ANALYSIS OF INPUT DEMAND AND OUTPUT SUPPLY FUNCTIONS IN CZECH MILK PRODUCTION*

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The paper deals with an analysis of input demand and output supply functions for the dairy sector in the Czech Republic. The analysis is based on a balanced panel dataset of 36 milk producers within the period 2004–2007. A Cobb-Douglas production function is fitted to describe the production process of the analyzed sample. The heterogeneous technology or efficiency of individual producers is captured by using the method of fixed effects. Then, the results show that the technology is significantly heterogeneous in the analyzed sample, and this causes significant differences in the derived input demand functions and the short-run conditional output supply function. Finally, an analysis of input demand functions and the short-run conditional output supply function shows that the behaviour of more than 50% of the analyzed milk producers is consistent with rational behaviour.

milk production; input demand function; output supply function; production function; rational behaviour

INTRODUCTION

The dairy sector is one of the most important sectors of Czech agriculture. The task of policy makers is to support an environment and make decisions which will improve the competitiveness of this sector. In light of this, an analysis of the determinants of productivity and efficiency is fundamental for identifying the sources of competitiveness for milk producers and the sector as a whole, and thus to supply policy makers as well as milk producers with information on which to base their decisions.

The assumption that individual farmers exhibit rational behaviour is a crucial in this regard. This means that each farmer should produce with minimal costs to reach maximal profit from a given level of output, or should maximize the profit from given input and output prices subject to its technology. This paper attempts to analyze the input demand and output supply functions in a sample of randomly chosen milk producers. Specifically, the analysis concentrates on the characteristics of the mentioned functions and on verification of the stated assumption, i.e., whether the behaviour of milk producers is consistent with rational behaviour.

An empirical analysis of input demand and output supply functions for the dairy agri-food chain and an accompanying resolution of optimization problems was done by Dean et al. (1972), Ghebremariam et al. (2006), and Yelou et al. (2007, 2009), among others.

Dean et al. (1972) analyzed and discussed possibilities for increasing the efficiency and profitability of dairy production through improved feed formulation and feeding programs. The research combined production response functions, which are estimated based on experimental data, and standard linear programming techniques. The analysis used different types of production functions for different combinations of feed components and different types of cows. Ghebremariam et al. (2006) estimated a production function for fresh milk in Eritrea. The authors estimated three production functions for three different regions, based on questionnaires from 120 respondents. Least-cost criteria and the condition of profit maximization were then employed, analyzed and discussed. The analysis showed that dairy farmer respondents are using their resources in the rational stage of the production function, but they are not allocating their resources on a minimum-cost basis. However, the profit maximizing and least-cost criteria assume perfect knowledge, a risk-free environment and competitive markets. The authors suggest that improved information, farmer training, and better infrastructure to promote competitive markets could help to enhance resource allocation decisions by dairy producers. Yelou et al. (2007, 2009) analyzed dairy production in Canada. The authors used a fixed effects stochastic frontier model on a panel of 302 dairy farms located in the province of Quebec, and observed them during the period from 1993 to 2003. They employed both models, with and without thresholds. An empirical analysis tested and discussed different thresholds in dairy production. The efficiency of milk production in the Czech Republic was analyzed by Kopeček (2002, 2004) and Jelínek (2007), among others. Kopeček (2002, 2004) analyzed relationships between the level of milk yield and the economic results of the breeding of dairy cows, based on data from 135 farms in the year 2000 and 146 farms in the year 2002, respectively. They found that milk yield tends to grow faster compared to the costs for market milk for one feed-

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ing day. Maximum profit per one litre of milk, maximum profit per dairy cow and the interval of profitability of milk production were also determined based on the estimated cost functions. J e l í n e k (2007) focused his research on the efficiency of milk production. The author identified the explanatory variables of inefficiency, and emphasized the conclusion that the applied technology currently available significantly influences technical efficiency. A stochastic frontier model was employed within the analysis.

MATERIAL AND METHODS

The aim of the paper is to analyze the input demand and output supply functions in the Czech dairy sector based on the fitted production function for a group of randomly chosen milk producers.

The paper attempts to verify the following hypotheses. First, the production process and thus the derived input demand and output supply functions differ significantly within the group of analyzed milk producers. Second, the input demand functions have low elasticities. Finally, the behaviour of milk producers is consistent with rational behaviour, i.e., they demand inputs which will minimize the costs of production, and they produce an amount of output which will maximize revenue.

