise, in the current analysis we specified the enforcement costs by the size of the outbreak (2.7 million Euro per infected farm).

The third component of additional costs comprises <u>logistic slaughter costs</u> and the associated reduced revenues due to <u>suboptimal value creation</u>. It is assumed that in the situation in which the transport ban is eased within infected areas (except PS area) it is possible to transport fattening pigs to slaughter houses (one origin per transport). Idle fattening pig places are stocked with piglets from breeding farms within the area (one origin per transport). Logistic slaughter costs and suboptimal value creation in infected areas are comparable to the value loss of vaccinating animals (which need to be logistically slaughtered as well) and amount 0.44 Euro per kg (Bergevoet et al 2007). The total volume affected depends on the number of animals slaughtered in the infected areas during the outbreak.

The first component of cost foregone arise from abandoning culling and destruction of piglets and the second component results from abandoning culling and destruction of fattening pigs. Alternatively, within the partial budget approach additional benefits could be accounted for in term of extra revenues of piglet sales and finishing pig sales instead of accounted for costs forgone.

With a transport ban welfare problems will arise after a while. During the CSF outbreak in 1997/1998 an extensive welfare culling programme was implemented. Welfare culling is a term used to describe the culling of animals because of overcrowding or other deteriorating animal husbandry conditions on farms placed under movement restriction. The current contingency plan does not foresee such programme so it is unlikely that a welfare culling programme will be applied to such extend as in the past. However, in the current default situation we include costs associated with welfare culling and thus accounting for the overall costs (but do not address whether these costs are borne by the sector or government).

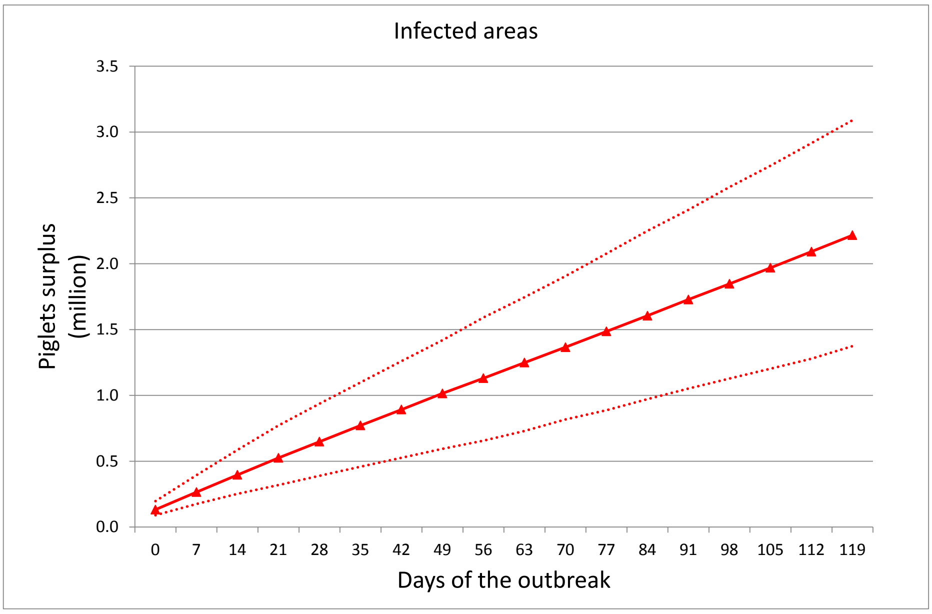
It is assumed that animals under the welfare culling programme are destroyed and rendered (Meuwissen et al., 2003). Welfare slaughter generally refers to animals that are ready to be delivered (farrowing farm: 23 kg piglets; other types of farms: 116.9 kg fattening pigs). Cost foregone comprises expenses for killing and destruction as well as the market value of the animal. Accounted foregone costs are assumed to amount to 56 Euro and 147 Euro per piglet and fattening pig respectively (Meuwissen et al., 2003). The total volume affected depends on the number of piglets and fattening pigs in the infected areas during the outbreak. Note if meat under the welfare culling programme is allowed to enter the food chain logistic slaughter costs and the associated reduced revenues due to suboptimal value creation need to be accounted for.

