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Abstract. Animal movement restrictions applied in eradicating a contagious animal disease may lead to a situation where hog farmers are forced to keep ready-to-slaughter animals on the farm. Feeding heavy animals may reduce carcass quality and cause income losses. Therefore, feeding strategies are of importance when marketing and transporting hogs is restricted. The problem is interesting also from society's point of view since a large number of farms could be affected by the quarantine measures related to a single infected farm.

In this paper, a dynamic programming model is developed to study optimal feeding strategies under animal movement restrictions in Finland. The model takes into account carcass quality, increased animal density due to quarantine and optimal slaughter time under specific prices. The results show that farmers are encouraged to reduce energy feeding of the hogs in order to minimise losses due to reduced carcass quality. The results give information on designing policies and insurance coverage schemes so that all farmers have economic incentives to implement the eradication policy that is optimal for society.

Index words: animal diseases, quarantine, culling, financial losses, compensation

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1. Introduction

Highly contagious animal diseases, such as classical swine fever (CSF) and foot and mouth disease (FMD), can have significant economic consequences. A disease outbreak may affect a large number of industry participants, farmers and consumers either directly through contaminated and lost production animals, or indirectly through regulations and market distortions. The outbreak can cause large budgetary expenses for the affected country, since eradicating an epidemic is costly and farmer insurance against losses from the highly contagious animal diseases is subsidised in many EU-countries. In addition, farms and meat processing industry may suffer substantial consequential losses that are not compensated. Indirect losses, however, dependent on characteristics of pig population and export orientation of infected country (cf. Saatkamp et al., 2000, Mangen et al., 2002, Meuwissen et al., 2003).

Cost efficient eradication of a contagious animal disease requires choosing policies that minimise losses for society, conditional on the requirement that all agents (e.g. farmers), who can avoid contaminating their herd or can otherwise reduce the outbreak, have incentives to do so. Thus, when an outbreak occurs, the first problem for government authorities is to choose and force cost efficient treatment, preventive measures and regulations to eradicate the disease. The standard measures applied in eradicating a highly contagious animal disease include stamping-out infected premises, imposing restrictions on animal movements, tracing contacts and screening and surveillance of farms. In addition to infection, a farm can be quarantined due to suspicion of a highly contagious animal disease (MMM, 2002). Furthermore, government may have an option to cull the animals to prevent spread of the disease ("preventive slaughter"). This policy has been applied especially in high animal density countries such as the Netherlands.

The second problem is to design compensation schemes so that all agents have sufficient economic incentives to implement the eradication policy that is optimal for society. In other words, the combination of policies and compensation schemes should be designed so that policies do not suffer from moral hazard problems. Compensation schemes are needed, since individual farmers may face losses due to eradication measures which benefit the society or farmers as a group (Mangen et al., 2002).

Limited liability problems of individual agents become quickly an issue if preferred management practices are not triggered by clear economic incentives. A flawed compensation scheme could, for example, generate an incentive for a farmer to avoid costly maintenance of ready-to-slaughter animals by increasing the probability of having his livestock infected in order to gain quick access to a slaughter program. It is, therefore, important to have unbiased estimates on farmer losses from delayed timing of slaughter compared to losses from culling the animals when designing insurance schemes that do not suffer from moral hazard. Unbiased estimates require adjustments on endogenous hog feeding even when the culling is exogenously determined.

From the farmer's point of view, major economic consequences of culling and following re-population ban are due to an idle production capacity whereas animal movement restrictions delay timing of the slaughter (Meuwissen, 1999). A farmer is expected to receive extra profit called retention pay-off when replacing an animal with an equivalent young animal at the economic optimum rather than at another moment (Huirne et al., 1993). A major determinant for losses could be that postponed slaughter reduces carcass value, since producer price for meat in Finland is adjusted by fat content and carcass weight. A heavy carcass, for example, often contains more fat than a light carcass (Whittemore, 1993). Another determinant could be that farm is overpopulated. Increased animal density on the farm or pen may cause increased stress, behavioural problems, respiratory diseases and animal mortality, reduce weight gain or feed conversation ratio. Big animals may also dominate smaller ones leaving small pigs suffering from hunger (Brumm and Miller, 1996, Kornegay and Knotter, 1984) and housing facilities may suffer damages due to too heavy animals (Pluimers et al., 1999). Under certain epidemic situations, the problems can be avoided by culling the animals due to animal welfare reasons (after at least 30 days of quarantine in case of CSF for example) and their value will be compensated for farmers (MMM, 2002).

The goal of this study is to estimate hog producer losses caused by an animal movement ban and preventive slaughter program on Finnish fattening pig farms. Losses from exogenously delayed slaughter are estimated as the difference between hog production value under optimal (unrestricted) slaughter policy and delayed (restricted) slaughter policy. Several scenarios on the duration and timing of the animal movement ban are simulated. Impact of the ban is specified to start at fattening pigs of certain weight. Thus, a fixed term animal movement ban will delay timing of slaughter more on a farm stocked by mature pigs than on a farm stocked by young pigs.