The dataset employed in estimating the milk production function was gathered based on a questionnaire for a group of randomly chosen milk producers. The producers were randomly chosen from a particular region of the Czech Republic, in numbers which corresponded to the structure of the population. The sample contains data from 44 milk producers. After the cleaning process, we were left with 36 milk producers. Since the data cover the period of 2004–2007 we disposed with the panel dataset which allows capturing the time specifics of production. Moreover, the majority of milk producers keep Holstein or Czech Fleckvieh Breed types of cows or a combination thereof, respectively.

The panel dataset is balanced. Table 1 contains basic statistical characteristics of variables employed in the analysis. It can be observed that all variables showed a slightly increasing movement during 2004–2007. Then, the variables differ significantly in the sample. We can also deduce that increases in the use of silage and compound feed, as well as in costs per feeding day, result in an increase of milk yield.

The production function is estimated in the form of the Cobb-Douglas production function. The reason for this option is the simplicity, usefulness and efficiency of this form in the analytical part, despite the fact that the Cobb-Douglas form has some restrictive properties. Then, the general form of the fitted production function is as follows:

$$y_{it} = \alpha_0 x_{1it}^{\beta_1} \ldots x_{kit}^{\beta_k}, \quad \text{(i)}$$

Table 1. Statistical characteristics of employed data set

Year 2004						
Series	Abbreviation	Obs.	Mean	Std. deviation	Minimum	Maximum
Silage	SI	36	2690.39	1843.011	354	8869
Compound feed	KF	36	1016.339	628.489	26	2645
Costs per feeding day	CFD	36	149.377	34.693	58.552	224.431
Milk yield / year	Y	36	6624.97	1263.18	4324.783	9614.43
Year 2005						
Series	Abbreviation	Obs.	Mean	Std. deviation	Minimum	Maximum
Silage	SI	36	2755.697	1839.42	226	8755
Compound feed	KF	36	1064.277	631.403	17	2416
Costs per feeding day	CFD	36	149.661	35.21	62.682	218.144
Milk yield / year	Y	36	6874.804	1194.816	4859.269	9507.162
Year 2006						
Series	Abbreviation	Obs.	Mean	Std. deviation	Minimum	Maximum
Silage	SI	36	2713.642	1788.523	206.3	9793
Compound feed	KF	36	1070.223	598.139	29	2373
Costs per feeding day	CFD	36	154.536	35.752	65.491	209.936
Milk yield / year	Y	36	6965.088	1244.67	4125.302	9599.127
Year 2007						
Series	Abbreviation	Obs.	Mean	Std. deviation	Minimum	Maximum
Silage	SI	36	2775.888	1863.67	277.2	9305
Compound feed	KF	36	1048.064	597.196	39	2454
Costs per feeding day	CFD	36	162.779	37.736	73.18	221.786
Milk yield / year	Y	36	7169.993	1334.664	4242.076	9944.15

Source: own calculations based on own data gathering process where y_{it} is the output (production, i.e., in this case annual milk yield) of the *i*-th milk producer in time *t*, $x_{1it}…x_{kit}$ represent inputs into the transformation (production) process of the *i*-th milk producer in time t (in this case the inputs are silage /SI/, compound feed /CF/ and costs per feeding day /CFD/), α_0 is the efficiency parameter and β_1,.., β_k are parameters of inputs that are interpreted like elasticities in this functional form.

The parameters are estimated using the method of fixed effects. This method allows us to verify the above stated hypothesis about significant differences in the efficiency of the analysed milk producers. Moreover, if the hypothesis holds, then the use of methods (e.g. OLS) that do not control for firm-specific effects leads to the biased and inconsistent estimation of parameters. That is, the parameters are biased and inconsistent due to the omission of "important" variables, i.e., we have omitted variable bias.