2.3 Results

Determining the extent of piglet surplus in the different areas during a CSF outbreak

The number of piglets produced in each area depends on the number of sow farms. The extent of piglet surplus in each area subsequently depends on whether or not transport is allowed from fattening farms to the slaughter house and between farrowing farms and finishing farms. Current analysis is based on the spatial model of Backer et al. (2013) in which the number of sow sections and piglet sections amounted 2425 and 2629 respectively. Average herd size amounted to 390 sows and 1718 piglets (see Table 1.1, section Epidemiological evaluation).

The total number of piglets produced increases linearly over time in all areas (Figure 2.3). The average number of piglets produced in infected areas (outside the 10 km PS-zone of infected premises) amounted 2.22 million after 119 days. For ease of interpretation only outcomes for this time period are presented because it approximately equals the average duration to produce fattening pigs. A wide variation in the number of piglets produced in areas with transport bans was observed as presented in terms of the 5% percentile and 95% percentile values. The average number of piglets produced in areas without transport bans amounted approximately 4.12 million after 119 days.



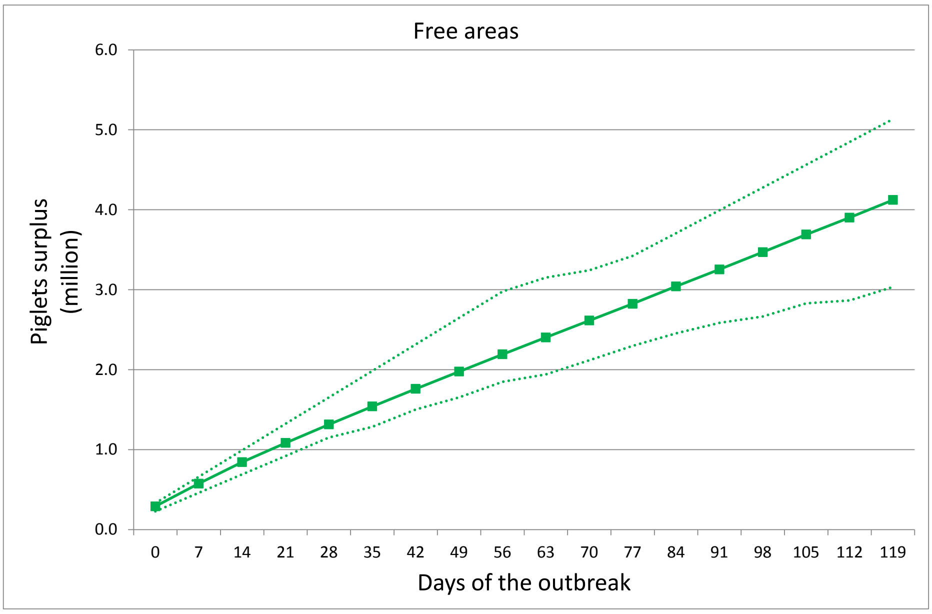


Figure 2.3: Cumulative number of piglets of 25kg per week in infected areas (above) and free areas (below). Solid line represents average, dashed lines represent 5% and 95% percentile values.

In the epidemiological model of Backer et al. (2013) the total number piglets present amounted 4.52 million (assuming 0.945 million sows). Given these characteristics the **annual** production of piglets inside the 10 km PS-zone of an infected premises, in the infected areas and free areas was on average 4.52 million piglets, 6 million piglets and 12 million piglets respectively. Although the majority of the piglets are domestically fattened, the average number of piglets exported is approximately 6.9 million per year (Westra, 2013).

