Survival analysis of culling reasons and economic examination of production period in sow culling*

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Paper prepared for presentation at the 104th (joint) EAAE-IAAE Seminar Agricultural Economics and Transition:

„What was expected, what we observed,

the lessons learned."

Corvinus University of Budapest (CUB)

Budapest, Hungary. September 6-8, 2007

* The article has been prepared by the support of OTKA No. F 62949.

ABSTRACT

The culling of the sows is an important task of the breeders and farmers, besides it is a determining factor of profitable pork production. During our research we have surveyed the data of 1969 sows in a Hungarian large-scale pig farm. For the calculation of our results we used one of the non-parametric forms of survival analysis, the Kaplan-Meier analysis. For the quantification of death intensity we applied another survival analysis model, the log-rate exponential model. We have found out the risk values of various culling reasons form the point of view of culling. Besides, we tried to quantify by an economic model how the production period of sows influences the average costs of piglets and the average costs of piglets per kilo at 2006 prices. We calculated that the 5^{th} farrowing is the minimum cost place.

Keywords: Sow culling, Risk analysis, Sow productivity, Average costs of piglets

2 INTRODUCTION

Annually, up to 60 % of sows are culled all over the world. Culling for most sows is not planned in advance and its causes can be generally traced back to sow reproduction, amounting to approximately one third of the total number of cases. Findings have shown that lameness and loco motor diseases account for 11-14% of cullings, and 4-7% of sows die (LUCIA et al. 2000). The rate of planned cullings, according to studies by different authors, can vary from 23 to 41%, due to mostly older age and poorer fertility (HEINONEN et al. 1998).

Sows are primarily culled as a result of their low fertility. 15-20% of culled sows farrows only once and sows on product-manufacturing farms usually do not live until their 5^{th} farrowing cycle (varying between 3.1-4.6) (LÓPEZ-SERRANO et al. 2000; RAJNAI et al. 2001). The elimination of young, culled sows from production is mostly not planned in advance (LE COZLER et al. 1999), but the rate of pre-planned cullings increases along with the growing number of farrowing cycles (DIJKHUIZEN et al. 1989). Culling reasons, in the order of their frequency are the following: sterility, reasons of health (disorders in leg structure), early use for breeding, farrowing anomalies (WITTMANN 1988; TARRES et al. 2005). Research by STALDER et al. (2003) has found that sows have to farrow minimally three times to meet the requirements of profitable animal breeding. Other authors claim that the economically optimal lifetime sows spend in production is the fifth farrowing (SCHOLMAN AND DIJKHUIZEN 1989, RASMUSSEN 2004). FAUST et al.'s (1993) simulation has shown that production systems with lower rates of cullings are more profitable than farms with higher culling rates. In the five year interval prognosticated for modern hybrids, producers can only achieve increased prolificacy by +1 weaned pig per sow if they maintain the culling ratio of sows at a high level. Long lifetime can also be significant if animal protection is taken into consideration. The level of animal protection can be analysed by the rate of dead and emergency slaughtered sows in a given system of production.

3 MATERIAL AND METHODS

Our investigations were performed in a Hungarian large-scale pig farm in Hajdú-Bihar County, where pork production, its conditions and key indicators were studied. Data were collected by questionnaires, interviews and methodical observations. On average, 51% of productive sows was culled on the farm. Our findings were evaluated by one of the non-parametric forms of Survival Analysis, the Kaplan-Meier analysis (NAGY et al. 2004). Mortality intensity was quantified by one of the other models of Survival Analysis, the log-rate exponential model.

3.1 Models of Survival analysis

Survival analysis is a relatively new area of statistics. Its name and related notions suggest that it is primarily used to compare various treatments of serious diseases and the studied event is the patient's death or the date of death calculated from the onset of treatments. This can be investigated by various statistical models, such as survival time analysis. This model differs from regression models as it is suitable to treat events which did not occur during a given time instant (NAGY et al. 2002), or the individual could be followed-up only for a certain period and no information was available on the occurrence of the event after this date. These events are called mutilated (BOLLA 2005.) or censored (HAJTMAN et al. 2003) events.

There are several available methods for the estimation of the survival function, which stipulates the probability that the event does not occur until time instant t. Kaplan-Meier's assessment provides a solution for discrete time instants. It can also be used to determine the median of survival time or a survival rate for certain periods.