Values of production are estimated so that feeding of the hog is optimal but conditional on the slaughter policy. In other words, a farmer can ration daily feeding to slow down hog growth and improve carcass value when the slaughter is exogenously delayed. Similarly, preventive slaughter scenarios are specified according to the weight of the pig at culling. After culling, the capacity unit is idle until the animal movement ban is lifted. As above, values of production are compared to the values under optimal (unrestricted) and restricted slaughter policy.

The value of hog production under alternative scenarios is estimated with a numerical dynamic programming routine (Bellman, 1957). Value functions and optimisation routine are normalised for one capacity unit. Hog growth and feed uptake functions are based on experiments of Sevón-Aimonen (2001). A subsequent section describes the model. The results are presented thereafter and a further section draws conclusions.

2. The model

2.1. Optimal feeding problem

Pig's liveweight can be estimated by the amount of lean and fatty tissue, despite that it includes components other than protein and energy as well. Hog growth is modelled by splitting the animal's liveweight x_t^w into fat free (lean) tissue x_t^p and fatty tissue x_t^e, where p refers to lean (protein) tissue and e to fatty (energy) tissue. The growth of the components is modelled separately and possible interactions between the components are taken into account. The liveweight of the hog and the value of the carcass can be presented as a function (g_w) of the amount of these two fractions (Glen, 1983, Sevón-Aimonen, 2001).

$$(1) \qquad x_t^w = g_w(x_t^p, x_t^e)$$

Similarly, feeding is split into protein and energy components. The feed's protein content is assumed to be ideal in the sense that it meets the pig's amino acid requirements. Each period hog farmer is allowed to control feeding within limits set by the pig's natural growth and feed uptake characteristics. The farmer may apply unrestricted feeding or he/she may ration the amount of protein feed, energy feed or both. Hence, he/she has a chance to improve value and quality of the carcass. Control variables are defined so that u_t^e is the amount of digestible energy and u_t^p is the amount of digestible protein and is proportional to u_t^e.

2.2. Growth under restricted feeding

Under restricted feeding, hog growth is determined by the amount of protein and energy that is available to the synthesis of new tissue (growth) after subtracting maintenance requirements. The amount of both protein and energy feeds are bounded by the pig's biological maximum feed uptake. Defining all the protein to be used in protein synthesis does not result in any losses of generality since converting excess protein first into energy and then into fatty tissue is inefficient (Whittemore, 1993).

Under restricted feeding, growth of the lean tissue is specified as a linear function of the digestible protein given in the feeds and current liveweight composition of the animal. The transition equation for lean tissue is

$$(2) \qquad x_{t+1}^p = \theta_{11} x_t^p + \theta_{12}(x_t^w)^{\theta 18} + \theta_{13} u_t^{pl},$$

$$\text{where } x_t^w = x_t^p + x_t^e + [\theta_{14}(x_t^p)^{\theta 15} + \theta_{16}(x_t^p)^{\theta 17},$$

where θ_{1j} are parameters (coefficients) for all *1j*, where 1 refers to transition equation for lean tissue (x^p_{t+1}) and *j*=1,2,3 refers to relevant variable and u^{pl}_t is the amount of digestible protein in feed. u^{pl}_t is measured in lycine, that is assumed to be the first limiting amino acid in the protein synthesis. At least 7 % of the digestible protein supplied in the feeds needs to be lycine (u^{pl}_t=lycine supplied in the feeds/0.07) (Agricultural Research Council,1981). 70 % of protein is assumed to be utilised after absorbion (Fuller et al. 1989). The amount of lycine required in the protein synthesis is 36 mg lycine per kg liveweight per day (Wang and Fuller, 1989). The parameter values are presented in Table 1.

Maintenance energy ($e^m(x_t^p, x_t^e)$) is a function of the hog's liveweight and its composition of lean and fatty tissues. Energy required for the protein synthesis that maintains the current protein level is defined as a function of protein tissue $p^m(x_t^p)$. Finally, the transition equation for fatty tissue takes the form

$$x^e_{t+1} = \gamma_2 \Delta x^p_t + \theta_{21} x^p_t + \theta_{22} x^e_t + \theta_{23} u^p_t + \theta_{24} u^e_t - p^m(x^p_t) - e^m(x^p_t, x^e_t), \tag{3}$$

where γ_2 and θ_{2j} are parameters, subscript 2 refers to transition equation for x^e_{t+1}, *j*=1,2,3,4 refers to relevant variable and Δx^p_t is the amount of protein synthesis. Equation (*3*) is further simplified by collecting like terms and re-parametrising. The final form is