The method of fixed effects is employed in our case in the form of the "least squares dummy variable (LSDV) model":

$$ly_{it} = \left[lX_{it} \; e \; I_1 \; I_2 ... I_{35} \; T_1 ... T_3 \right] \begin{bmatrix} \beta \\ \alpha \\ \gamma \end{bmatrix} + \varepsilon_{it} \quad , \qquad \text{(ii)}$$

where ly_{it} represents output (production) of the *i*-th milk producer in time *t*, *i* = 0, 1, …, 35 and *t* = 1,…, 3, lX_{it} is the matrix of k explanatory variables (variable inputs into the transformation process, i.e. in this case SI, CF, CFD) of the *i*-th milk producer in time *t*, *e* is the unit vector, I_i stands for the *i*-th dummy variable modelling the firm-specific effects (whereas the dummy variable is indexed from 1 because the 0^{th} milk producer's efficiency parameter is represented by the value of the intercept), T_t is the *t*-th time dummy variable, β is *k* x *1* vector of the parameter of explanatory variables (inputs), α is 36 x *1* vector of parameters representing firm-specific effects, γ is 3 x *1* vector of parameters of time dummy variables and $\varepsilon_{it} \sim nid(0,\sigma^2)$ is an error term (disturbance or residuals) of the *i*-th observation in time t with zero mean and constant and finite variance.

The use of the least squares estimator of β, α and γ for the analytical form of the production function (i) asks for the logarithmic transformation of y_{it} and the explanatory variable (this is expressed by letter *l* in relation (ii)). Thus the power form of relation (ii) representing the estimated form of the Cobb-Douglas function can be written as:

$$y_{it} = \alpha_0 x_{1it}^{\beta_1} ... x_{kit}^{\beta_k} e^{\alpha_i I_i} e^{\gamma_t T_t} e^{\varepsilon_{it}} \, . \qquad \text{(iii)}$$

The estimation is carried out through the software Pc-Give 12.

RESULTS

The chapter is organized as follows. First, an estimation of the production function, including its verification and interpretation, is presented. Then, the input demand functions are derived based on the fitted production function. Finally, the output supply function is presented.

Estimation of production function

Estimation of the production function, including Wald and AR tests, is presented in Table 2. Several different specifications of the milk production function preceded this final version. In these versions we included other inputs relevant to the milk production process, including two other types of feeding (hay and haylage). However, these specifications did not have satisfactory properties, both statistical and econometric. The parameters were not significantly different from zero, and in addition, other tests suggested that there might have been a specification prob-

Table 2. Estimation of Cobb-Douglas production function

Variable	Coefficient	Std. error	*t*-value	*P*-value
SI	0.0481064	0.02068	2.33	0.022 *
CFD	0.1478350	0.04967	2.98	0.004 **
KF	0.0136292	0.01383	0.99	0.327
Constant	7.5494300	0.33200	22.70	0.000 **
T2005	0.0263479	0.00753	3.50	0.001 **
T2006	0.0382151	0.01104	3.46	0.001 **
T2007	0.0520405	0.01338	3.89	0.000 **
Sigma	0.04283951		sigma^2	0.001835223
R^2	0.94416810			
RSS	0.17618143		TSS	3.155569917
Wald (joint):	$Chi^2(3)$ =		15.96	[0.001] **
Wald (dummy):	$Chi^2(40)$ =		6991	[0.000] **
Wald (time):	$Chi^2(3)$ =		17.49	[0.001] **
AR(1) test:	N(0.1) =		0.5282	[0.597]
AR(2) test:	N(0.1) =		–3.642	[0.000] **