To determine the national piglet surplus besides domestic supply (i.e., piglets produced) also domestic demand (i.e., size of fattening pig production) need to be quantified. In the epidemiological model of Backer et al. (2013) 5688 fattening pig herds were included, with an average herd size of 1139 fattening pigs (see Table 1.1, section Epidemiological evaluation).

As a result of the simulated CSF outbreak and transport ban control strategy the number of places with ready to slaughter pigs will increase over time in infected regions but outside the 10 km PS-zone of an IP. In case only transport of fattening pigs to the slaughter house but no transport of piglets to fattening farms is allowed, all fattening pigs are slaughtered 119 days after transport ban commenced (Figure 2.4). The average number of idle fattening pig places after 119 days amounted to approximately 2 million, although a wide variation was observed as presented in terms of the 5% percentile and 95% percentile values. The average number of fattening pig places in areas without transport bans exceeded 3 million.

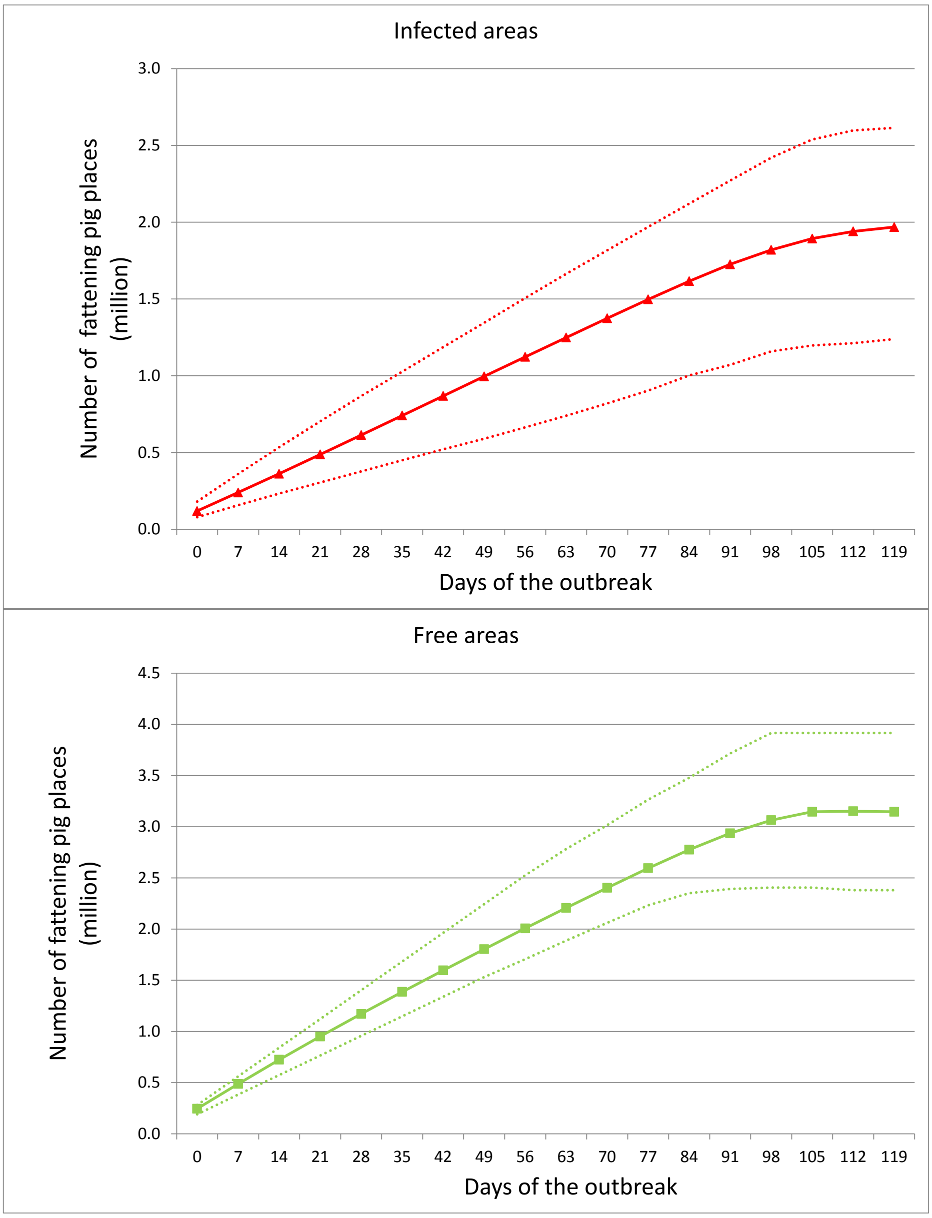


Figure 2.4: Cumulative number of fattening pigs per week in infected areas (above) and free areas (below). Solid line represents average values, dashed lines represent 5% and 95% percentile values.

In the epidemiological model of Backer et al. (2013) the total number of fattening pigs present amounted 6.5 million. The average number of fattening pigs in inside the 10 km PS-zone of an IP was on average 1.5 million (total animals 6.5 million minus 2 million in infected areas minus 3 million in free areas).

Evaluating strategies to manage the surplus of piglets.

In the current contingency plan piglet transport to fattening farms in not allowed in affected regions (i.e., infected areas). Allowing transport in affected regions will reduce piglet surplus considerably. In Figure 2.5 idle places refer to the availability of fattening pig places for piglets, while in the case of a surplus this option is not feasible. On average supply balances demands, however in 5% of the outbreaks piglet surplus will exceed 0.28 million after 119 days.

