FACTORS INFLUENCING THE GROSS VALUE ADDED IN THE SHEEP PRODUCTION CHAIN

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Abstract: The competitiveness of the sheep sector in East Europe has been decreasing from year to year. The value added in the sector is not generated in the countries as a high proportion of the lambs are exported. For example, in Hungary, 95% of the lambs, unnecessary for replacement, are sold at an average weight of 21 kg and are slaughtered abroad. A stochastic model was constructed to investigate the connections between the cycle phases of the mutton production. Three modules were distinguished, the lamb production, fattening and slaughtering-processing sub-modules. The aim of our study was to identify the gross value added generated in the three sub-modules and to analyse the main factors influencing its volume using the conditions in Hungary as an example. The major hypothesis of our research was that the profitability of the production chain is mainly determined by the breed. The results showed that, considering market prices, the gross value added in the processing module was mostly influenced by the number of lambs sold per ewe per year at the bottom level of the mutton product chain. The next most important factors were the weight gain in the lamb producing and fattening sub-modules and dressing percentage in slaughtering-processing sub-module. Contour plots were constructed which help to describe the relationship among analyzed factors. Using the contour plots, the gross value added for different combinations of these factors might be forecast.

Keywords: sheep; simulation model; litter size; gross value added, contours

Intorduction

The four major products of sheep production are mutton, wool, milk and skin. In several parts of the world, especially under temperate climate conditions, mutton is the most relevant sheep product and its importance has continuously increased all over the world (Morris, 2009). Mutton has a highlighted significance also in Hungary for years, because the largest part of the revenues comes from selling live animals for slaughter (Cehla, 2009). Hungary has a rich sheep breeding traditions; however the sheep sector contributes only 1 % to the total production value of the agriculture and merely 2 % to the whole livestock sector (Cehla, 2009). The number of females over 6 months of age was 1 015 556 in 2010. Sheep are currently kept on 6892 farms with the average size of 141 ewes. Mutton consumption in Hungary is about 0.3 kg/person/year and 19 571 tons of sheep for slaughter were produced in 2008. Presently only one sheep slaughterhouse operates in Hungary and even its capacity is not utilized due to the low domestic demand. The Hungarian sheep sector is not sustainable in the long term due to its declining competitiveness, its low efficiency in terms of added value and lack of innovation (Nábrádi, 2009). This situation has been mostly caused by the poor Hungarian mutton supply chain.

For economic analyses of livestock enterprises, several Monte Carlo simulation models have been tested for sheep (Blackie & Dent, 1976; Cacho *et al.*, 1995). The economic efficiency of non-dairy sheep production system under various production and economic conditions were analysed also by bio-economic models (e.g. Wang & Dickerson, 1991; Connington *et al.*, 2000; Krupová *et al.*, 2012), but these models do not include the processing chain of the sheep sector. In Hungary, Cehla (2011) constructed a product chain model for analysing the coupling of the different parts of the sheep production sector.

The aim of our study was to analyse the economic-market problems of sheep production applying the extended model of Cehla (2011). The main factors should be found which are crucial for the generation of gross value added in the sheep production chain. Furthermore, we intended to establish the value creation process innovation by describing the function of the gross value added and the main factors in each sub-module. The research hypothesis was that the profitability and the success of the production chain is mainly determined by the breed.

Material and methods

To calculate the effect of influencing factors on the economics of the sheep sector, a stochastic model with Monte Carlo simulation was used which was constructed by Cehla (2011) originally only for lamb production and fattening, but in its extended form connects all three modules of the product chain, lamb production, fattening and slaughtering-processing sub-modules.

The gross value added (henceforth abbreviated as GVA) was chosen as an indicator variable and was calculated using the method of the Hungarian Central Statistical Office. GVA at basic prices was defined as the difference between the value of output at basic prices and the value of intermediate consumption at purchaser's prices. Basic price is the price for a good or service the seller collects for the sale, less any tax and plus any subsidies.

The output of the lamb producing sub-module was calculated from the value of the produced lambs and other products (wool, manure) counted at basic prices. The output of lamb fattening sub-module was from the fattened lambs sold on basic price. The value of slaughterhouse output was calculated as a product of the weights of useful lamb body parts and their prices applied at the investigated slaughterhouse (Cehla & Nábrádi, 2010).

Intermediate consumption is the value of such products and services that were purchased in the accounting period from another producer and were used for the production of new products and services. However, the depreciation of tangible assets is not included in intermediate consumption. Intermediate consumption is evaluated at purchaser's prices and was calculated separately for each sub-module.

