POTENTIAL FOR PORK PRODUCTION IN THE CZECH REPUBLIC

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Abstract: The main aim of the paper was a partial analysis of the production potential for pig fattening in the Czech Republic. This aim was achieved by econometric modelling of the production function, which was specified as a Cobb-Douglas function, with the level of average daily increase as the dependent variable, and feed compounds, mortality and weight of new stock as independent variables. The model was specified as a fixed effect model, and the parameters of the function were estimated by the method of least squares dummy variable, based on the ordinary least squares method. Verification of the estimated model was based on a *t*-test, coefficient of determination, Wald test, autoregressive test, and test of normality distribution of residuals. Subsequently, the estimated function was analysed and significant determinants of production were identified. The behaviour of the production functions was analysed for the average and marginal productions. The functions were also illustrated in graphs of production surfaces, from which the maps of isoproduction functions were derived. The isoproduction functions were used for the final analysis of the potential for pork production. The analysis was based on panel data from 32 farms focused on pig fattening, collected by our own survey. The research indicated significant differences between the surveyed farms. It also declared the most important factor of final production to be, with 99% probability, the new stock weight. The second most important determinant of final production is the feed compound A3, which is used in the final stage of fattening. For maximized production, the farmer should focus on the weight of pigs coming into fattening, choose the biggest one, and introduce the use of the feed compound A3. The results in the submitted paper should also be used by farmers to evaluate their production activity, and to compare their actual output with the theoretical value enumerated by the production function.

Key words: production function, maps of isoproduction functions, allocation of production factors, exchange rate, rational stage

Pork is the most consumed meat in the Czech Republic. Pork accounts for about 50% of the total meat consumption. The strong position of pork is connected with the customs and habits of the Czech people. It is also affected by the relatively low consumer price of this meat in comparison with the prices of other types of meat. Domestic production plays an important role in satisfying the domestic demand for pork. Pork imports satisfy a smaller portion of the domestic consumption (Table 1).

Despite this strong position of domestic supply, the number of pigs decreased within the whole period under examination, as can be identified from Table 1. The number of pigs dropped from the level of 4 million heads in 1995 to 2.5 million heads in 2007. This decrease was caused by a gradual decline in the pork consumption and it was also connected with a rise in the average costs, caused primarily by an increase in the feed and energy prices. This increase was not followed by a corresponding increase in the pork prices, and thereby led to a drop in the producers' profits.

The decrease in stock was also followed by a decrease in the domestic production. This went from 650 000 t in 1995 down to 463 000 t in 2007, meaning a 30% decrease over that period. In spite of these developments, domestic production is still the most important part of the total pork supply, satisfying around 70% of the total demand.

The relationship between the total supply and domestic consumption is shown in Figure 1.

From a long-term point of view, the market for pork meat can be characterized by a stable overproduction

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Table 1. Balance of pork (thousand head, thousand t)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Number of pigs	3 805	4 048	3 960	3 817	3 489	3 256	3 348	3 429	3 309	2 915	2 890	2 741	2 662
Opening stock	14.5	9.5	9.6	10.3	12.5	13	12	15	18.9	19.2	15.3	19.7	17.3
Domestic production	650	714	680	669.9	638.8	583.9	584	585.4	576.3	547	472	449.3	463.7
Imports	12	8.4	3.4	33.7	23.5	19.2	22.3	34.3	40.2	93.5	147	154.6	183.5
Total supply	676.5	731.9	693	713.9	674.8	616.1	618.3	634.7	639	659.7	634.3	623.6	664.5
Domestic consumption	666.7	720.8	663.8	663.5	648.6	596.1	589.2	586	602.5	599.4	569.9	564	589
Exports	0.3	1.5	18.9	37.9	13.2	8	14.1	29.8	17.3	45	44.7	42.3	57.2
Closing stock	9.5	9.6	10.3	12.5	13	12	15	18.9	19.2	15.3	19.7	17.3	18.3

Source: author by the MA CZ

and a decreasing supply, as well as demand. Supply evolved in the same way as domestic consumption within the period 1995–2001, but different tendencies have existed since 2002. Consumption has been decreasing, but supply has slowly increased. The difference between supply and domestic consumption went from 26 700 t in 1995 up to 201 200 t in 2007. This growing deviation gave rise to the growth of pork exports to foreign countries, especially to the states of the European Union. These exports increased from 300 t in 1995 to 57 200 t in 2007.

In spite of the fact of the significance of pork meat in the Czech meat market, there were published only a few studies focused on this kind of meat in the recent time period (Čechura and Šobrová 2008; Lechanová 2006). The mentioned studies analyzed especially the transmission process in Czech pork chain without the analysis of the production process, therefore, the main aim of the presented paper was a partial analysis of the production potential in pig fattening in the Czech Republic. This aim was divided into the following sub-goals:

(1) Specification of a production function;
(2) Quantification of a production function;
(3) Quantification of the characteristics of production;
(4) Modelling of a production surface;
(5) Analysis of isoproduction maps.