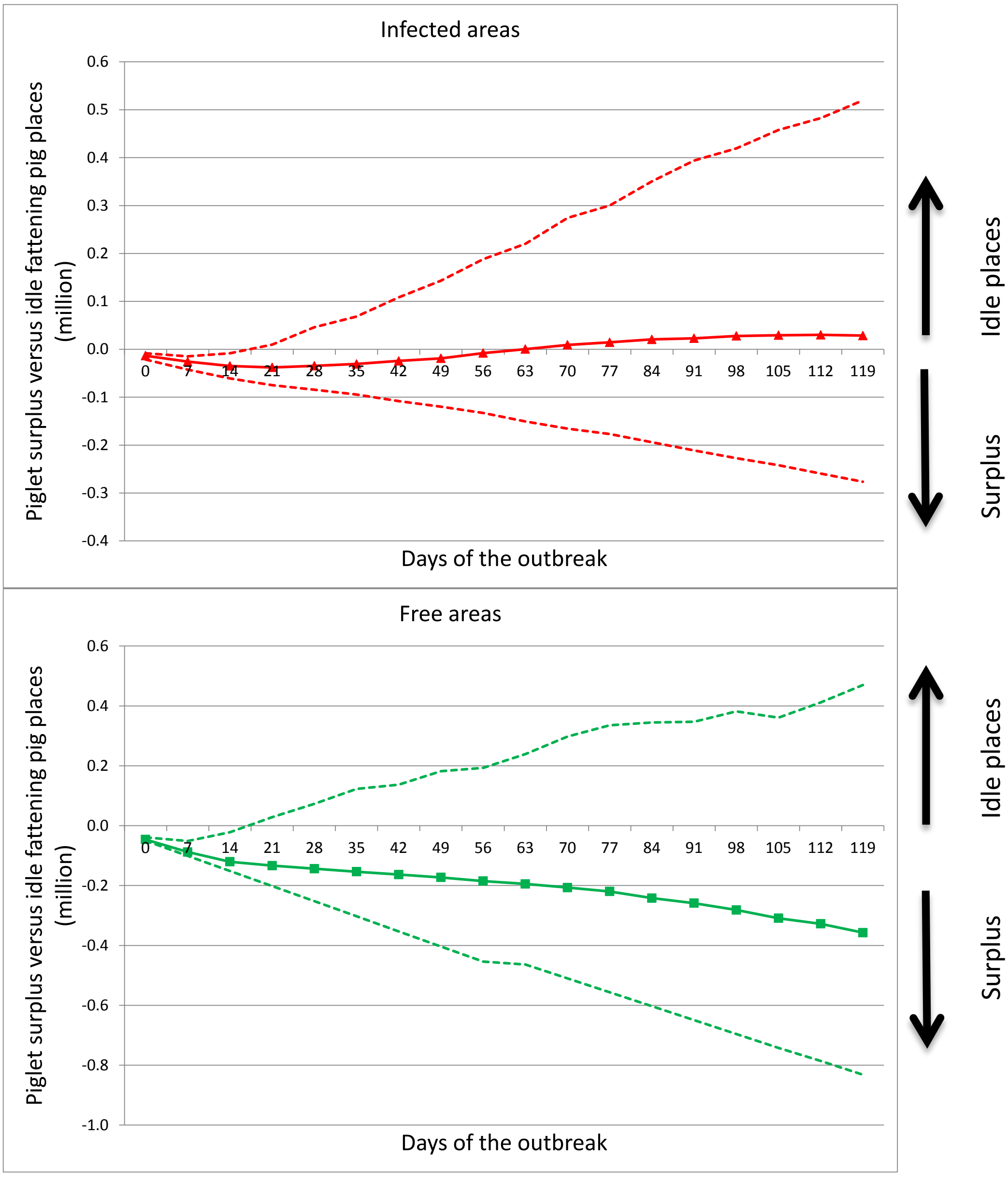


Figure 2.5: Cumulative number of piglet surplus per category per week in infected areas (above) and free areas (below). Solid line represents average, dashed lines represent 5% and 95% percentile values.

Note that piglet surplus in regions without transport bans is still existing. Allowing transport between both areas will on average not reduce domestic piglet surplus since the annual number of piglets exported is approximately 6.9 million (Westra, 2013), but because idle places are minimised the surplus is not increased.

If besides allowing transport in red zone also permitted stocking density is temporarily increased with 10% or 30% supply will exceed demand in both areas of interest (Figure 2.6). However, increased stocking density will raise welfare concerns, especially at high slaughter weights of fattening pigs.