$$x^e_{t+1} = \gamma'_2 \Delta x^p_t + \theta'_{21} u^{pl}_t + \theta'_{22} x^e_t + \theta'_{23}(u^p_t - u^{pl}_t) + \theta'_{24} u^e_t + \theta'_{25}(x^p_t)^{\theta 26}, \tag{4}$$

where γ'_2 and θ'_{2j}, are parameters for j=1,…,6 and u^p_t - u^{pl}_t is the amount of (excess) protein that is supplied in feeds and converted to energy instead of protein. The growth of the lean tissue (Δx^p_t) is measured in lycine that is used in the protein synthesis (i.e. u^{pl}_t). θ_{25} and θ_{26} are parameters for maintenance energy after re-parametrisation. Maintenance energy requirements are based on Whittemore (1983).

2.3. Growth potential and feed uptake

When hog feeding is unrestricted, it can fully utilise feeds up to biological growth potential. Under unrestricted feeding both state variables follow the Compertz function:

$$x^i_t = \alpha^i_j \, exp(-k^i_j \, exp(-\beta^i_j t)), \tag{4}$$

where x_t^i is the state variable at period *t* when *t* is age of the animal measured in days and α_j^i, β_j^i, and k_j^i are parameters. x_t^i measures amount of lean tissue when upper index *i* is *p* and amount of fatty tissue when *i* is *e*. Parameters α_j^i and β_j^i are usually referred to as an adult weight and maturing ratio of the animal.

Differentiating the equation (4) with respect to the age of the animal, and by further discretising the change and rearranging, we obtain the next period state:

$$x_{t+1}^i = x_t^i\left(1+\beta_j^i\left(1n\alpha_j^i - 1nx_t^i\right)\right) = x_t^i\left(\gamma_j^i - \beta_j^i 1nx_t^i\right), \tag{5}$$

$$\text{where } \gamma_j^i = 1+\beta_j^i \ln\alpha_j^i$$

The feasible set (growth potential) for the ratio of protein to energy (x_t^p / x_t^e) is bounded from below by λ_-^x and from above by λ_+^x. Also, the natural feed uptake function $u^i(\bullet)$ follows the Compertz function. In case of an animal movement ban, the feed uptake is such that the farmer is not allowed to feed the hog less than what is required for 0.5 kg daily weight gain. The values of the hog growth and feed uptake are based on Sevón-Aimonen (2001).

2.4. Optimal stopping

The farmer's decision when to cull the hog is modelled on an optimal stopping framework with a binary choice variable u_t^s. The choice variable is u_t=0 when feeding the animal is continued and u_t=1 when the animal is culled. After culling the animal, components of the liveweight are set to correspond fat and lean tissue of a newly weaned piglet. The final period *T* always results in culling.

2.5. Value function and optimality

The farmer's objective is to maximise expected net present value from the planning period. Over the continuation region u_t^s=0, cash flow is generated by the variable cost of feeding the animal $C(x_t^w)$, which is a product of feed price w_t^i and quantity of feeds supplied (u_t^i) for all feeds *i*. If the hog is culled (u_t^s = 1), the return from culling (salvage value) is obtained as well as the expenditure from purchasing a new piglet incurred, provided the farm is not under an animal movement ban. Hence, one period cash flow is given by the function:

$$(6) \qquad R(x_t^{\,e}, x_t^{\,p}) = -(1-u_t^{\,s})[C(x_t^{\,w})] + u_t^{\,s}[(x_t^{\,w} + \delta(x_t^{\,w}))p(x_t^{\,p} x_t^{\,e}) \\ -(C_t^{\,pcc} + C_t^{\,mor})(\kappa W^{0.67} - A^n) - w_o + ss].$$

where $\delta(x_t^w)$ is the percentage share of meat lost at slaughter, w_0 is the price of the piglet and $p(x_t^p, x_t^e)$ is the function for the quality adjusted price of pig meat as paid by the Finnish slaughter houses. Under animal movement restrictions, hogs are not allowed to be optimally slaughtered and the binary slaughter variable is exogenously restricted at u_t^s=0. When the optimal slaughter weight is exceeded due to restrictions, extra costs are assumed to occur through excess meat lost in partial carcass condemnations C_t^{pcc}, increased mortality C_t^{mor} and decreased daily weight gain (higher feed cost for heavy carcasses). The economic effects of farm overpopulation are modelled as a linear function of liveweight using the basic formula of allometry (Brumm and Miller 1996) and using the area allocated at the optimal slaughter weight as zero cost alternative. Quantity of meat lost in increased partial carcass condemnations is estimated based on Tuovinen (1992). The latter two costs occur only when the pen area requirement per overweighted pig is more than 10 percent compared to the area that is required for hogs at the optimal slaughter weight (Heikkonen, 1998).