MATERIAL AND METHODS

Pork production was specified as a multifactor function in which the individual production factors, such as the specific feedstuffs, zoo-technological factors, intensity of fattening and specific runt, are exogenous variables which determine the final production. Of the above-mentioned factors, the type of feed and the intensity of fattening can be identified as the main ones affecting the level of

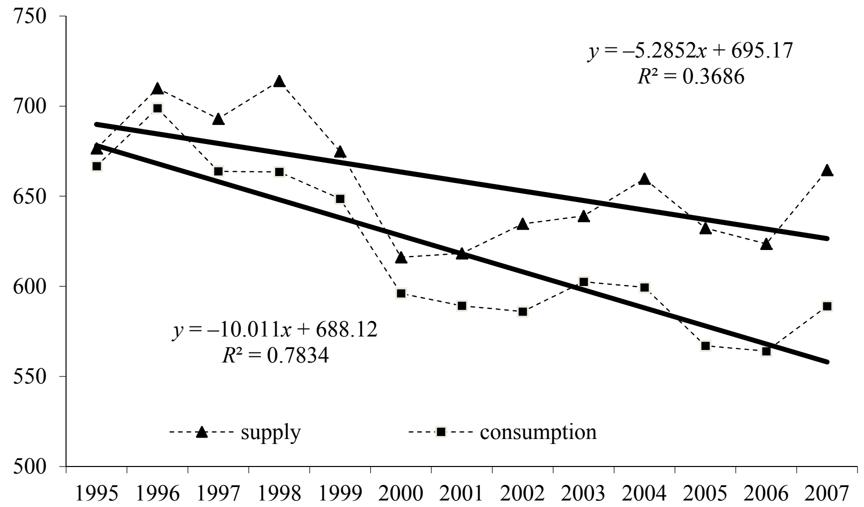

Figure 1. The relationship between the total supply and domestic consumption

Source: author

production. Pork fattening uses three feed compounds in particular:

A1 – used for piglets between 15 and 35 kg live weight;

A2 – used for pigs between 35 and 65 kg live weight;

A3 – used for pigs with the weight higher than 65 kg.

The main hypothesis is that pork production in the category of the average daily increase in live weight (*YP*) is positively affected by all of these feed compounds, but the intensity characterised by elasticity is under-proportional. The feed compound A2 is supposed to be the most effective of the above-mentioned feed compounds.

Other factors representing the technology of fattening are the mortality of stock (*M*), and the weight of new stock (*W*). These factors negatively affect the level of production.

On the basis of these hypotheses, an economic model of pork production can be formulated as:

$$YP = f(\mathrm{A1}, \mathrm{A2}, \mathrm{A3}, M, W) \quad (1)$$

The mathematical form of this function was chosen to be a Cobb-Douglas function, which is characterized in the publication of Varian (1992) and Kralik et al. (2006) by the constant elasticity of production factors, the constant elasticity of factor substitution, and the convexity of the isoproduction function.

Data used for the estimation of the function was collected from a panel of 32 farms during the period 2004–2007, and it was also obtained through the authors' own questionnaires. The character of the data resulted in the addition of dummy variables into the function, representing a farm specification. The last hypothesis states that there is a significant variability in efficiency among the farms under examination.

The econometric model can be written as:

$$YP_{it} = \gamma_0 A1_{it}^{\gamma_1} A2_{it}^{\gamma_2} A3_{it}^{\gamma_3} M_{it}^{\gamma_4} W_{it}^{\gamma_5} e^{I_{it}} u_t \quad (2)$$

where:

YP_{it} = level of average daily increase on farm *i* for time *t* (kg/FD)[1]

$\mathrm{A1}_{it}$ = consumption of feed compound A1 on farm *i* for time *t* (kg/FD)

$\mathrm{A2}_{it}$ = consumption of feed compound A2 on farm *i* for time *t* (kg/FD)

$\mathrm{A3}_{it}$ = consumption of feed compound A3 on farm *i* for time *t* (kg/FD)

M_{it} = mortality of piglet stock on farm *i* for time *t* (%)

W_{it} = average weight of new stock on farm *i* for time *t* (kg)

$\gamma_0, \gamma_1, \ldots, \gamma_5$ = structural parameters

I_{it} = dummy variable for farm *i*

u_t = stochastic variable for time *t*, $u_{it} \sim nid(0, \sigma^2)$

t = 1, 2, ..., *T*

i = 1, 2, ..., *N*

The method of the least squares dummy variable (LSDV) was used to estimate the parameters in this model, with respect to a farm specification. The specification is modelled by dummy variables for *N* – 1 farms. The farm specification of the last farm is characterised by an intercept.