Our calculation shall include the product of conditional probabilities:

$$P(T \geq t_i) = P(T \geq t_i | T \geq t_{i-1}) =$$
$$= P(T \geq t_i | T \geq t_{i-1}) \cdot P(T \geq t_{i-1} | T \geq t_{i-2}) \cdot \ldots \cdot P(T \geq t_0) =$$
$$= \prod_{j=1}^{i} \left(1 - \frac{d_j}{n_j}\right)$$, where

T is survival time

$t_1, t_2, \ldots t_i$ refer to those time instants, where the investigated event occurred

d_j shows the number of events occurred in time instant t_j

n_j shows the number of those individuals in time instant t_j, where the given event may still occur.

Censored events shall be taken into consideration when n values are calculated:

$$n_i = n_{i-1} - d_{i-1} - c_{i-1}$$,where

c_{i-1} refers to the number of censored events in time instant t_{i-1}

Kaplan-Meier curves formed for the survival function are shaped stepwise. The primary conditions to apply the Kaplan-Meier method are the facts that censored and survival events shall be independent, they must not contain hidden, explanatory factors, the number of censored events cannot be high and events censored for lack of information shall be independent of time.

Mortality intensity

Another model of survival analyses is the log-rate exponential model, which requires the clarification of some notions. With mathematical formulas: if f(t) is the varying density function of T (time) and F(t) is the distribution function of T, the correlation is the following:

$$f(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t)}{\Delta t} = \frac{\partial F(t)}{\partial t},$$

$$F(t) = P(T \leq t) = \int_0^t f(u)du$$.

Function F(t) is called mortality probability (ÁGOSTON AND KOVÁCS 2000). The survival function, which gives the probability that the event will not occur until time instant t, is the following:

$$S(t) = 1 - F(t) = P(T \geq t) = \int_t^{\infty} f(u)du$$

Mortality intensity is referred to by h(t), which indicates the risk that the event may occur in time instant T=t, presuming that it has not occurred before. At this time h(t) takes the following form (HEINEN et al. 2003):

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t | T \geq t)}{\Delta t} = \frac{f(t)}{S(t)},$$

where $P(t \leq T < t + \Delta t | T \geq t)$ indicates the probability that the event occurs in time instant $[t \leq T < t+\Delta t]$, presuming it has not occurred until time instant t. f(t) and S(t) can also be expressed on the basis of function h(t) (PÖTTER AND ROHVER 1999):

$$S(t) = \exp\left(-\int_0^t h(u)du\right)$$

$$f(t) = h(t)S(t) = h(t)\exp\left(-\int_0^t h(u)du\right)$$

Functions f(t), S(t) and h(t) describe the distribution of T in a mathematically equivalent way.

Theoretical bases of the Log-Rate model

Assume that h(t|xi) is mortality intensity for a given individual in time instant T=t, where xi are explanatory variables ….., as mortality intensity values can range from 0 to infinite. If the logarithm of mortality intensity is taken, the following regression model can we formed:

$$\ln h(t|\mathbf{x}_i) = \ln h(t) + \sum_j \beta_j x_{ij} \qquad (1)$$

This model is not only loglinear, but proportional as well. Time dependence is multiplicative, and as logarithm transformation is applied, it becomes additive. Proportional models are characteristically time dependent, and correlation is not presumed among explanatory variables, so they are independent (SZŐKE 2005).

Some authors have defined loglinear models as Poisson models (HEINEN et al. 2003), which are called “log-rate models” in specialist literature.

Assume that we have the required information on event history (which event is focused on and when it has occurred) and there are two categorial explanatory variables: A and B. Besides this, assume that the time axis is divided into a finite number of sub-intervals and mortality intensity is constant in these intervals.

Assume that time factor T is of unit value. Assume that h_{abt} is constant mortality intensity in interval t^{th} for one individual, when the value of variable A is a and that of variable B is b. If the representation of hierarchic log-linear models is used, the total saturation model can be formed as follows:

$$\ln h_{abt} = u + u_a^A + u_b^B + u_t^T + u_{ab}^{AB} + u_{at}^{AT} + u_{bt}^{BT} + u_{abt}^{ABT}$$

where u log-linear parameters can be considered as the interaction parameters of ANOVA analysis. The shape of the model shows that this is not a proportional model, as it includes interactions containing time factor and explanatory variable as well (U_{abt}).

When the appropriate parameters (interactions) are left out and limitations are introduced (VERMUNT AND MOORS 2005), the proportional variant similar to model (1) is received:

$$\ln h_{abt} = u + u_a^A + u_b^B + u_t^T$$

If individual influences do not change with time, the model becomes simpler: $u_t^T = 0$, this is the exponential model. (If no limitations are introduced for u_t^T, then the model is a "piecewise" exponential one (VERMUNT 1996).