The three sub-modules of the model were connected through the number of sold lambs. Parts of the models were based on experts experiences, while in other cases on analyzes of empirical data. In the stochastic model, differences among production parameters of special breeds were reflected in appropriate distributions.

For the simulation, Crystall ball software package was used. OptQuest is a multiple optimization tool of Crystal Ball developed by Glover *et al.* (1996) on the basis of the so-called "scatter search methodology" principle. "Scatter search" is a population based method which bears common similarities with genetic algorithms, but it is basically built on another search philosophy (Laguna & Armentano, 2005). In OptQuest, the objectives (e.g. the minimization of the standard deviation of the GVA or the maximization of the GVA or its fall between two values) are the actually values which become known after the Excel model has been evaluated for actual input values. During optimization, the ratio of Easter, Christmas and August lambs, number of ewes and number of newly born lambs per ewe were set as decision variables. When determining the stock size, the simulation of the lamb fattening sub-module was run in case of a farm size of 500 to 1000 ewes. During the sensitivity analyses, the model was run 250.000 times in a way that the values of decision variables were fixed and only conditions (input variables as feed prices, weight gain, gross wages, monthly average prices of slaughter lambs of different weight group, feed conversion, dressing percentage, number of lambs sold per ewe per year) were varied. The distributions of inputs were simulated on the basis of time series data from previous years, farm level data and expert assessments. During simulations, saved data were analyzed and a sensitivity report on GVA was prepared revealing the size of the effect of the input variables. Crystal Ball calculates sensitivity by computing the Spearman rank correlation coefficients between all the inputs and the GVA. In order to interpret rank correlations, Crystal Ball also provides the so called "Contribution to variance" index. We must emphasize the fact that this index is not precisely a variance decomposition, only an approximation. Contribution to variance is calculated by squaring the Spearman rank correlation coefficients and normalizing them to 100%. This index estimates the percentage of the variance in GVA due to the given inputs.

During the simulation, Response Surface Methodology (RSM) was used to describe the GVA as a function of input variables. RSM is a combined method of mathematical and statistical techniques, which is beneficial when the modelled variable is a function of several other variables (Myers & Montgomery, 2009). In addition, we also attempt to exploit the multi-dimensional surface generated by dependent and independent variables, its local maximum, minimum, and optimum (Bradley, 2007). Quadratic response surface methodology is a mixture of polynomial and factorial regression. The regression function includes the secondary polynomials of variables and the interaction effects (Bradley, 2007):

$$y = \beta_0 + \sum_{j=1}^{q} \beta_j x_j + \sum_{j=1}^{q} \beta_{jj} x_j^2 + \sum \sum_{i<j} \beta_{ij} x_i x_j + \varepsilon$$

where y is the GVA in the three sub-modules of the product chain; x_i, x_j are the most influencing factors obtained in the sensitivity analysis, β_0 is an estimated constant; βj are regression coefficients; β_{ij} are parameters indicating interaction effects between the factor j and i and ε is the error term with normal distribution. The values of i and j are 1 and 2 in the two-dimensional graphs and $j \neq i$.

In each sub-module, the two most influential factors were selected in order to construct two-dimensional contour plots. For lamb producing sub-module, these were the price of meadow hay (χ_1) and number of lambs per ewe (χ_2), for fattening sub-module, the price of starter lamb feed (χ_1) and feed conversion efficiency (χ_2) and for slaughtering-processing sub-module, daily weight gain (χ_1) and dressing percentage (χ_2). The value of q in the formula is therefore equal to 2.

The two-dimensional contour plots, that show one-dimensional curves on which the plotted quantity q is a constant, were defined according to Boyd (2000):

$$q\,(x, y) = q_j \quad j = 1, 2, \ldots, Nc$$

where Nc is the number of contours that are plotted. These curves of constant q are known as "contours" or as "isolines" or as "level surfaces" of the parameter q.

We fitted a second-order polynomial surface to the points in the 3-D scatter plot by using the Respose Surface Methods package of R 2.11.1 software (Lenth, 2009).

The input data used for the simulation were taken from the databases of the Hungarian Central Statistical Office, Research Institute of Agricultural Economics, Sheep Product

Council and Hungarian Sheep and Goat Breeders' Association. Several distributions were fitted to the inputs establishing the stochastic nature of our model.

Results and Discussion

The results of the sensitivity analyses are presented in Table 1. Only the most influencing variables (rank correlation is higher than 0.2) to the GVA are summarized in this table.