The method uses the least squares estimation, which is based on 10 assumptions as published by Gujarati (2003), as well as Kennedy (2008):

(1) The model is linear in its parameters.

(2) The values of independent variables are fixed in the repeated sampling and variable in time period.

(3) The mean value of the stochastic variable is zero for given values of exogenous variables.

(4) The variance of the stochastic variable is homoscedastic.

(5) There is no autocorrelation in the stochastic variable.

(6) The stochastic variable and explanatory variables are uncorrelated.

(7) The model is correctly specified.

(8) There is no multicollinearity in the regressors.

(9) The stochastic variable is normally distributed.

(10) There must be a positive number of degrees of freedom.

As a result of assumption 1, the power function used must be linearised by logarithmic transformation. The estimation model was in the form:

$$YP_{it} = \ln\gamma_0 + \gamma_1 \ln \mathrm{A1}_{it} + \gamma_2 \ln \mathrm{A2}_{it} + \gamma_3 \ln \mathrm{A3}_{it} + \gamma_4 \ln M_{it} + \gamma_5 \ln W_{it} + I_{it} + \ln u_t \quad (3)$$

Fulfilment of the other assumptions mentioned was verified by the analysis of residuals, especially by the autoregressive test (AR test) and the test of normality. Statistical verification of the estimated model was based on the coefficient of determination (R^2), Wald test and *t*-test.

The parameters were estimated using the PC GIVE 12 econometric software.

Data characteristics

The panel data used for the estimation were collected through our own examination of 32 Czech

[1]FD = feeding day

farms focused on pig fattening, which were randomly chosen with respect to the population structure from all regions of the Czech Republic. Each of the analysed farms used a continuous lot for piglets, and grid housing. They also used the same feed compounds.

During all the years under examination, the production process was characterized by an average daily production increase at the level of 0.675 kg/FD. This production was gained by using 0.51 kg/FD of feed compound A1, 1.06 kg/FD of the feed compound A2, and 1.06 kg/FD of the feed compound A3, with the new stock weight at the level of 32.08 kg and with 4.52 % mortality.

Table 2. Statistical characteristics of the data used in analysis

Series	Mean	Std. error	Minimum	Maximum
2004				
W	32.776	9.957	17.6	56
M	4.343	2.856	0.51	12.56
A1	0.507	0.346	0.026	1.13
A2	1.092	0.742	0.09	3.03
A3	1.006	0.498	0.22	2.65
YP	0.691	0.057	0.578	0.782
2005				
W	30.628	9.532	16.8	55
M	4.806	3.47	0.82	15.49
A1	0.586	0.328	0.16	1.28
A2	1.014	0.79	0.15	3.12
A3	1.05	0.586	0.21	2.65
YP	0.658	0.075	0.507	0.792
2006				
W	31.869	9.198	17.3	5.000
M	4.588	2.937	1.01	12.24
A1	0.48	0.361	0.05	1.19
A2	1.028	0.81	0.062	3.3
A3	1.046	0.527	0.091	2.59
YP	0.671	0.074	0.486	0.804
2007				
W	33.058	9.096	18.1	55
M	4.324	2.66	1.01	13.73
A1	0.476	0.369	0.02	1.154
A2	1.093	0.794	0.02	3.26
A3	1.135	0.574	0.23	2.63
YP	0.678	0.075	0.489	0.792

Source: own calculation

The common statistical characteristics of the variables used in the databases for all years are introduced in Table 2.

The most significant difference among the surveyed farms was in the weight of the new stock. The value of this variable varied from 16.8 kg per piglet to 56 kg, in all farms and all years. An analysis of the data revealed that the farm with the highest value for weight of the new stock also achieved the highest value for the daily production increase. On the other hand, there is no connection between the lowest value for the new stock weight and the lowest daily production increase. Another variable with strong differences was the mortality of piglets, which ranged from 0.51% to 15.49%.

As for the feed consumption, the most significant difference can be seen in the consumption of the feed compound A2, which had a standard error of around 0.8 in all years; its lowest value was 0.02 kg/FD and its highest level was 3.3 kg/FD.

Table 3. Results of estimation

Variable	Coefficient	Std. error	*t*-value	*t*-prob
A1	−0.027165	0.01949	−1.39	0.176
A2	0.05568	0.02191	2.54	0.018
A3	0.115019	0.02139	5.38	0
M	−0.108471	0.03283	−3.3	0.003
W	−0.335769	0.1066	−3.15	0.004
Constant	1.04065	0.407		0.017
I_1	−0.065564	0.03216	−2.04	0.052
I_2	−0.235748	0.06514	−3.62	0.001
I_3	−0.221249	0.07598	−2.91	0.007
I_4	−0.149023	0.05825	−2.56	0.017
I_5	−0.190572	0.03447	−5.53	0
I_6	−0.115983	0.08819	−1.32	0.2
I_7	−0.005753	0.03567	−0.16	0.873
I_8	−0.233993	0.04345	−5.38	0
I_9	−0.103835	0.0725	−1.43	0.164
I_{10}	−0.271503	0.06054	−4.48	0
Verification				
Sigma	0.0645788	sigma^2	0.00417	
R^2	0.8282031			
RSS	0.1042606	TSS	0.606883	
Wald (joint):	Chi^2(5) = 392.1 [0.000]**			
Wald (dummy):	Chi^2(11) = 66.33 [0.000]**			
AR(1) test:	N(0.1) = −1.648 [0.099]			
AR(2) test:	N(0.1) = −1.318 [0.187]			