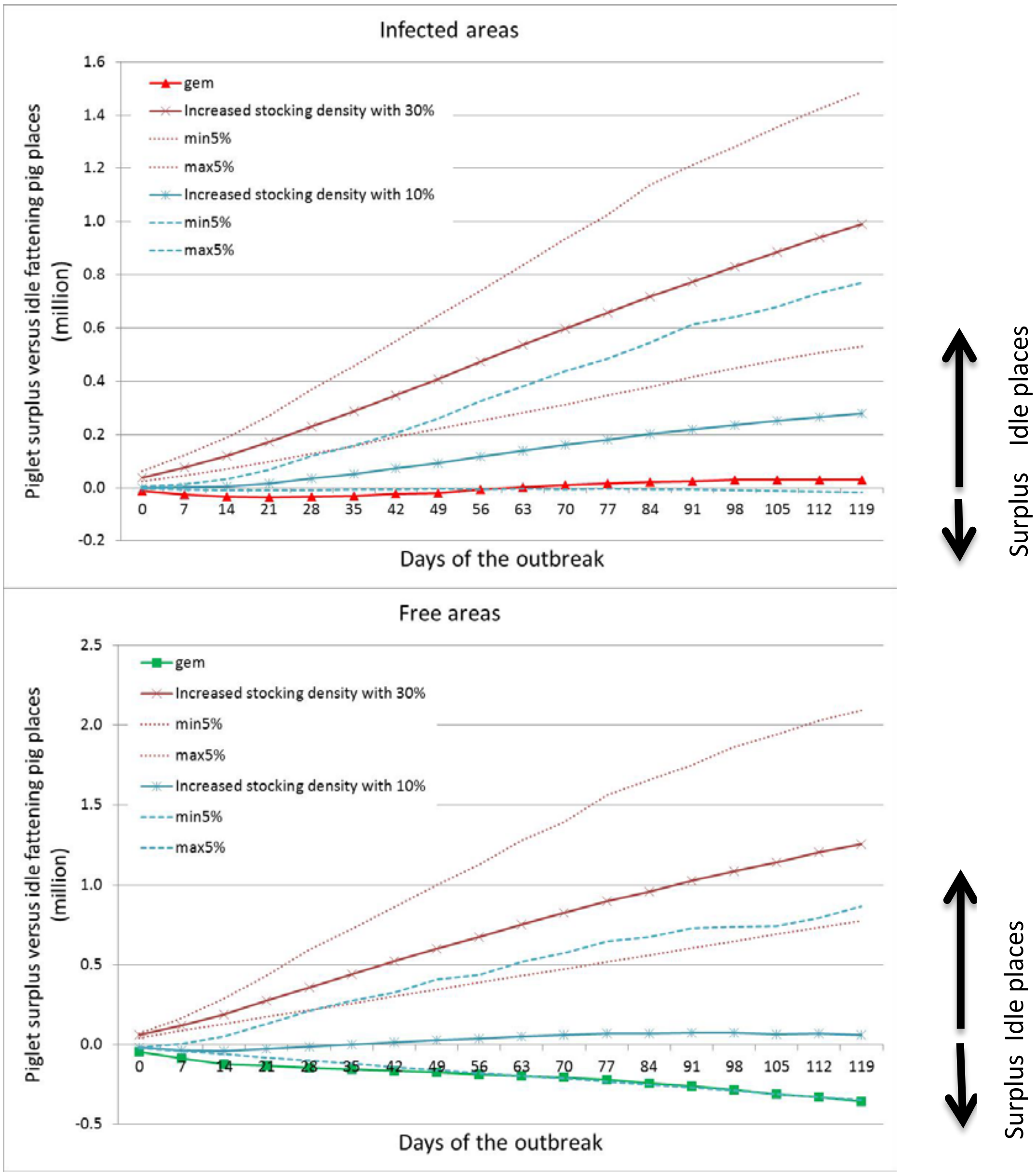


Figure 2.6: Cumulative piglet surplus for default situation, and increased stocking density with 10% or 30% (above) and free areas (below). Solid line represents average values, dashed lines represent 5% and 95% percentile values.

An alternative or even complementary option is to allow transport in infected zones while fattening pigs are slaughtered at lower weights (resulting in a fattening period of 100 days versus 115 days). Ultimately, this will increase demand for piglets in the zones and reduce piglet surplus (Figure 2.7). However there are number of issues that will hamper adoption of the latter strategy. Lower slaughter weights will reduce profit margins per fattening place. Moreover, slaughter capacity might become a constrained. Note that The Dutch pig meat production is an open system with considerable import and export of live fattening pigs (and meat).