Table 1: The relationship between inputs and the GVA in the three sub-modules

Input variable	Spearman rank correlation coefficient	Contribution to the GVA variance (%)
Lambs producing sub-module		
Meadow hay price Eurocents/kg	-0.214	5.86
Number of lambs sold per ewe per year	0.858	94.14
Fattening sub-module		
Starter lamb feed price Eurocents/kg	-0.378	18.59
Feed conversion kg feed/kg gain	-0.371	17.91
February's average price of 16-20 kg weight slaughter lambs	-0.353	16.21
July's average price of 16-20 kg weight slaughter lambs	-0.224	6.53
August's average price of 24-27 kg weight slaughter lambs	0.202	5.31
December's average price of 27-30 kg weight slaughter lambs	0.224	6.53
December's average price of 24-27 kg weight slaughter lambs	0.242	7.62
March's average price of 27-30 kg weight slaughter lambs	0.277	9.98
Daily weight gain in fattening	0.295	11.32
Slaughtering-processing sub-module		
March's average price of 27-30 kg weight slaughter lambs	-0.425	22.36
December's average price of 27-30 kg weight slaughter lambs	-0.303	11.36
Daily weight gain in fattening	0.241	7.19
Dressing percentage	0.691	59.09

Contribution to variance percentages indicate that the variance of the GVA (given in Table 2) increased by the given percents when the input variables with positive correlation coefficient increased to the maximum value and input variable with negative correlation coefficient decreased to the minimum value.

Table 2: Some statistics of the (GVA) per lamb sold in the three sub-modules (in EUR)

Statistics	Lamb producing sub-module	Fattening sub-module	Slaughtering-processing sub-module
Mean	5.4	9.6	15.3
Median	6.2	9.6	15.2
Standard Deviation	7.8	2.8	3.7
Minimum	-31.1	-5.6	1.8
Maximum	31.9	24.3	31.5

The demanded increases in the inputs for the change in the GVA variance presented in Table 1 can be seen in Table 3.

Table 3: Some statistics of the main input variables employed in the simulation

Main input variables	Mean	Hungarian average	Standard Deviation	Minimum	Maximum
Starter lamb feed price Eurocents/kg	25.00	23.39	3.38	15.00	60.40
Meadow hay price Eurocents/kg	4.23	3.79	0.97	1.90	15.20
Number of lambs sold per ewe per year	1.30	1.38	0.22	0.60	1.81
Daily weight gain in fattening	276.67	280.00	30.63	200.11	349.81
Feed conversion kg feed/kg gain	4.03	3.95	0.51	2.80	8.49
Dressing percentage	50.60	50.00	0.01	48.00	55.00

The results of sensitivity report showed that the GVA in the lamb producing sub-module was determined primarily by the number of newly born lambs per ewe per year.

Similar results were obtained by Dickerson (1969), who stated that the profitability of a breed is determined by the number of lambs weaned, by fertility of females and by meat production of young animals. According to Dickerson (1969), an increasing in prolificacy of ewes from 1 to 2 lambs means a 34 times higher economic efficiency than an increasing in prolificacy of sows from 16 to 17 piglets. Borg *et al.* (2007), calculating the impact of different traits on economic efficiency of American Targhee sheep, found the number of lambs weaned and weaning weight be the most important trait .

Under British extensive grazing conditions, the profitability of sheep industry was determined by ewe prolificacy, survival rate and sale weight of lambs (Conington *et al.*, 2004). The authors concluded that the market prices had only a small impact on the relative economic importance of traits. All these founding were strengthened by the results of our simulations. When investigating the prices of lamb feed, among others (rearing lamb feed, alfalfa hay and corn) meadow hay had the largest negative influence on the GVA in the lamb producing sub-module with a rank correlation coefficient of -0.214 and its contribution to the GVA variance was 5.86% (3.57 EUR according to Table 2).

The starter lamb feed price had the largest negative influence on the GVA in the fattening sub-module with a rank correlation coefficient of -0.378 and its contribution to the GVA variance was 18.59% (1.46 EUR according to Table 2).

Regarding animal traits, weight gain and feed conversion rate had high relevance in the fattening sub-module. In the slaughtering-processing sub-module, mainly the dressing percent determined the GVA. The summary statistics for the GVA obtained in the sensitivity analyses in the three sub-modules of the sheep production chain are shown in Table 2. We did not assume that all lambs sold in the first sub-module will also be slaughtered in the last sub-module as there was a 2-5% loss in the fattening sub-module.