The net present value is obtained from the value function (V_t), where all the future revenues and costs are discounted to the present. The value function defines a finite horizon dynamic programming problem which can be solved by iterating on the following Bellman's equation:

$$(7) \qquad V_t(x_t) = \max_{\{u_t^s, u_t^f\}_{t=0}^{T}} \{R_t + \beta V_{t+1}(x_{t+1})\}$$

$$s.t.\ (3),\ (5)\ and\ x_0\ given,$$

where β is the discount factor and u_t^f is the quantity of protein and energy feed given to the animal.

The solution to equation 7 is iterated starting from the terminal period T and then moving backwards in time. The optimal control as well as resulting value function are first computed at every grid of the space (for each day). Then, the optimal solution is traced out through the time starting from the given initial state. The solution maximises the value function and gives corresponding values for the control variables. After the animal movement restrictions are removed, the farmer is expected to slaughter the hog (provided that it is mature enough to be slaughtered) and thereafter follow the same unrestricted optimal slaughter policy as before the ban.

2.6. The data and scenarios

The model is applied to unrestricted slaughter policy and scenarios in which animal movements restrictions are imposed for hogs of different weight. In the first scenario, the restrictions are imposed on hogs of 109 kg (1 week before the optimal timing of slaughter). In the second scenario, the restrictions are imposed at 89 kg liveweight (4 weeks before the optimal slaughter). Because the duration of the simulated restriction is the same in both alternatives, the timing of the slaughter is delayed 21 days more from the optimal timing in the 109 kg case. The length of the quarantine is 0-66 days. The scenarios include cases in which the hog is either fed or it is culled immediately (pre-emptive slaughter) and thereafter, the capacity unit of the fattening pig is kept empty until the ban is lifted (re-population ban). A decision to feed the hog includes feeding until the ban is lifted. Once the ban is lifted the ready-for-slaughter hog is killed and replaced by a newly weaned piglet (the optimal welfare slaughter can be a combination of these two cases).

Notice that some scenarios are not applicable to certain diseases or farms that have certain location. For example, minimum length of the time a farm on classical swine fever protection zone is idle is approximately 45 days when the herd is immediately culled preventively (less potential delay due to preparations). The results are subject to the meat pricing scheme and parameters illustrated in Table 1. The amount of barley (energy feed) used in the diet varies between 0.8 and 4 kg. The amount of soy (protein feed) is 0-35 % of barley. The controls are evaluated at 47 x_t^e and 45 x_t^p states of nature. The state-control space is still continuous since interpolation is carried out between the nodes. Protein and energy composition of barley and soy are derived from Board of Agriculture National Research Counsil (1998). A kilogram of soy is assumed to contain 380 g digestible protein, 25.67 g digestible lycine and 6.66 MJ digestible energy. Corresponding values for a kilogram of barley are 79.1 g protein, 0.0032 g lycine and 10.93 MJ energy. The total amount of protein and energy supplied in the feeds is the sum of corresponding components supplied in both feeds.

Table 1. Prices and parameters used in the calculations.

Pig meat, €/kg [1)]	1.43	θ_{12}	0.00095	θ'_{21}	0.06534
Weaned piglet, €/piece	68	θ_{13}	0.07000	θ'_{23}	0.21783
Soy feed, €/kg	0.28	θ_{14}	5107.45	θ'_{25}	-0.03498
Barley, €/kg	0.12	θ_{15}	0.87100	θ'_{26}	0.78000
Synthetic lysine, €/g	3.20	θ_{16}	195.060	θ'_{24}	0.01893
Methionin, €/g	2.86	θ_{17}	0.95070	α_j^p	29.6895
Treonin, €/g	5.89	θ_{18}	0.75000	β_j^p	0.01460
Slaughter subsidy, €/carcass [2)]	23,70	θ'_{22}	1.00000	α_j^e	52.8535
θ_{11}	1.00000	γ'_2	-0.26913	β_j^e	0.01460

3. Results

3.1. Optimal solutions without the ban

Under an unrestricted animal movement policy, the model results in optimal slaughter at 114.5 kg liveweight (105 days). The equivalent daily income from a hog place is € 0.38 at 10 % discount rate (€39.1 per animal). The hogs are fed with a protein rich feed during the first 40 days. Thereafter, the share of soy in the hog's diet decreases rapidly whereas the share of barley increases until the hog is culled. During the last 20-25 days, feed composition is rationed to obtain optimal carcass quality (Figure 1). Furthermore, the hog is provided with extra amino acids.

3.2. Adjusted feeding policy

Under animal movement restrictions, the model suggests rationing the feeding. This implies lower daily weight gain than under the normal slaughter policy. The optimal feeding policy depends on the starting weight (either 98 or 109 kg's) at which the animal movement restrictions are imposed. Scenarios for younger pigs have similar characteristics as 89 kg scenario but effects of the quarantine are smaller than in 89 kg scenario.