Source: own calculations

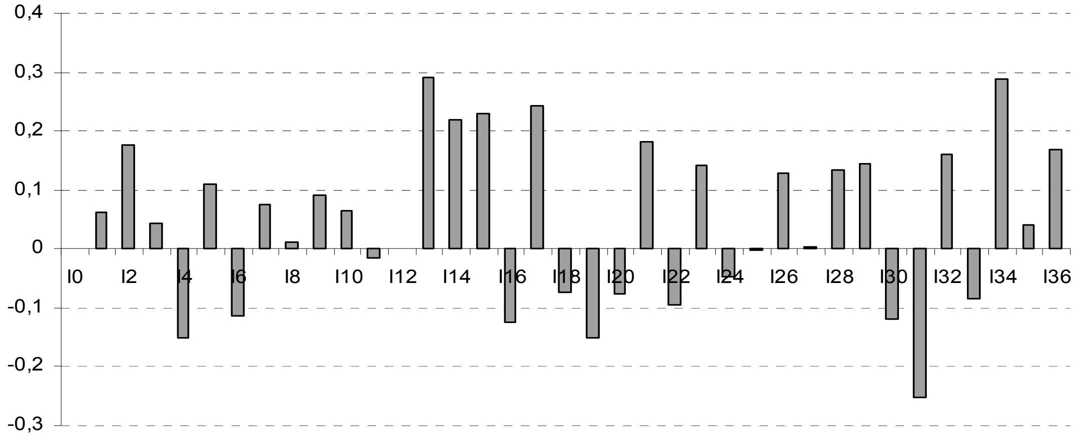

Fig. 1. Firm specific effects
Source: own calculations

lem. These results might have been caused by the low variability of these variables and/or higher collinearity or multicolinearity between or among regressors, respectively. Thus, the null restrictions were imposed on the parameters of inputs, which were both not significant and in the position of omitted variable biased, i.e., these factors are treated in the last version of the production function as fixed. Moreover, the estimations were carried out with robust errors; therefore, a possible violation of the assumption about the properties of the error term does not distort the test statistics. The interpretation of the fitted production function is then as follows.

The parameters are all positive, i.e., an increase in costs per feeding day, as well as consumption of both silage and compound feed, causes an increase in milk yield. The reaction of milk yield is inelastic; the coefficients of elasticity occur between 0.0136 and 0.1478%. Costs per feeding day have the highest influence on milk yield. In other words, a 1% change in costs per feeding day leads to a 0.1478% change in the output (milk yield). However, since this could be connected with the cost structure (costs per feeding day cover costs of silage, compound feed and other factors which were treated as fixed), a change in the feeding program, resulting from both a change in relative prices and the level of production, might simultaneously bring about a change in the output through all variables and fixed inputs. That is, this feature of our production function enables us to incorporate implicitly the influence of fixed inputs (as treated above) through monetary units. Furthermore, other factors such as reproductive factors also influence milk yield.

The parameters of time dummy variables (Table 2) show the change in output over time. The parameters reached a value of 0.026 for the year 2005, 0.038 for the year 2006 and 0.052 for the year 2007. That is, we observe a positive technological change in the analyzed period.

The parameters of fixed effects suggest that there are significant differences in the technical efficiency of the analyzed milk producers. According to the values of firm-specific effects, the most efficient firms are firms no. 13 and 34, and the least efficient firm is no. 31 (Fig. 1).

Then, almost all estimated parameters are statistically significant at a significance level of 1% (see * in Table 2) or 5% (see ** in Table 2), respectively. A coefficient of determination equal to 94.42% (Table 2) shows that the model fits the dataset well.

Residual analysis shows good statistical attributes for the model (Table 2). The results of the Wald test show the importance and significance of all explanatory variables, time dummy variables and dummy variables relating to specific effects. The AR(1) test does not suggest the presence of autocorrelation of the first order. However, we may face autocorrelation of the second order according to the AR(2) test. That is, the estimated parameters may not be efficient. Since we use robust error, the significance tests of estimated parameters as well as other tests and statistics are not biased. Since the parameters are unbiased and consistent, we then use the production function in our analysis. Moreover, among other specifications of the function, this one was the best. Finally, Fig. 2 shows the differences between the actual and theoretical values of milk yield, the test of normality, and autocorrelation of residuals.

To verify the stated hypotheses, we have to construct and analyze input demand and output supply functions for our group of milk producers.

Input demand functions

The input demand functions can be obtained from a solution of the cost minimization problem, which can be written

$$C(p_1, p_2, y) = \min_{x_1, x_2} p_1 x_1 + p_2 x_2 \quad s.t. \quad y = \alpha x_1^{\beta_1} x_2^{\beta_2}, \quad \text{(iv)}$$

where x_1 stands for the variable input silage and x_2 for compound feed, and p_1 and p_2 are corresponding prices of these factors. Then, the production function, in which we fixed other explanatory variables, represents the production constraints.