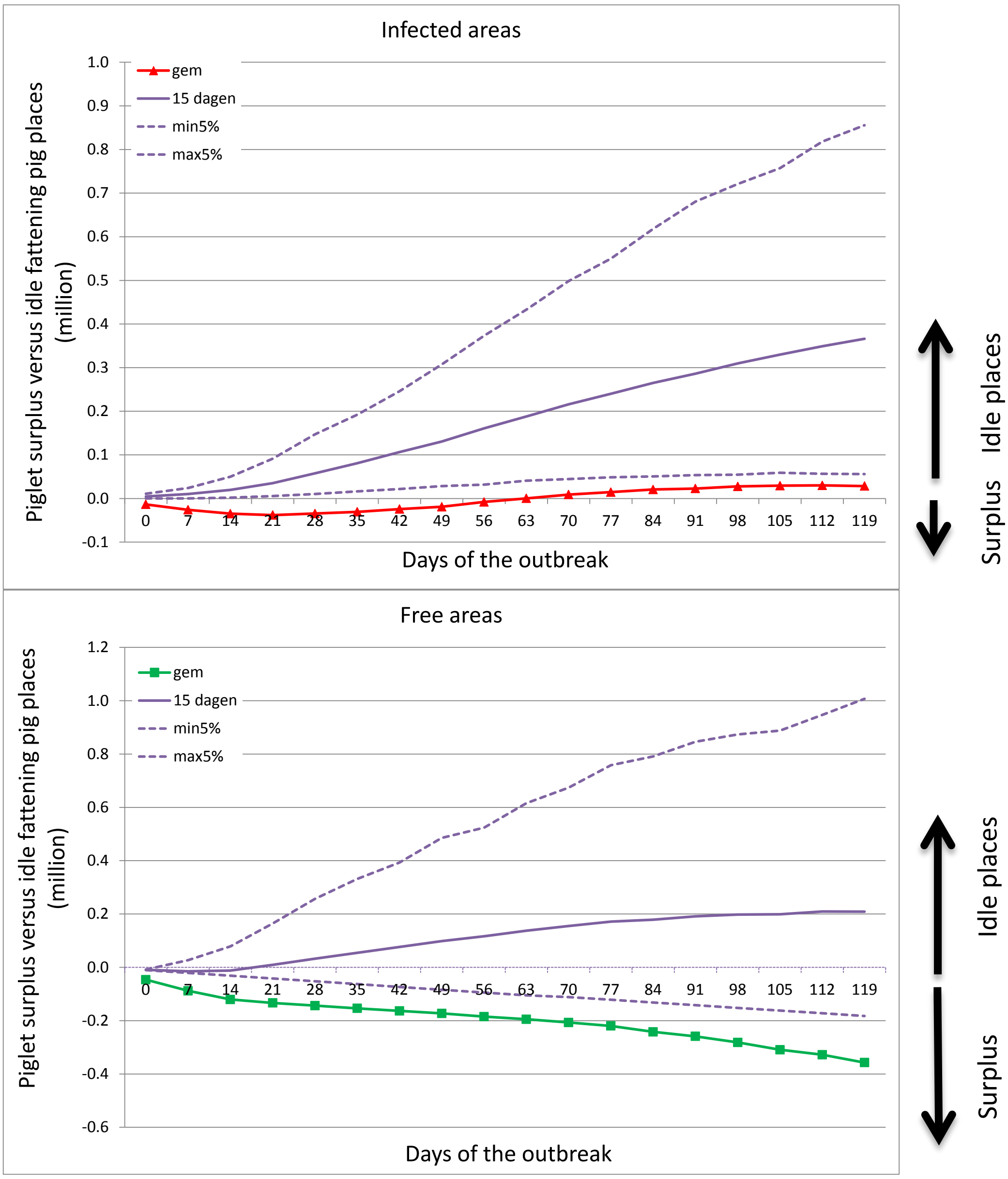


Figure 2.7: Cumulative piglet surplus for default situation and 15 days shortened fattening period in infected areas (above) and free areas (below). Solid line represents average, dashed lines represent 5% and 95% percentile values.

Economic evaluation of reducing the area under transport ban

The additional costs and cost foregone in the partial budget model depends on the estimated epidemic outcomes. The mean number of detected farms per epidemic in the default situation is 15.8 and this increases to 16.8 in case additional movement of animals in infected areas is allowed. The number of animals produced in the infected areas is elaborated on in the previous section. In summary, the average number of piglets ready for markets and pigs ready for slaughter amounts 7.7 million and 2.2 million respectively (Table 2.1).

Table 2.1: Number of animals produced in infected areas (million animals).