Source: own calculation

In spite of this variability, production was characterized by the lowest variability that was also seen in the standard error. In all years and on all farms, the production only varied from 0.486 kg/FD to 0.804 kg/FD. The lowest variability can be identified in 2004, when the mean was 0.691 kg/FD and the standard error was 0.057.

RESULTS AND DISCUSSION

The results of the estimation by the LSDV are shown in Table 3, which also provides the outcomes of the statistical and econometric verification of the model.

Apart from the variable A1, the estimated parameters verified the proposed hypotheses about the positive influence of feed consumption, and the negative relationship between mortality, as well as the new stock weight, and endogenous variables. Statistically, the parameters of the exogenous variables, again with the exception of the variable A1, are significant at a 5% level of probability.

As it was previously mentioned, all these parameters can be defined as a percentage change in the weight increase, as a result of a one percent change in the exogenous variable. The relative character of a change in the endogenous variable affords a comparison of the intensity of the relationship between the exogenous variables and the dependent variable. From this point of view, the most significant variable which changes production is the new stock weight. When the weight increases by 1%, the production decreases by 0.34%. The second significant factor is the consumption of the feed compound A3. An increase of one percent in these feeds affects the increase in production by a level of 0.11%, which means around 1.1 grams of live weight per feed, per day. Apart from the feed consumption, the next most important influence was identified as the consumption of A2 (0.056%). This result, which was not anticipated, could be important in the analysis of the optimal combination of production factors.

Dummy variables and a constant were also used in the model. Finally, the estimation was done using the data from 11 farms, because farms with missing values were eliminated from the analysis by the software. This explains why there are only 10 dummy variables. The farm specification of the 11th farm is characterised by a constant.

Most of these dummy variables have statistically significant parameters with a high level of probability (5%). Only I_6, I_7 and I_9 are not statistically significant. This outcome verified the hypothesis of the significance of the farm-specific technology for production. The interpretation of the dummy variable can be done through the example of a linear function form for the model:

$$\underset{(SE)}{YP} = -\underset{(0.0195)}{0.027}\mathrm{A1} + \underset{(0.0219)}{0.056}\mathrm{A2} + \underset{(0.0214)}{0.115}\mathrm{A3} - \underset{(0.0328)}{0.109}M - \underset{(0.107)}{0.336}W + \underset{(0.407)}{1.041} - \underset{(0.0322)}{0.066}I_1 - \underset{(0.0651)}{0.236}I_2 - \underset{(0.076)}{0.221}I_3 - \underset{(0.0583)}{0.149}I_4 - \underset{(0.345)}{0.191}I_5 - \underset{(0.0882)}{0.116}I_6 - \underset{(0.0357)}{0.006}I_7 - \underset{(0.0435)}{0.234}I_8 - \underset{(0.0725)}{0.104}I_9 - \underset{(0.0605)}{0.272}I_{10} \quad (4)$$

The intercept declares the efficiency of the compared farm. The technological efficiency of the second farm can be quantified as the sum of the constant and the dummy I_1. The technological efficiency of the third farm can be quantified similarly – the sum of the constant and the dummy I_2. It is obvious that the dummy variables can be used for characterisation of each farm and for an analysis of farm differences. Figure 2 represents the farm dummy variables in absolute values.

In addition, the R^2 value of 82.82% shows that the regression line fits perfectly to the data. This result is also supported by the Wald test, which verified a significant relationship between the endogenous and exogenous variables. Autocorrelation, which can negatively affect the efficiency of the estimated