3.2 Calculating Costs and Incomes

We tried to quantify by an economic model how the production period of sows influences the average costs of piglets and the average costs of piglets per kilo (RAJNAI et al. 2001). During our examinations we collected the following basic data: the entrance value of gilt, costs between the entrance and weaning, total variable costs per farrowing, value of the sow at culling, variable costs of progeny, number of weaned pigs, weight (kg) of weaned pigs, costs of the sow between two subsequent weanings. Using these data we can show where the minimum of the average costs of piglets per piece and the average costs of piglets per kilo is with certain input prices.

4 INTRODUCTION OF RESULTS

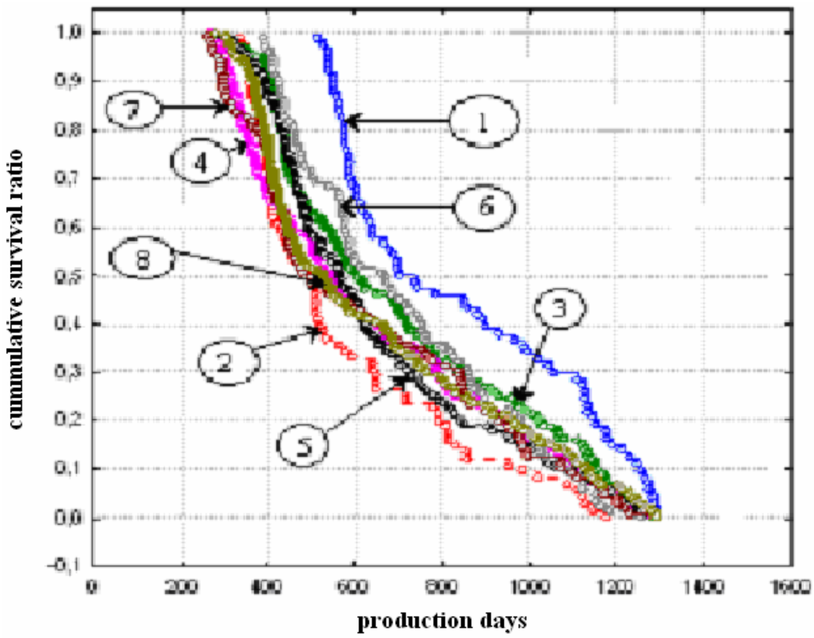
In the course of data collection, comparative evaluation was performed on the basis of more than 10 thousand records of the culled stock. Several records could be related to one sow depending on the number of its insemination and farrowing.

As the number of culling reasons is significant, about 14 in the farm, the survival functions of Kaplan-Meier estimation are presented in two figures, making the run of individual curves easier to follow.

Figure 1. presents the correlation of culling reasons and lifecycles from birth to culling. Those individuals, whose farrowing performance was poor, remained in production by an average of 100-200 days more than those animals, which were culled for other reasons shown by the figure.

The left hand curve shows the riskiest culling reason, presenting sows remaining non-pregnant on day 110. No significant difference could be detected among risks related to other factors presented here.

Figure 1: Comparison of sows' production days related to various culling reasons by survival functions I.