A selection of optimal feeding patterns is reported in Figures 2 and 3. In each Figure, the optimal feeding policy of three scenarios with different quarantine lengths are depicted. Fluctuation in some series' feeding policies are due to numeric iteration techniques and discrete changes in meat prices. When the ban is imposed at 109 kg, the hog is given less barley (kg per animal per day) and the diet is richer in protein than without the ban (Figures 1 and 2). Soy content depends on the duration of the quarantine. For example, in case of 31-45 days quarantine the amount of barley is reduced from 3 kg to approximately 2.5 kg per day and demand for protein is filled up with 100 g soy per day and additional amino when necessary. When the lifting of the ban approaches, energy feeding is increased. In scenarios with a long quarantine (59 days for example) energy content of the feed remains at a high level and the amino acids are substituted for soy (Figure 2).

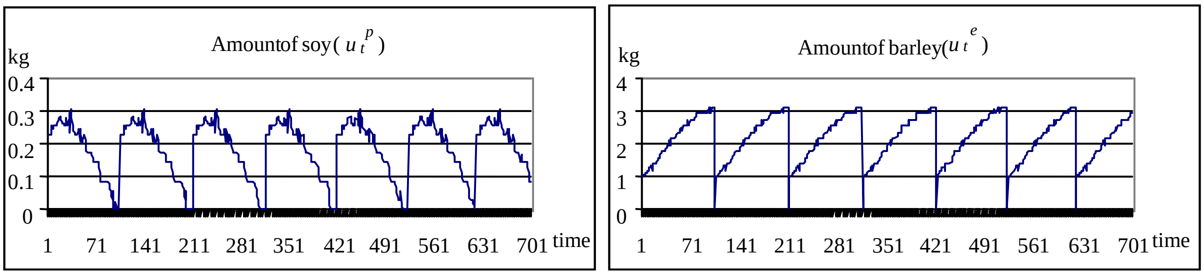

Figure 1. Patterns of the optimal feeding policy (kg feed per day) under unrestricted feeding policy (when the amount of barley drops to zero, the pig is slaughtered and replaced by a new piglet).

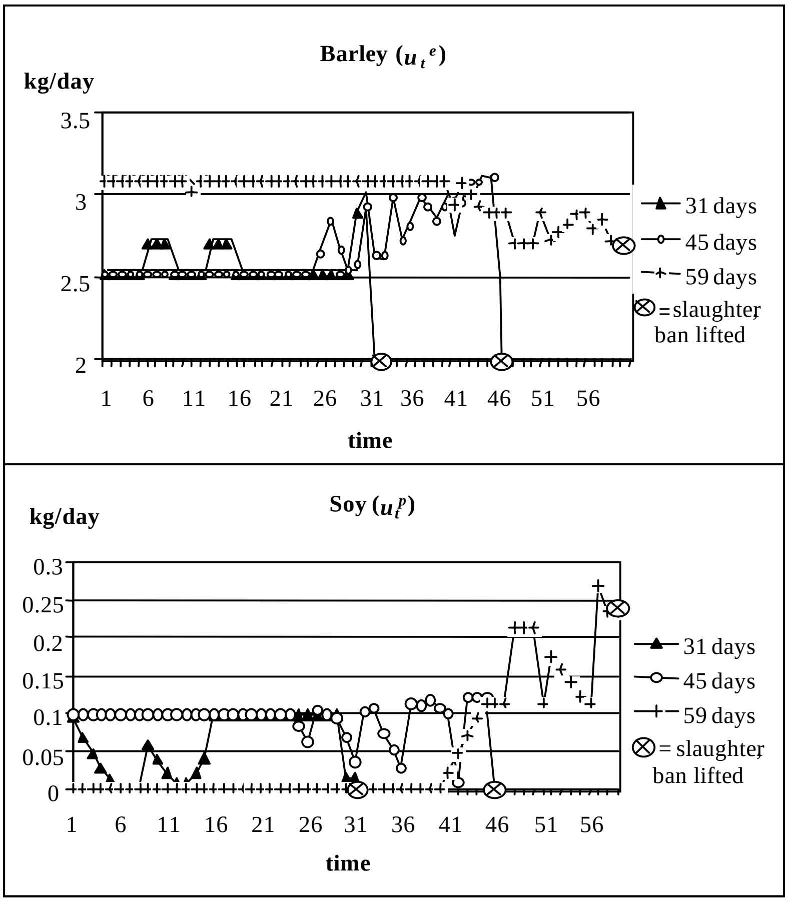

Figure 2. Selected results for optimal feeding strategies (kg feed per day) when the restrictions are imposed at 109 kg (1 week before the optimal slaughter moment) and they last for 31, 45 or 59 days.