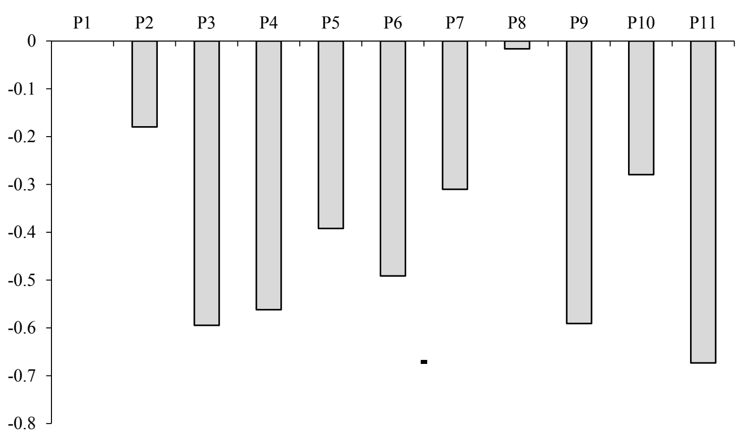

Figure 2. Differences in farm dummy variables in comparison with the farm F1

Source: own calculation

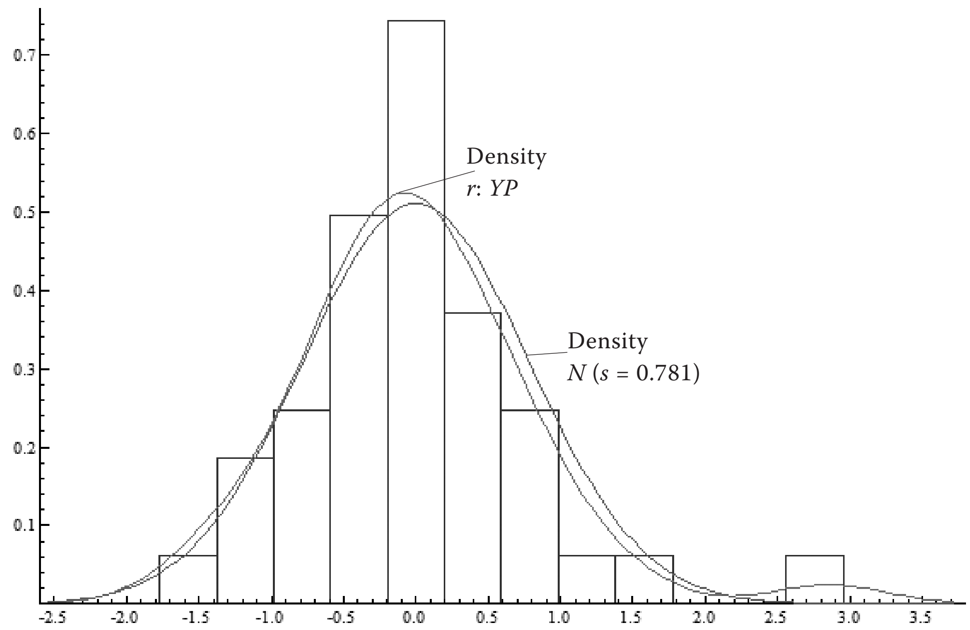

Figure 3. Normal distribution of disturbance term

Source: own calculation

parameters, was also tested. The AR test was used for the tested hypothesis of no autocorrelation. The value for this test in Table 3 verified this hypothesis.

Assumption 9, about the normal distribution of the stochastic term, was also tested. This test was performed through Figure 3.

Microeconomic analysis of the estimated production function

The estimated production function can be modified into a production function for each farm in the selected group of farms. These production functions are shown in the Table 4.

From the analytical point of view, the most important part of the analysis is the relationship between the feed compound A2, the feed compound A3, and production, assuming that all other variables are constant. This dependence can be graphically described by a production surface which is created by the points of production values for all combinations of A2 and A3.

For the next analysis, it is better to modify the production functions into the production function of the farm with the highest value of the dummy variable

Table 4. Production functions for the selected farms

Production function of farm *F*1	$YP_{F1} = 2.83106 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*2	$YP_{F2} = 2.65140 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*3	$YP_{F3} = 2.36477 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*4	$YP_{F4} = 2.26914 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*5	$YP_{F5} = 2.43910 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*6	$YP_{F6} = 2.33983 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*7	$YP_{F7} = 2.52103 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*8	$YP_{F8} = 2.81482 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*9	$YP_{F9} = 2.24041 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*10	$YP_{F10} = 2.55184 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$
Production function of farm *F*11	$YP_{F11} = 2.15793 \times A_1^{-0.02717} \times A_2^{0.05568} \times A_3^{0.11502} \times M^{-0.10847} \times W^{-0.33577}$