The Lagrange methods can be used to solve this problem. The corresponding Lagrangian is

$$L(x_1, x_2, \lambda) \equiv p_1 x_1 + p_2 x_2 + \lambda(y - \alpha x_1^{\beta_1} x_2^{\beta_2}) . \tag{v}$$

Then we set all of its first-order partials equal to zero:

$$\frac{\partial L}{\partial x_1} = p_1 - \lambda\alpha\beta_1 x_1^{\beta_1 - 1} x_2^{\beta_2} = 0 \tag{vi}$$

$$\frac{\partial L}{\partial x_2} = p_2 - \lambda\alpha\beta_2 x_1^{\beta_1} x_2^{\beta_2 - 1} = 0 \tag{vii}$$

$$\frac{\partial L}{\partial \lambda} = y - \alpha x_1^{\beta_1} x_2^{\beta_2} = 0 \tag{viii}$$

We can get the input demands equations from the solution of the system of equations (vi) to (viii) for x_1 and x_2. Thus, after a small mathematical exercise we are left with:

$$x_1 = \left(\frac{p_2}{p_1} \frac{\beta_1}{\beta_2} \alpha^{-\frac{1}{\beta_2}} y^{\frac{1}{\beta_2}} \right)^{\left(\frac{1}{1+\frac{\beta_1}{\beta_2}} \right)} \tag{ix}$$

$$x_2 = \left(\frac{p_1}{p_2} \frac{\beta_2}{\beta_1} \alpha^{-\frac{1}{\beta_1}} y^{\frac{1}{\beta_1}} \right)^{\left(\frac{1}{1+\frac{\beta_2}{\beta_1}} \right)} \tag{x}$$

which stand for input demand equations. Input demand functions for our sample of milk producers can then be written as (also with respect to estimated deterministic terms and fixed variable CFD:

$$x_{1,i,t} = \chi^*_{1,i,t} p_{1,t}^{-0.220767} p_{2,t}^{0.220767} y_{i,t}^{16.19811} , \tag{ix}'$$

where $\chi^*_{1,i,t} = \left(\frac{\beta_1}{\beta_2} (\alpha_i + \delta_{i,t})^{-\frac{1}{\beta_2}} \right)^{\left(\frac{1}{1+\frac{\beta_2}{\beta_1}} \right)}$, α_i is an intercept of the *i*-th milk producer and $\delta_{i,t}$ contains deterministic terms and fixed variable CFD.

$$x_{2,i,t} = \chi^*_{2,i,t} p_{1,t}^{0.779233} p_{2,t}^{-0.779233} y_{i,t}^{16.19811} , \tag{x}'$$

where $\chi^*_{2,i,t} = \left(\frac{\beta_2}{\beta_1} (\alpha_i + \delta_{i,t})^{-\frac{1}{\beta_1}} \right)^{\left(\frac{1}{1+\frac{\beta_1}{\beta_2}} \right)}$, α_i is an intercept of the *i*-th milk producer and $\delta_{i,t}$ contains deterministic terms and fixed variable CFD.

The corresponding cost function for these two inputs can be written as

$$C(p_1, p_2, y)_{i,t} = p_1 \left(\frac{p_2}{p_1} \frac{\beta_1}{\beta_2} \alpha^{-\frac{1}{\beta_2}} y^{\frac{1}{\beta_2}} \right)^{\left(\frac{1}{1+\frac{\beta_1}{\beta_2}} \right)} +$$

$$+ p_2 \left(\frac{p_1}{p_2} \frac{\beta_2}{\beta_1} \alpha^{-\frac{1}{\beta_1}} y^{\frac{1}{\beta_1}} \right)^{\left(\frac{1}{1+\frac{\beta_2}{\beta_1}} \right)} =$$

$$= \chi^*_{1,i,t} p_{1,t}^{0.779233} p_{2,t}^{0.220767} y_{i,t}^{16.19811} + \chi^*_{2,i,t} p_{1,t}^{0.779233} p_{2,t}^{0.220767} y_{i,t}^{16.19811}$$

$$= \left(\chi^*_{1,i,t} + \chi^*_{2,i,t} \right) p_{1,t}^{0.779233} p_{2,t}^{0.220767} y_{i,t}^{16.19811} \tag{xi}$$