	Infected areas		
		Percentile	
	Average	5%	95%
Piglets ready for market	7.7	4.7	10.6
Pigs ready for slaughter	2.2	1.5	2.9

The increased control costs and enforcement costs given the strategy to ease the transport ban is derived by accounting for the additional costs per extra farm detected. The additional outbreak costs amount 3.4 million Euro, while extra enforcement costs amount 2.7 million Euro (Table 2.2). Compared to other costing components the relative impact of an increased outbreak size is less relevant.

The economic losses due to reduced revenues in infected areas (channelling and suboptimal value amount on average 115.2 million Euro) are offset by the foregone costs of culling and destructing valuable products (on average 434.3 million Euro and 329.2 million Euro for piglets and fattening pigs respectively) in case welfare culling is foreseen.

Table 2.2: Economic evaluation of reducing the area under transport ban (million Euro).

	Average	Percentile	
		5%	95%
Additional costs			
Increased control costs	3.4	-	-
Extra enforcement costs	2.7		
Logistic slaughtering and suboptimal value creation	115.2	74.6	149.2
Costs foregone: Welfare culling and no breeding ban			
Culling and destruction piglets	434.3	262.8	600.1
Culling and destruction fattening pigs	329.2	213.1	426.2

The estimated amounts for channelling and suboptimal value as well as for culling and destructing valuable products are substantial. Meuwissen et al., (2003) estimated in the most likely CSF scenario for the southern region that welfare slaughter would cost 94 million Euro. However, their control strategy included a breeding prohibition 4 weeks after the onset of an epidemic (Meuwissen et al., 2003). A breeding prohibition was also declared during the CSF outbreak in 1997/1998. In the current simulation study the epidemiological impact and associated costs of a breeding prohibition are not estimated . Moreover, it is unlikely that a welfare culling programme will be applied to such extend as quantified.

2.4 Discussion and conclusions

Model simulations revealed that the average number of piglets produced in infected areas but outside the 10 km PS-zone of infected premises amounted to 2.22 million after 119 days (given an outbreak in three specific regions 8, 18 and 19). Allowing transport in affected regions will reduce piglet surplus considerably. On average supply balances demands, however in 5% of the outbreaks piglet surplus will exceed 0.28 million after 119 days. If besides allowing transport also permitted stocking density is temporarily increased (with 10% or 30%) or fattening period shortened (from 115 days to 100 days) supply will exceed demand in areas of interest.

Easing the transport ban would increase the risk of transmission (i.e., larger outbreaks) thereby increasing control and enforcement costs by 6.1 million Euro. Compared to other costing components the relative impact of an increased outbreak size is less relevant. The economic losses due to reduced revenues in infected areas (i.e., channelling and suboptimal value) are offset by the foregone costs of culling and destructing valuable products (i.e., welfare slaughter programme).

Besides easing transport regulation additional control measures can be taken to limit the additional risk of transmission. For example screening of all piglets transported within the infected area might be considered as well.

In the current analyses less tangible benefits are not accounted for. For example the reduced animal welfare problem and impact of public opinion are difficult to ascertain but are important issues favouring to ease transport bans. Another important issue to address is the impact of the chosen transport strategy on export. As a result of an epidemic, national and international market access for animals of susceptible species and their products is restricted. After the last outbreak it takes at least 6 weeks until the first movement restrictions are lifted. However, it can take up to 6 months until all trade restrictions in the EU are lifted. The Netherlands is a net exporting country of piglets and meat. The export losses might differ between the strategies, but the extent is unclear. Additional trade losses might be incurred due to loss of confidence of trade partners and especially when an outbreak occurs in previously free areas as a result of piglet transport.

In summary, allowing transport between infected areas and free areas will on average not reduce domestic piglet surplus since the annual number of piglets exported is approximately 6.9 million (Westra, 2013). But allowing transport in affected regions will reduce local piglet surplus considerably.

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