Source: own calculation

Table 5. Production function of ϕmax and ϕmin farms

TP Φmax	$TP\text{max} = 0.70954 \times A_2^{0.05568} \times A_3^{0.11502}$
TP Φmin	$TP\text{min} = 0.70083 \times A_2^{0.05568} \times A_3^{0.11502}$
*AP*A2 ϕmax	$AP_{A2}\text{max} = 0.70954 \times A_2^{-0.94432} \times A_3^{0.11502}$
*AP*A2 ϕmin	$AP_{A2}\text{min} = 0.70083 \times A_2^{-0.94432} \times A_3^{0.11502}$
*MP*A2 ϕmax	$MP_{A2}\text{max} = 0.03951 \times A_2^{-0.94432} \times A_3^{0.11502}$
*MP*A2 ϕmin	$MP_{A2}\text{min} = 0.03902 \times A_2^{-0.94432} \times A_3^{0.11502}$
*AP*A3 ϕmax	$AP_{A3}\text{max} = 0.70954 \times A_2^{0.05568} \times A_3^{-0.88498}$
*AP*A3 ϕmin	$AP_{A3}\text{min} = 0.70083 \times A_2^{0.05568} \times A_3^{-0.88498}$
*MP*A3 ϕmax	$MP_{A3}\text{max} = 0.08161 \times A_2^{0.05568} \times A_3^{-0.88498}$
*MP*A3 ϕmin	$MP_{A3}\text{min} = 0.80609 \times A_2^{0.05568} \times A_3^{-0.88498}$

TP – total product, AP – average product, MP – marginal product, ϕmin (max) – farm with lowest (highest) dummy variable

Source: own calculation;

(Φ max), representing the highest level of technological equipment for the set of farms, and into the production function of the farm with the lowest value of the dummy (Φ min). These production functions are shown in Table 5, which also introduces the functions of the average and marginal productions.

The average as well as marginal production functions are decreasing in all intervals under examination, i.e. A2 ∈ <0.92; 1.39 > and A3 ∈ < 0.83; 1.33 >. The maximum values of all average and marginal production functions were achieved using the initial values from the intervals of both factors. The character of production and also of the marginal production functions does not allow for the specification of the local maximum of the stated production functions in the factors' intervals.

The production function for the Φ max farm is represented by the concave production surface in Figure 4. This behaviour of the production function is characterised by the above-mentioned decrease in marginal production. Feeding with a higher quantity of both feed compounds implies the expansion of the daily weight increase, but in an under-proportional way. The highest value of production was achieved for the finite values in the above-mentioned intervals of production factors.

The production surface is the basis for the map of isoproduction functions. This map permits the definition of the production factor combinations which generate the same value of production. Figure 5 shows the map of isoproduction functions for the Φ max farm. The convex scheme of the isoproduction functions determines the negative exchange rate of production factors, which is bordered by the positive exchange rate stage. This behaviour allows the substitution of production factors in the negative exchange rate stage. This part of the isoproduction function is known as the rational stage of production. For example, a production of 0.72 kg/FD can be achieved by A2 = 1.151 kg/FD and A3 = 0.974 kg/FD. The feed compound A2 can substitute for A3, which implies the same production value for consumption of 1.239 kg/FD of A2 and 0.842kg/FD of A3. This