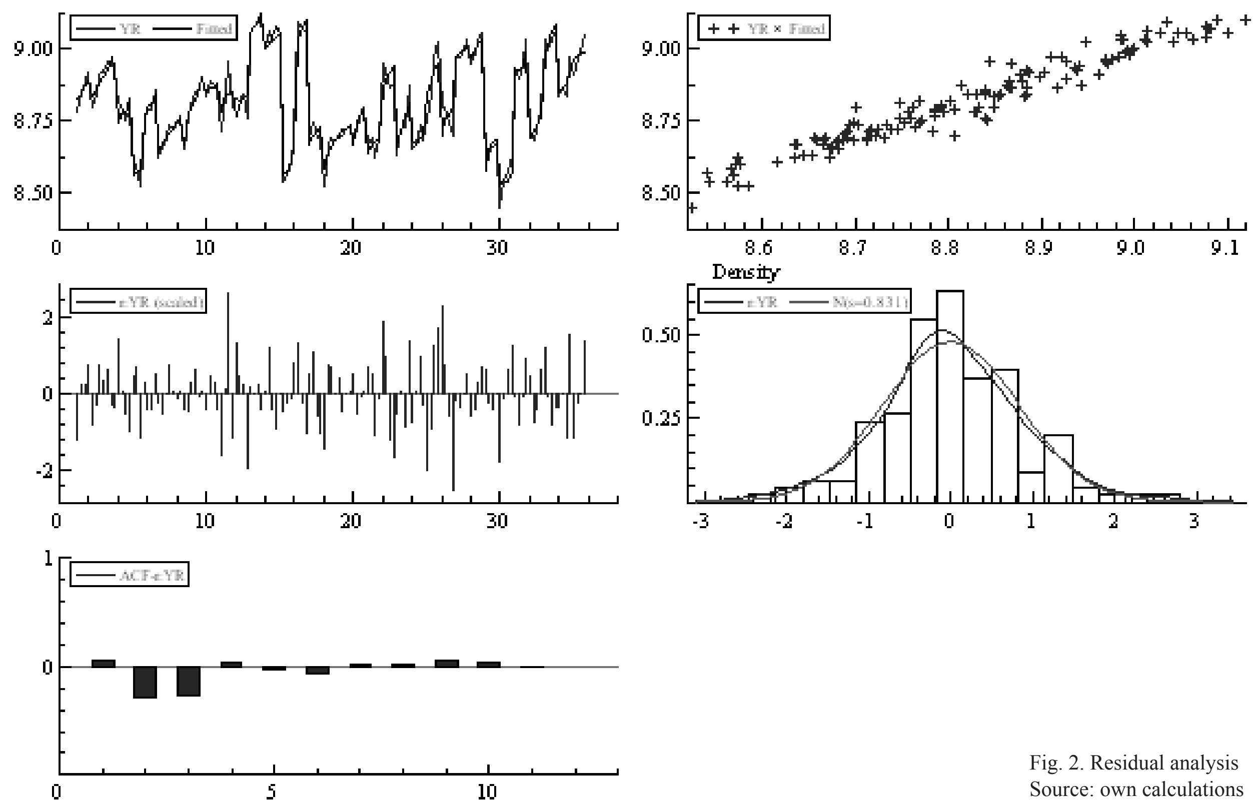

Fig. 2. Residual analysis
Source: own calculations

Table 3. Prices of variable and fixed inputs

Year	Haylage	Silage	Hay	Compound feed	$Haylage_t$ / $Haylage_{t-1}$	$Silage_t$ / $Silage_{t-1}$	Hay_t / Hay_{t-1}	Comp. $feed_t$ / Comp. $feed_{t-1}$
2004	624.00	634.92	1251.00	5575.00	–	–	–	–
2005	639.25	646.33	1252.25	4607.25	1.0244	1.0180	1.0010	0.8264
2006	512.75	632.73	1049.00	4282.00	0.8021	0.9789	0.8377	0.9294
2007	551.36	645.17	1127.00	5201.75	1.0753	1.0197	1.0744	1.2148

Note: The prices of compound feed in years 2005, 2006 and 2007 are estimated based on the price changes of other types of compound feed that were observed in these years.
Source: CZSO and own estimation

Table 4. Rational input behaviour

Year	d (theoretical SI / theoretical Y)		d (real SI / real Y)		d (theoretical KF / theoretical Y)		d (real KF / real Y)	
	decrease	increase	decrease	increase	decrease	increase	decrease	increase
2005	21	15	20	16	21	15	17	19
2006	17	19	20	16	16	20	20	16
2007	17	19	18	18	17	19	20	16