The average GVA values generated in the three sub-modules of the production chain were 5.4, 9.6 and 15.3 EUR per lamb per ewe per year and the highest values were 31.9, 24.3 and 31.5 EUR per lamb sold per ewe per year (Table 2). That means, in favourable scenarios, a positive GVA could be realized. Therefore, reproduction and production traits should be paid more attention in the sheep industry. The value of these traits was highly influenced by sheep breed and the breeding values.

The most important parameters influencing GVA, which was selected in the sensitivity report, are illustrated in the two-dimensional contour plots. The lines (contours) reflect the varying combinations, which represent equal GVA in the simulation (Bradley, 2007). The distance between the contour lines is also important as it reflects the amount of change in one of the inputs that causes an increase in the output ceteris paribus. Observing the contour plots, the contours of two types of surfaces may be separated. The first type of surface is an inclined plain, on its contour inclined lines may be found. The other type of surface is similar to a plain, which has a bulge or a valley on a part of it, and the plain bends to any direction.

The contour plots of the GVA generated in the lamb producing sector is illustrated in Figure 1.

The GVA value is mainly influenced by two variables, by meadow hay price and by the number of lambs sold. In the horizontal axis number of lambs was inserted. The more steep the contours are, the larger is the effect of the number of lambs on the output in comparison to the price of meadow hay. Vertical lines would mean that meadow hay price could be neglected. If there is a bugle or valley on the surface, the direction of the lines will change, thus it may happen that the line curves back on a given area. The surface of GVA regressed on these two variables is of typically sidelong plain, thus there are sidelong lines on its contour. Considering the given price of meadow hay, an increase in the number of lambs sold per ewe per year by 0.1 to 0.15 was necessary for one stage increase in the value of GVA. Fixing the number of lambs, a decrease of meadow hay price by 2-

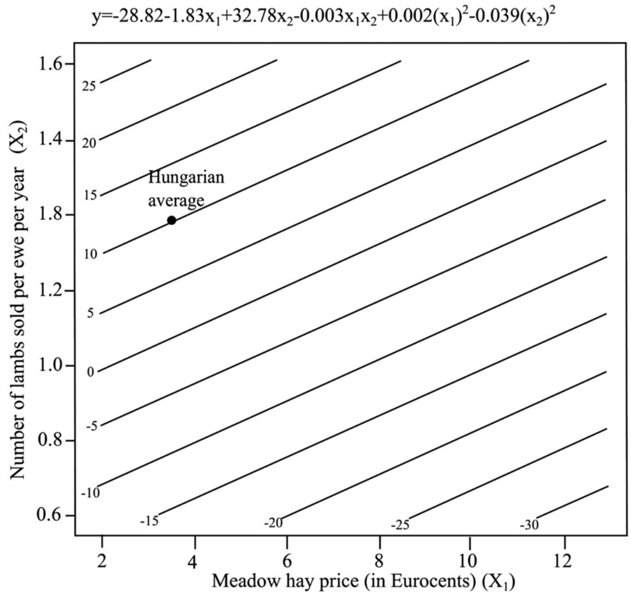

Figure 1. The contour plot of GVA (y) in EUR per lamb sold in the lambs producing sub-module

2.5 Eurocents caused a stage increase in the surface. Regarding the steepness of the lines, the effect of the two variables was not balanced relating to stage increases, the effect of the number of lambs sold per ewe per year was more important which was supported by the sensitivity report as well. On the basis of Figure 1, at least one lamb per ewe per year had to be sold in order to reach zero GVA regarding minimum prices for meadow hay. A relatively high number of sold lambs (1.7) may cause zero GVA if the price of meadow hay will be high (15.2 Eurocents/kg). Regarding high hay prices, GVA may be positive if the number of lambs sold per ewe per year will be high as well (at least 1.4-1.5). In general, the price of meadow hay price should not exceed 9 Eurocents in Hungarian conditions (number of sold lambs of