Figure 3 reports results for a scenario where the restrictions are imposed at 89 kg liveweight. As in the previous scenario, less barley is used to feed the hog at first when the ban is imposed. Thereafter, the amount of barley gradually increases to a higher level until the ban is lifted. Reduction in energy feeding is the stronger the longer the quarantine period is. Furthermore, energy feeding policy under 31 days quarantine is close to no quarantine-policy and soy feeding is generally 200-400 g higher in case of 31 days quarantine when compared to no quarantine-policy. Since the changes in protein feeding due to an animal movement ban are smaller than the changes in energy feeding, the hog is fed with a protein rich feed.

In most cases, the optimal feeding policy under animal movement restrictions is characterised by rationed energy feeding to reduce daily weight gain. Furthermore, attention is paid for the carcass quality. In most cases, an attempt to improve carcass by increased soy feeding and the adding of amino is observed few days before the ban is lifted. Despite varying slaughter weights between scenarios, the fat/lean-ratio of the meat is generally the same as the price-maximising ratio.

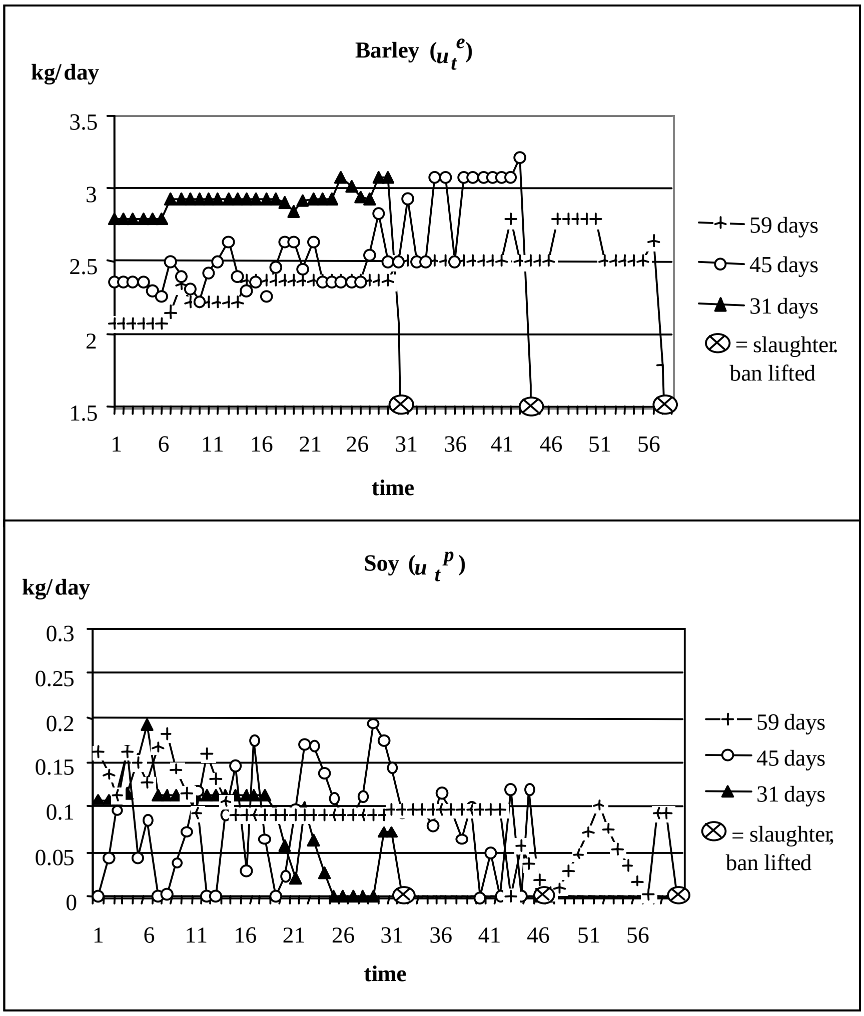

Figure 3. Selected results for optimal feeding strategies (kg feed per day) when the restrictions are imposed at 89 kg liveweight (4 weeks before the optimal slaughter moment) and they last for 31, 45 or 59 days.

3.3. Economic consequences

Farmer's monetary losses due to animal movement restrictions or slaughter programme were estimated as the difference between value function's value under no restrictions and alternative scenarios on quarantine and slaughter policy (Figures 4 and 5). Imposing, for example, a 31 days animal movement ban on an 89 kg hog causes €1.2 income loss per capacity unit (i.e. optimal timing of slaughter is exceeded by 4 days). When the restrictions are imposed for a longer time, income losses increase significantly.