Source: Own calculations

Table 5. Rational output behaviour

Year	Milk price	Milk $price_t$ / Milk $price_{t-1}$	Y theoretical		Y real	
			decrease	increase	decrease	increase
2004	7963.67	–	–	–	–	–
2005	8237.08	1.034	2	34	10	26
2006	7864.08	0.955	5	31	11	25
2007	8219.33	1.045	1	35	9	27

Source: CZSO and own calculations

The derived input demand functions differ among the milk producers. The differences stem from the efficiency variation among the producers that was captured in the estimation of the production function by dummy variables (see firm-specific effects). Since the derivation of input demand functions (see above) is based on the production function, the differences in input demand functions are determined by the firm-specific effects and the level of fixed variable CFD. That is, the derived input demands function differs by the terms $\chi^*_{1,i,t}$ and $\chi^*_{2,i,t}$. As far as technical efficiency is concerned (as was already stated), the milk producers seem to be significantly heterogeneous. There are also significant differences in CFD (Table 1 min and max values). Consequently, the input demand functions differ significantly as well. It is evident from the analytical form of the model that the differences are in the locations of the input demand functions.

The price and cross price elasticities of the derived input demands function are –0.220767 and 0.220767 for silage and 0.779233 and –0.779233 for compound feed. In other words, a one percentage increase in the price of the *i*-th variable input leads to a less than one-percent decrease in the demand of the *i*-th variable input, and a less than one-percent increase in the demand of the *j*-th variable input, and vice versa. That is, we cannot reject the hypothesis about the low elasticity of the input demand function.

The third hypothesis regarding input demand functions can be verified by a comparison of theoretical and real figures of SI and CF.

Calculations of the demand quantities of SI and CF, for a particular company and year, show that the majority of companies used different amounts of variable inputs in the milk production process during 2004 and 2007. Specifically, the majority of milk producers consume less silage and more compound feed than the input demand functions suggest. On average, the variable input silage should be used 72.4% more and the input compound feed used 81.8% less. That is, since the theoretical demanded quantities of SI and CF do not correspond with the real consumed values, one may suggest that the milk producers do not behave rationally. However, a deeper analysis of real and theoretical figures, together with the behaviour of the demand functions, shows that there might be more reasons for the differences between theoretical and real figures.

Changes in demand quantities resulting from small changes in our parameters of interest (individually and jointly) show that we cannot significantly decrease differences between the theoretical and real figures in this way. Moreover, verification (see above) also suggests that the estimated parameters are unbiased and consistent. Thus, this reason might not be significant in explaining the differences.

Then, the differences between theoretical and real figures could also be partially caused by differences in firm-specific prices and employed prices (Table 3).

Moreover, a deeper mathematical analysis of the behaviour of demand functions, together with basic statistical characteristics of theoretical and real values of inputs, shows that the demand functions describe very well year-on-year changes in the consumption of variable inputs. This suggests that the reason for the differences between theoretical and real values could be that SI and CF are imperfect substitutes in the domain of definition of our functions or analysis, respectively. That is, we face one of the restrictive properties of the Cobb-Douglas production function, i.e., that the direct elasticity of substitution is equal to one for this function. This property of the Cobb-Douglas production function seems to be very serious and might prevent us from solving our optimization problem in the situation or in the function space, respectively, in which the variables SI and CF are imperfect substitutes. However, the input demand functions may behave well in the subset of domain of definition of our production function, as an analysis of production characteristics and isoquant functions suggests. Then, since the year-on-year changes in the consumption of SI and CF are very well described by the derived input demand functions, we may employ them together with real figures in the analysis of rational behaviour in our sample of milk producers.

The rationality of milk producers is investigated based on an evaluation of theoretical and actual changes in the employed variable inputs per unit of output, in the reaction to input price changes or relative input price changes, respectively. This approach also removes the problem stemming from differences in firm-specific prices and employed prices (above), since we may assume that the changes have the same direction. Table 3 then contains not only prices of variable inputs but also fixed inputs. Fixed inputs represent other feeding materials which were not significant in the fitted production functions, and thus are held in the function as fixed. However, for the purposes of evaluating rational behaviour we have to take them into account to avoid biased conclusions. If we investigate the prices and their changes in Table 3, we may conclude that silage should increase in the structure of consumed feeding in the year 2007 and decrease in 2005 and 2006. As far as compound feed is concerned, consumption should increase in 2005 and 2006 and decrease in 2007.