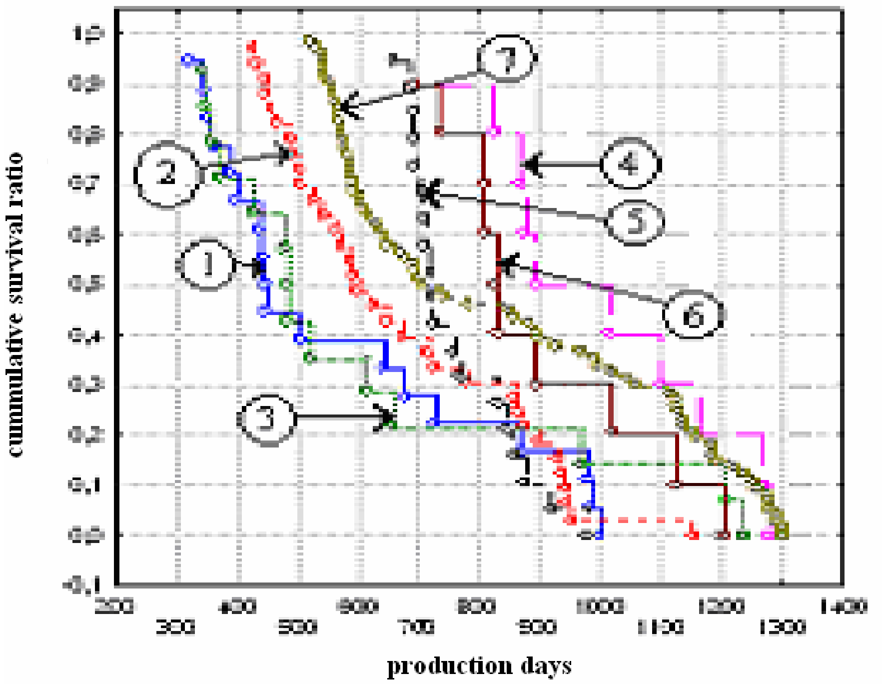


Sign:1.Poor farrowing performance, 2.Empty on day 110., 3.Leg disorders, 4.Re-rutting, 5.Emergency slaughter, 6.Cachexia, 7.Other reasons, 8.Death

The estimation considers time to be a discrete probability variable, so there is no estimated value between two points of time. The vertical gap indicates the higher rate of "survivors" in one group as compared to another one.
The horizontal distance on the figure shows how much later the rate of survivors in one of the groups becomes equal.

Figure 2. presents that the curves of culled sows aborted and inseminated, but not in heat at pregnancy test are placed on the left side of the figure. This is followed by the curve of the stock which was not in heat after weaning and whose farrowing performance was low; by the curve of those animals, which did not reach the index value calculated in the RÖFI program and then by that of culling due to too many empty days. Finally, the least risky culling reason seems to be teat disorder. It can be concluded that the probability of culling due to empty days is lower until day 830. than culling due to low farrowing performance.

Figure 2: Comparison of sows' production days related to various culling reasons by survival functions II.



Sign:1. Due to abortion, 2. Lack of being in heat after weaning, 3. Lack of being in heat at pregnancy test, 4. Teat disorder, 5. Under Index value, 6. Empty day, 7. Poor farrowing performance

Our estimation was prepared by the log-rate exponential model, taking the effects of culling reasons and the lifecycle spent in production into consideration, to show the intensity of cullings as the analogue of mortality intensity (Table 1). The relative risk value of about 1 means the risk of removing animals culled for this reason from production is of average. If this value is below 1, culling is less risky than average. If it exceeds 1, the given factor's significance in culling is higher than average.

On the basis of the above mentioned, the risk order is the following:

Most significant culling reasons: due to abortion, lack of being heat for pregnancy test, low farrowing performance.

Culling reasons slightly higher than average: re-rutting, lack of being heat after weaning, other reasons.

Average culling reasons: emergency slaughter, death, empty for day 110., empty days.

Least risky culling reasons: cachexia, index, teat disorder, old age, few pigs at weaning.

Intensity values can be calculated by the e^{β} values on the table, and the quotients calculated from them can be considered to be the ratio of two probabilities (odds ratios). This way it can be calculated that the probability of culling is 4.66 times higher due to abortion than to old age.

The odds ratio for inseminated, but empty animals at the time of pregnancy test and animals with teat disorder is 3.3. This means that the probability is more than three times higher for culling a sow, which is empty after insemination at the time of pregnancy test than for an animal with teat disorder. The highest risk difference can be observed in the case of culling reasons for abortion and for weaning few pigs. In this case the probability of abortion as a culling reason is 6.18 times higher than in the case of culling for weaning few pigs. Insignificant difference can be detected between the influences of emergency slaughter and death. The probability of culling for emergency slaughter is merely 1.03 times higher than for death.

Table 1: Relative risk values of parameter estimations prepared by Lem piecewise exponential survive model, by culling reasons