The results indicate that when no restrictions are imposed, the farmer receives the maximum of the quality adjusted price for the meat. Consequently, quarantine losses are significantly related to the reduction in meat prices due to heavy carcasses. The rest of the economic consequences are borne by the changes in feed consumption, hog growth, farm overpopulation or postponed future revenues. For example, when a 38 day quarantine is applied for an 89 kg hog, the farmer suffers €4.4 net

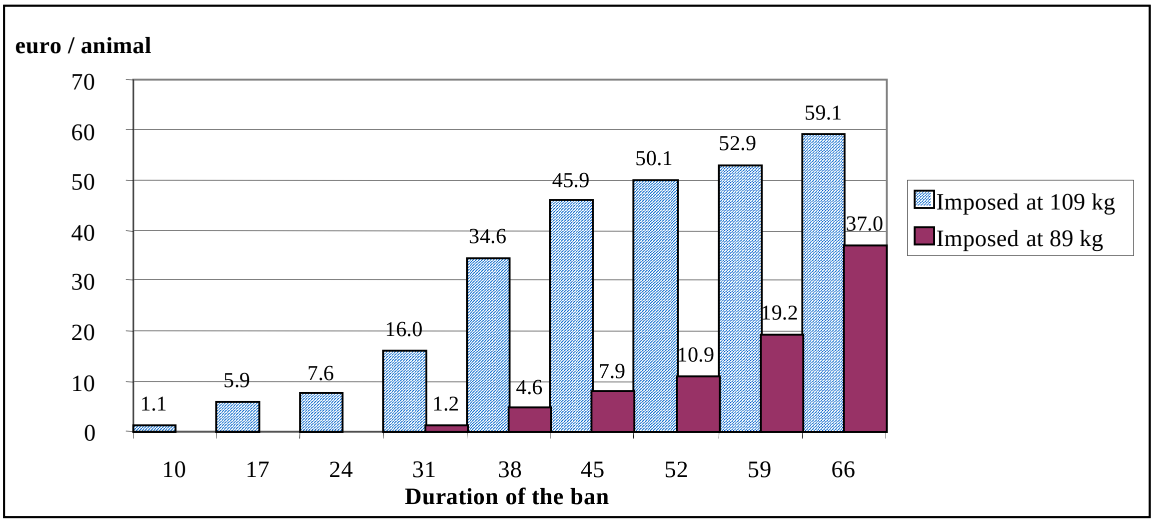

Figure 4. Farmer's loss (euro per animal) due to an animal movement ban that delays the optimal timing of slaughter and that is imposed for 10-66 days on hog's of 89 and 109 kg liveweight.

loss/capacity unit. However, the loss from selling the hog at the lower price is €4.6. Due to the different remaining feeding period of the hog, the losses increase when an animal movement ban is imposed closer to the optimal slaughter moment.

Due to optimisation approach, the losses reported in Figure 5 are minimum losses at prices and parameters given in table 1. Depending on quarantine length, adjusted feeding gives the farmer € 0-26.5 benefits when compared to continuing the feeding policy unchanged until the animal is slaughtered. The 109 kg scenario illustrates that the benefits are lower in case of a long or a short quarantine than medium length quarantine (38 days), because the farmer can influence meat price through decreased daily weight gain.

When the decision maker executes preventive slaughter and issues a re-population ban equal to the quarantine length, the farmer is compensated for the lost value of slaughtered pigs. The compensation equals the value of the meat and slaughter subsidy (€114.90 per animal culled at 89 kg and €138.30 per animal culled at 109 kg). Compensation is independent of whether or not the meat can be used in consumption. The possibility of consuming the meat still matters to society, but it will be ignored in our analysis, since we look at farmer's income change. Additionally, the farmer suffers income losses from the idle production facilities that may be compensated (Figure 5). One additional week of idle production capacity results approximately €2.5 in additional income loss/capacity unit. Income losses in the two scenarios differ, because the income flow from feeding a hog from 89 kg until it reaches 114.5 kg liveweight is larger than the income flow from feeding a 109 kg hog until it reaches 114.5 kg liveweight.