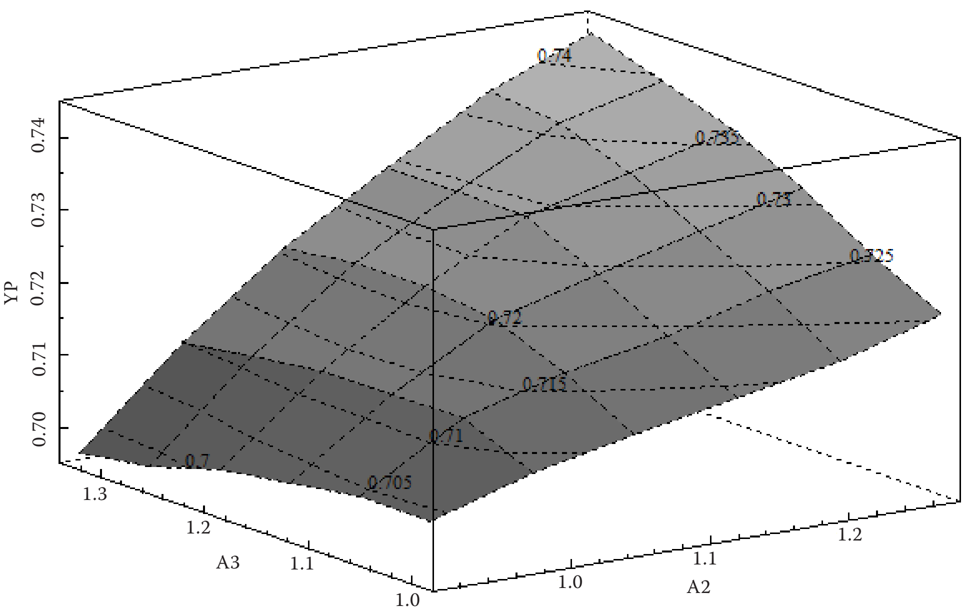

Figure 4. Production surface for Φ max farm

Source: own calculation

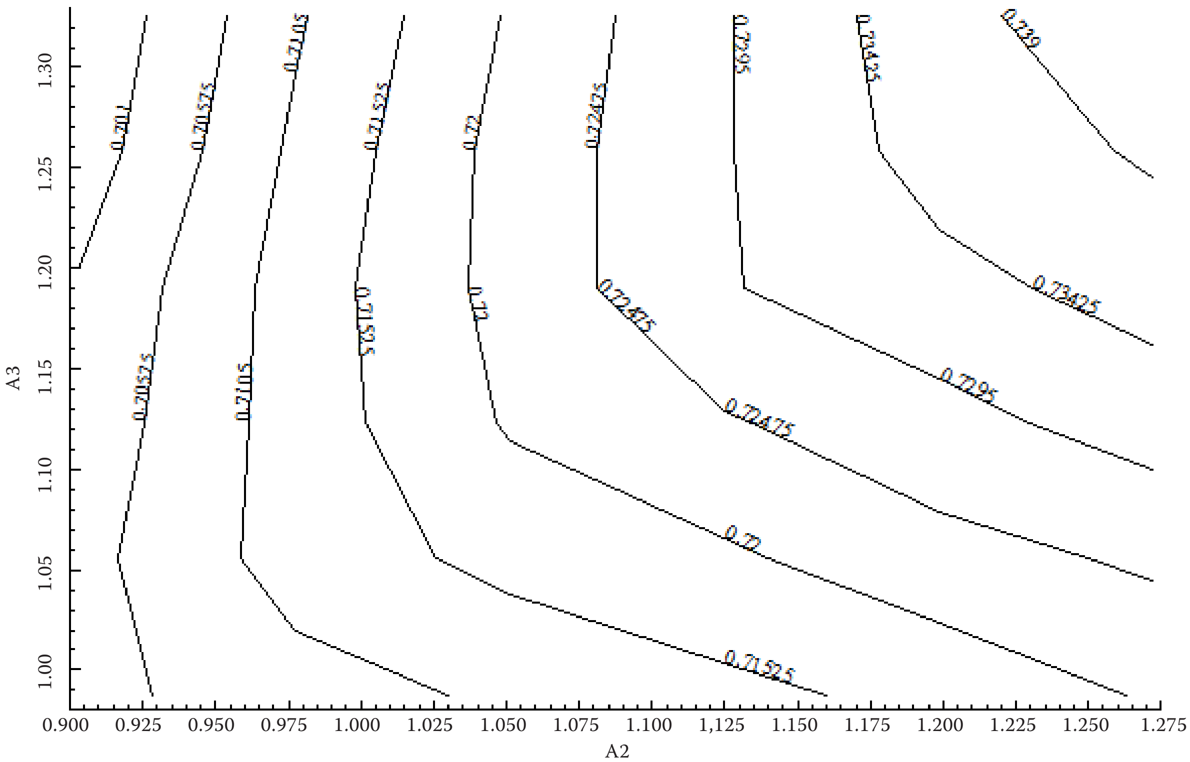

Figure 5. Map of isoproduction function for the Φ max farm

Source: author

substitution can be used for the cost minimisation, in which the more expensive factor is replaced by a cheaper substitute.

With regard to the positive factor exchange rate stage, the substitution of production factors does not exist. An increase in one factor is followed by an increase in the second one. This stage is irrational. A clear example of this irrational stage is the part of the isoproduction function for 0.702 kg/FD in 5. This production can be attained by using A2 = 0.92 kg per FD and A3 = 1.2 kg/FD, as well as A2 = 0.925 kg/FD and A3 = 1.3 kg/FD.