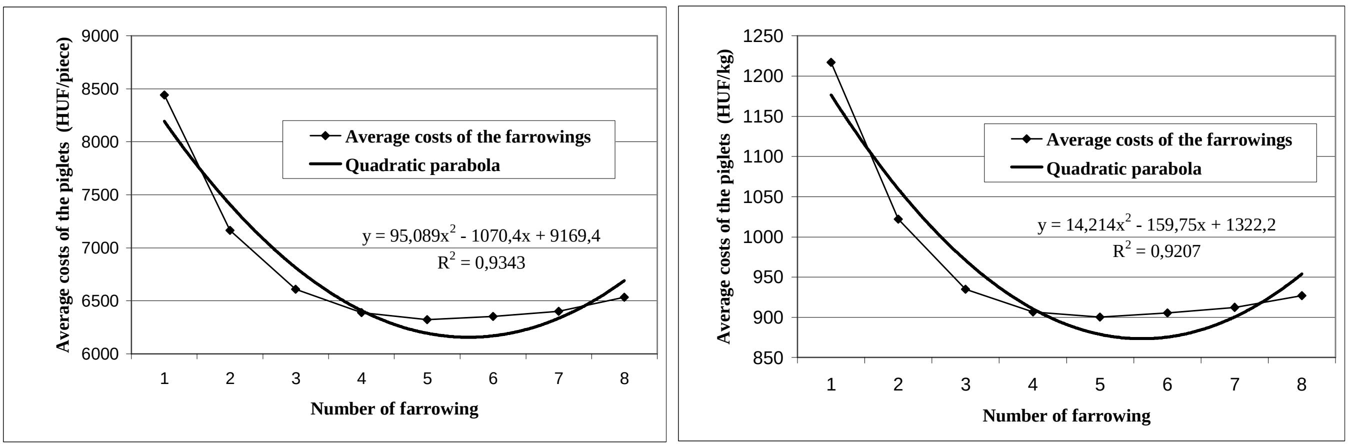
Name	Relative risk value e^{β}
Few pigs at weaning	0.4012
Old age	0.5302
Teat disorder	0.6721
Due to Index	0.7594
Cachexia	0.7827
Due to empty days	*0.9107*
Day 110. empty	*0.9647*
Death	*1.0470*
Emergency slaughter	*1.0794*
Other reasons	1.1402
Lack of being in heat after weaning	1.1764
Re-rutting	1.1902
Low farrowing performance	***1.7571***
Lack of being in heat for pregnancy test	***2.2115***
Abortion	***2.4731***

Besides, we tried to quantify by an economic model how the production period of sows influences the average costs of piglets and the average costs of piglets per kilo.

During our examinations we collected the following basic data: the entrance value of gilt, costs between the entrance and weaning, total variable costs per farrowing, value of the sow at culling, variable costs of progeny, number of weaned pigs, weight (kg) of weaned pigs, costs of the sow between two subsequent weanings.

Using these data we can show where the minimum of the average costs of piglets per piece and the average costs of piglets per kilo is with certain input prices.

Figure 3: The comparison of the average costs of farrowings



The Figure 3. shows big differences among the costs of certain cycles. The left side of the figure presents costs for one 21-day-old pig per farrowing at 2006 prices. It can be clearly seen that in the case of the first farrowing, the cost for 1 weaned pig is about 8500 HUF, while in the second cycle this value is about 7200 HUF. Average costs do not decrease to this extent from the third farrowing, but a slight decline can still be detected. We can see that the 5th farrowing is the minimum cost place (6320 HUF/piece). After this, growth can be observed again. The same tendency appears on the right side of the figure, where the production costs of 21-day-old pigs per body weight kilogram are presented. Values varied from 900 to 1200HUF/kg.

5 Discussion

- On the basis of survival functions, the greatest risks are posed by the following culling reasons: lack of being in heat after insemination at the time of pregnancy test, lack of being in heat after weaning and remaining empty on day 110.
- The survival curves suggest that the lowest risks are related to the culling reasons of poor farrowing performance and teat disorders. It can be concluded that those sows, which were culled for these reasons, remained in production with 100-200 days longer.
- On the basis of relative risk values prepared by the log-rate exponential model, the following can be considered to be the riskiest culling reasons: abortion, lack of being in heat for pregnancy test, low farrowing performance (e^{β}:1.75-2.47).
- The greatest risk differences can be found between the culling reasons of abortion and weaning few pigs. In this case abortion accounted for culling 6.18 times higher than weaning few pigs.
- We quantify by an economic model how the production period of sows influences the average costs of piglets and the average costs of piglets per kilo. The 5th farrowing was the minimum cost place (6320 HUF/piglet and 900 HUF/kg). Therefore, if we took into consideration only the economic respects on the certain farm, it would be practical to cull afterwards or at least do our best in order that most of the sows live to see this point of time.

5 Conclusions

Our estimation was prepared by one of the non-parametric forms of Survival Analysis, the Kaplan-Meier analysis. Mortality intensity was quantified by one of the other models of Survival Analysis, the log-rate exponential model. We find that the most significant culling reasons: due to abortion, lack of being heat for pregnancy test, low farrowing performance.

As a conclusion we can state that production efficiency can be increased in a fattening pig farm if the farrowing numbers of sows are taken into consideration and the place of cost minimum is calculated by the input prices of the given period. By this the optimal point of time as long as sows are worth keeping in production, can be calculated. Therefore, considerable cost savings can be attained on a big farm.

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