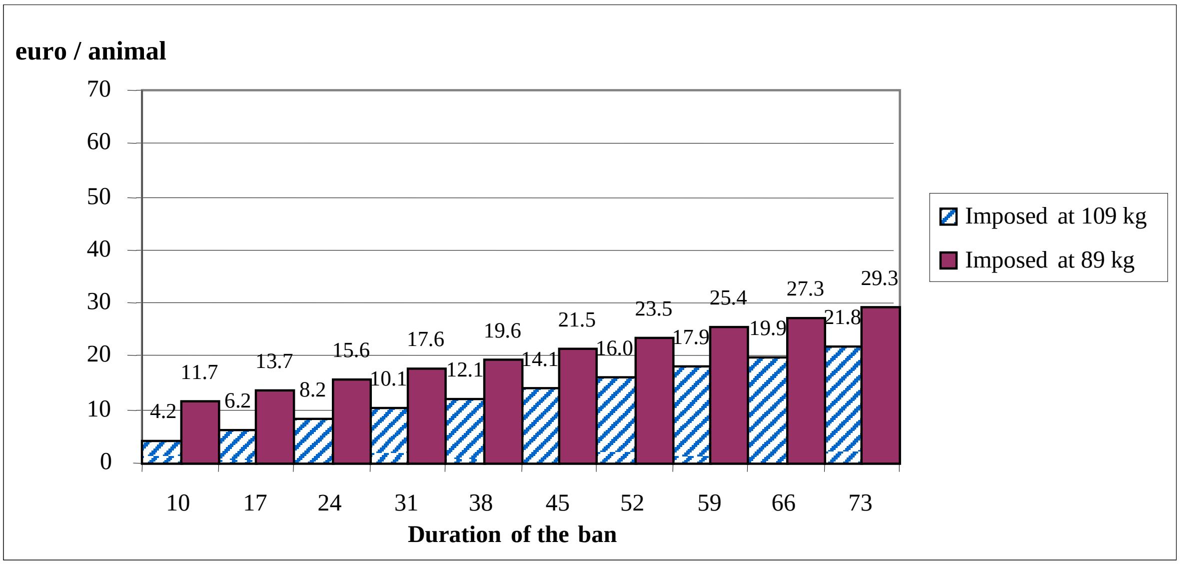

Figure 5. Farmer's loss (euro per animal) due to a preventive slaughter and the following re-population ban when the farmer is compensated for the lost value of the animal at preventive slaughter moment.

Determining the optimal timing for preventive slaughter involves considering risk for additional damages that society may suffer from either carrying out or not the slaughter. Preventive slaughter should be applied when the losses caused by the disease spread exceed the insurance compensation. Furthermore, if the meat is not allowed to enter the consumption, culling the animal would be financially preferred to imposing the restrictions. There is a point where an insured farmer is indifferent to the increased likelihood of getting access to preventive slaughter and corresponding insurance compensation compared to continuing feeding. A farmer that has pigs close to the finishing stage suffer economic losses that increase with quarantine length, when he/she is compensated for the slaughter subsidy and current value of culled pigs. Due to excess feed consumption and reduced carcass quality, a loss from not applying preventive slaughter is even greater when selling the pig to the slaughterhouse is restricted longer than 25 days (109 kg animal) or 61 days (89 kg animal) (Figures 4 and 5). Therefore, restricting slaughter of heavy animals for a long time increases farmer incentives to have his herd slaughtered instead of continuing the feeding.

4. Discussion

This paper estimated optimal feeding strategies under animal movement restrictions and consequent income losses for the farmers. The results suggest that optimal feeding policy under animal movement restrictions is characterised by reduced energy feeding. Some protein feed is substituted for barley in order to improve carcass quality. When quarantine duration is increased, only energy feed is given to the animal and additional amino acids are substituted for protein feed. When the duration of the restrictions is increasing, farmers have incentives to feed the hog too little since no compensation is paid for the inputs, or to switch to other feed components such as straw. Depending on feeding methods applied on the farm, adjusting hog feeding on daily basis and uncertainty related to the duration of the animal movement ban may cause additional cost that are not taken into account in this paper.

A hog grower can minimise losses caused by the animal movement ban through adjusted feeding. He/she has more time to react to the restrictions when they are imposed well before the optimal slaughter moment. Thus, long remaining feeding period implies smaller financial losses and better animal welfare than a short period. Also the time that the optimal slaughter moment is exceeded, is essential for the amount of losses. Incentives for decreasing animal welfare can be minimised by applying welfare slaughter in case of a long ban. Also, recent changes for example in classical swine fever regulation (prolonging the restriction zones) imply that heavy animals should be slaughtered due to risk for reduced animal welfare.

A long quarantine increases farmer incentives to have his/her herd slaughtered preventively when only the animal's current value is compensated. Hence, preventive slaughter is the optimal choice for the farmer but not necessarily for society. Similarly, long quarantine increases individual farmer's incentives to have his herd infected. Therefore, the insurance compensation scheme should be designed so that the compensation is conditional on non-infectious management practices, and that the compensation would depend on the animal's weight. Special attention should be paid to farmers having heavy animals in stock. Farmers may also have incentives to sell heavy animals just before the imposition of the quarantine when there is hidden information, and the expectation of compensation for idle production capacity.

A solution to the incentives' problem could be to account for the effect of meat price reduction due to decreased carcass quality when designing compensation and restriction schemes for heavy animals. Furthermore, a chance for a form limited liability for farms under restriction, or a chance to enter a reasonably compensated welfare slaughter program during a prolonged quarantine could be considered as options. Consequently, the farmer's loss between the quarantine and preventive slaughter would be smoothed out. Alternatively, compensation could be differentiated, based on quarantine length and animal weight. Furthermore, the groups that are morally and financially responsible for certain actions and consequences should be agreed before the emergency situation occurs in order to avoid any moral hazard as discussed by Meuwissen (1999).

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