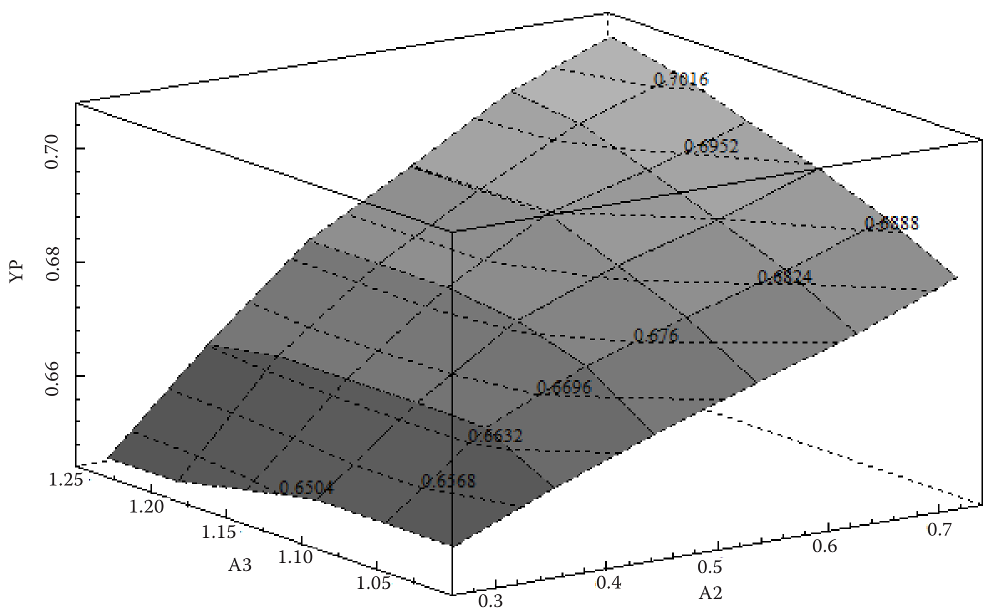

Figure 6. Production surface for the Φ min farm

Source: author

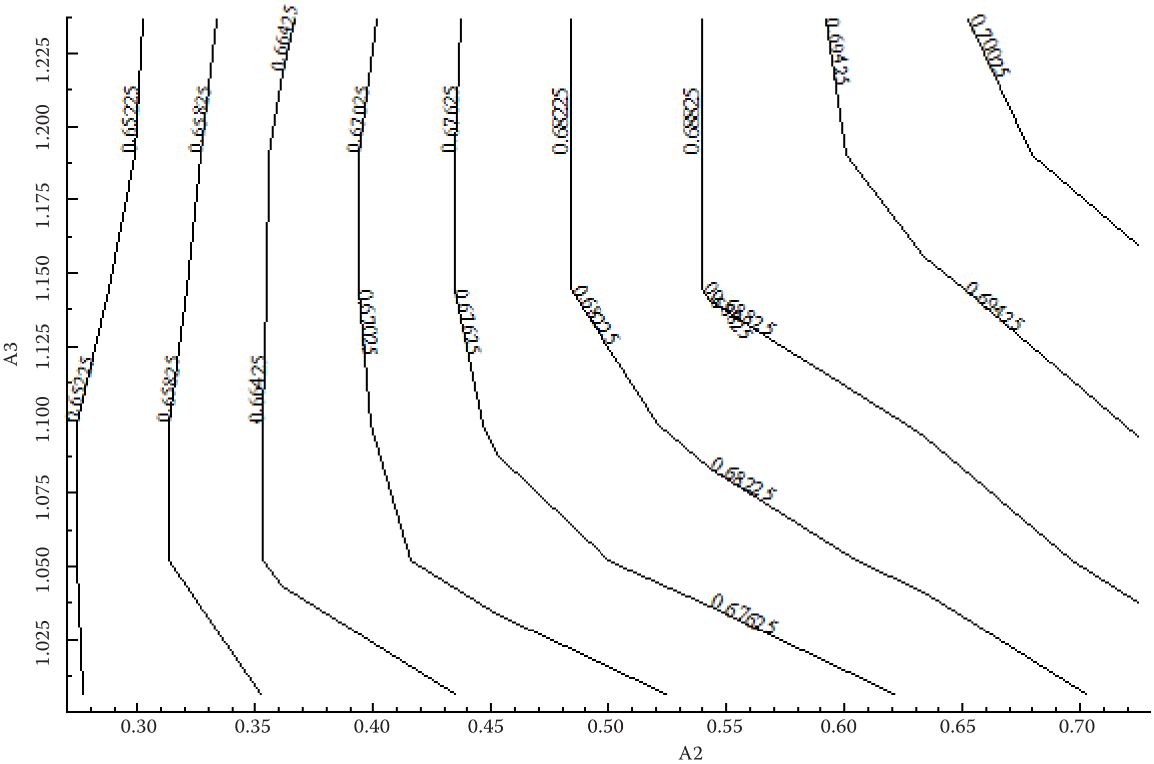

Figure 7. Map of isoproduction function for the Φ min farm

Source: author

An example of a production function for the Φ min farm is represented by the concave production surface in Figure 6, and the map of isoproduction functions for the same farm is represented in Figure 7.

CONCLUSION

Analyses of the pork production functions verified most of the specified hypotheses. The estimated model indicated that pork production in the category of the average daily increase in live weight is positively affected by the consumption of the feed compounds A2 and A3, but the intensity characterised by elasticity is under-proportional. Mortality of stock and weight of new stock negatively affect the production. The main effect, indicated by structural parameters which are represented by elasticity in the employed Cobb-Douglas function, is possessed by the variable new stock weight (0.336%). The second most influential variable is the feed compound A3, with an elasticity value of 0.115%. These results were statistically significant at a 5% level of probability and with an 82% fit.

From an analytical point of view, the feed compounds A2 and A3 were determined to be the most important factors influencing the production of pork. The production functions, defined and graphically represented with these feed compounds as the explanatory variables, also show the under-proportional effects of these factors. The behaviour of the production functions, graphically analysed by the maps of isoproduction functions, verified the substitution between the feed compounds mentioned; this is defined in the part of the isoproduction function with a negative exchange rate of substitution. This rational stage is important for the optimal allocation of production factors, implying the cost minimisation.

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