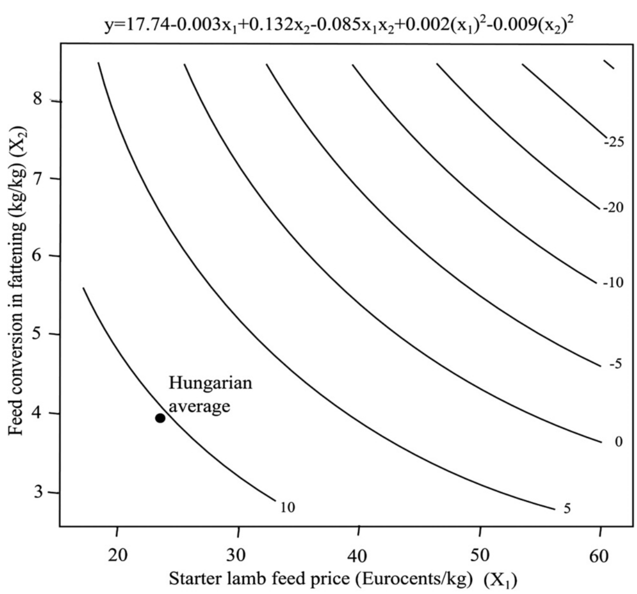

Figure 2. The contour plot of GVA (y) in EUR for the fattening sub-module

1.38). Considering the simulation-average number of 1.3 lambs sold per ewe per year and an average meadow hay price of 4.23 Eurocents, the GVA in the lamb-producing sub-module may be around 5 EUR per lamb sold.

The next participants of the product chain are the fattening farms, for which the contour plot is summarized in Figure 2 for the two most important factors (feed conversion and starter lamb feed price).

The contour plot of fattening farms may be classified into plots of bended surfaces. Regarding the width of the contours under unchanged feed conversion, there was a stage increase in GVA by approximately 5 EUR per lamb sold when decreasing the starter feed price by 10 to 20 Eurocents. If the price of the starter feed was held constant, a decrease in feed conversion rate of 1 to 2 kg feed/kg gain was necessary for GVA to increase by one stage. Under the simulation average feed conversion of 4.03 kg/kg and starter lamb feed price of 25 Eurocents per kg, the GVA would be around 10 EUR/lamb. In the case of an extreme high feed conversion (above 6 kg/kg), the prices of starter feed price may not exceed 35 Eurocents/kg to generate positive GVA.

The GVA in the slaughterhouse-processing sub-module depended mainly on the dressing percentage of slaughtered lambs and on daily weight gain in fattening. From the two factors, the second one was more important (Figure 3).

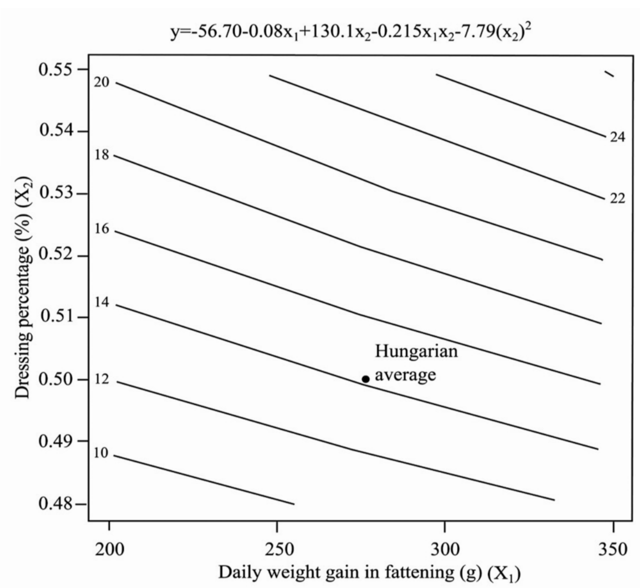

Figure 3. The contour plot of GVA (y) in EUR for the slaughtering-processing sub-module

The surface is typically sidelong plain, which is reflected on the basis of the contour plot. An increase of the dressing percentage by around 1 per cent points caused an increase of GVA by one stage (2 EUR/lamb). For the investigated range of the two parameters, the GVA may be as high as 31.5 EUR per slaughtered lamb per year. To reach this value or higher value then 24 EUR per slaughtered lamb per year, daily weight gain of 300 g and dressing percentage of 55% was necessary. In case of lower dressing percentage (54%), a higher daily weight gain (350 g) was needed. Considering the simulation-average daily weight gain of 276.67 g, already dressing percentage of 49% resulted in GVA of 12 EUR/lamb.

Factors influencing the GVA in the sheep mutton product chain were examined using the conditions in Hungary as an example. On the basis of the sensitivity report, the value added depends mainly on the number of lambs sold per ewe in the lamb producing sub-module, on the feed conversion and daily weight gain in lamb fattening and on the dressing percentage in the slaughtering-processing sub-modules. Regarding the inputs prices, lamb feed, alfalfa hay, corn and meadow prices had also large influence. Overall, our hypothesis that the profitability and the success of the production chain is mainly determined by the breed was supported. We might also conclude that animal traits as feed conversion, daily weight gain and the number of the newly born lambs should be further improved.

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