In Table 4 we see that in the case of silage, the assumption of rational behaviour is consistent with 21, 17 and 19 milk producers in the years 2005, 2006 and 2007, according to theoretical values, and with 20, 20 and 18 producers according to real figures. Thus, we may conclude that more than half of milk producers behave rationally in this case and that the results from theoretical and real figures are very close, especially when we investigate the differences, which are mainly on the edge. As far as compound feed is concerned, rational behaviour is consistent with 15, 20 and 17 milk producers in 2005, 2006 and 2007, according to theoretical values, and with 19, 16 and 20 according to real figures. That is, around half of milk producers behave rationally in this case. To sum up, we may conclude that in approximately 50% of cases the behaviour of the milk producer was consistent with rational behaviour.

Output supply function

Because we only have one output, the production function represents the short-run conditional output supply function. Therefore, differences in the output supply function or short-run conditional output supply function, respectively, among milk producers stem from the above-mentioned differences in technical efficiency. That is, differences in the location of short-run conditional output supply functions in the plane could be regarded as significant.

Consistency with rational behaviour may again be evaluated based on the responses of milk producers to milk price changes. Table 5 presents milk prices, relative milk price changes and responses of milk producers to milk price changes. These responses are again shown for both theoretical and real figures. According to milk price changes, the rational milk producer should have increased production in the years 2004 and 2007. An evaluation of the behaviour in each year is not provided since it might be biased due to the length of the production process or of production plans, respectively. Thus, from the overall responses to milk price changes we can see that the majority of milk producers behaves rationally.

DISCUSSION AND CONCLUSION

Jelínek (2007) concludes that the analyzed milk producers are technologically homogeneous due to the low variability of parameters of technical efficiency; however, the low variability of the parameters does not just mean the same technology. The impact of these parameters on milk yield should also be taken into account. In our case, the variability of firm-specific effects is small; however, their impact on milk yield is large. We might then conclude that technical efficiency differs significantly within the sample. By contrast, Jelínek (2007) concludes that the majority of the analyzed producers might be determined to be efficient (according to the values of technical efficiency). In our sample, the behaviour of more than 50% of milk producers is consistent with rational behaviour.

The analysis presented in the paper stems from the best fit of the Cobb-Douglas production function. The estimation was based on a balanced panel dataset gathered from questionnaires for a group of randomly chosen milk producers. An analysis of input demand functions shows that the chosen analytical form is not appropriate for a description of the substitution of analyzed variable inputs. That is, the property of the Cobb-Douglas production function, i.e., that the direct elasticity of substitution is equal to one, seems to be too restrictive. In light of this, a different analytical form of the production function should be used in further research. Moreover, significant differences in efficiency, respectively, suggest that different specifications within the framework of SFA (Stochastic Frontier Analysis) should be used, since that might provide better results.

Finally, we may conclude that the stated hypotheses cannot be rejected. That is, the production process and thus the derived input demands and output supply functions were found to differ significantly within the group of analyzed milk producers. The input demand functions then have low elasticity, and the behaviour of milk producers (in more than 50% of cases) is consistent with rational behaviour.

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Analýza poptávkových a nabídkových funkcí výrobců mléka v ČR.

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Tento článek se zabývá analýzou funkcí poptávky po vstupech do výroby a nabídky mléka v České republice. Hlavní cíl, tj. ověřit, zda se jednotlivé podniky chovají racionálně, byl naplněn na základě analýzy 36 producentů mléka v období 2004–2007. Panelová data byla získána prostřednictvím vlastního dotazníkového šetření ve skupině náhodně zvolených zemědělských podniků. Pro naplnění cíle byla nejprve pomocí metody fixních efektů odhadnuta dvoufaktorová produkční funkce v Cobb-Douglasově formě a dále byla pro jednotlivé podniky odvozena nákladová a příjmová funkce. Provedená analýza prokázala významné mezipodnikové odchylky jak v produkci mléka, tak i v parametrech vyjadřujících technickou efektivnost, a proto lze konstatovat, že jednotlivé podniky jsou technologicky heterogenní. Dále, na základě analýzy funkce poptávky po vstupech do výroby a funkce nabídky mléka, lze říci, že přibližně 50 % zkoumaných podniků se chová racionálně.

produkce mléka; poptávka po faktorech; nabídková funkce; produkční funkce; racionální chování

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