EFFICIENCY ANALYSIS OF CZECH ORGANIC AGRICULTURE

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Introduction

Organic agriculture, distinguished by limitations and bans on the use of artificial fertilizers, chemical preparations, sprays, hormones and other artificial substances, and a positive relationship with animals, plants and nature, is one of the most dynamic branches of agricultural production in the Czech Republic. Over the last decade we have seen a fivefold increase in organically managed land and a sixfold increase in the number of organic agricultural producers. These positive developments in organic agriculture are conditioned by several factors. Primarily, the development of organic agriculture is stimulated by the endowment policies of the Czech Republic and the European Union, which support organic producers through payments aimed directly at the organic economic system, as well as through point allowances in many endowment titles supporting development of the country and agricultural production. Secondarily, organic agricultural development is influenced by the increased demand of consumers for bio-foods, which are becoming common as part of a healthy lifestyle. Thirdly, a significant factor of organic agricultural development in the Czech Republic is the high percentage of less favourable localities for production, thanks not only to the endowment aid, but especially to the price allowances for organic production. [11]

However, economic research (e.g. Jánský and Živělová, Chavezová) which indicates a lower productivity of the mentioned economic system, on account of specific technological requirements which manifest themselves by limitations in the use of some inputs commonly used by conventional agriculture, or, for example, in a greater emphasis on the quality of the environment of bred animals, speaks against the mentioned developmental tendency of organic agriculture. [9] [10]

This lower productivity can result in organic farms being less profitable than conventional farms. In light of the positive externalities and public estates produced by organic agriculture, this is one of the main arguments for the endowment policy of organic agriculture. However, foreign research indicates that endowment aid can also lead to the inefficiency of agricultural producers (e.g. Tzouvelekas) [14]. Since the presented research has not yet been worked out in the Czech Republic, the aim of the submitted paper is to evaluate the efficiency of Czech organic farms from the standpoint of technical efficiency, defined by Bravo-Ureta as the ability of a farm to produce a maximal output volume with a given input volume and a given technology. [5]

A partial aim is also to evaluate the suitability of organic technology for enterprises of selected collection, and to discover the basic determining factors for converting agricultural producers into users of organic production technology.

First of all, the submitted paper specifies a model of a frontier production function, which is a basis for analyzing the efficiency of organic agriculture in the Czech Republic, and defines a methodological frame of parameter estimation for the mentioned model and its econometric verification. Subsequently, it suggests a model for quantifying inefficiency determinants.

One part of Chapter 1 also contains a model specifying an inclination function for using organic technology, and methods of estimating it. Chapter 2 defines a database, using which the above-mentioned analyses are made, and describes the basic developmental tendencies of selected indicators of the selected collection. Chapter 3 provides the results of the efficiency analysis of organic agriculture, and also compares them with results for conventional agricultural producers. The fifth chapter presents the results of estimating the inclination function for using organic production technology, and defines the basic determining factors for choosing the mentioned economic system.

At the close of the submitted paper, results of the above-mentioned analyses are summarized, and recommendations for changes to the present endowment support system for organic agriculture are proposed.

1. Econometric Model

The model used to analyze the efficiency of Czech organic agriculture stemmed from a functional delimitation of a frontier production function done by Meeusen and van der Broeck, who defined the frontier production function in the form of a Cobb-Douglas function form. The following transcription presents the mentioned model with an adjustment for panel data of „k" subjects and „t" period:

$$y_{kt} = f(x_{kt};\beta)e^{\varepsilon_{kt}}, \qquad (1)$$

$$\varepsilon_{kt} = v_{kt} - u_{kt}, \qquad (2)$$

where:

- y_{kt}...... a production level of the k-th subject at time t,
- x_{kt}...... a vector of inputs in a production process of size [Nxj] corresponding with consumption of input of work, land and capital of the k-th subject at time t,
- β....... a vector of estimated parameters of size [Jx1],
- ε_{kt}...... an error term of estimation containing a random component (v_{kt}) and a rate of technical inefficiency (u_{kt}) corresponding with the k-th subject and time t, $j = 1,2,...J$, $k = 1,2,...K$, $t = 1,2 ...T$ [13].

The error of estimation of the above-mentioned model was divided into two parts:

- A random component with a symmetric and normal distribution v_{kt}~iid/N(0,σ_u^2) representing errors of measurement of variable values, the influence of factors not included in the analysis, and errors due to simplification of the analytical form of the chosen production function.
- A non-negative rate of technical inefficiency representing a divergence of production of the k-th subject from the margin of production possibilities, independent of the distribution of the random component and with the supposed half-normal u_{kt}~iid/N(0,σu^2). [1]

The output quantified by the mentioned function was represented by production in constant prices for the year 2005, in thousands of crowns. The following factors entered in as explanatory variables in the above-mentioned frontier production function:

- Land (*L*), defined as hectare acreage of managed agricultural land;
- Work (*WU*), represented by an average number of workers;
- Capital (*K*), expressed as a summary of tangible and intangible long-term property, in thousands of crowns.

The use of panel data reduced the problem of multicollinearity, which was tested by VIF-test [7], but called for a heterogeneity analysis, whose omission could lead to a distortion of parameter estimations for the constructed model. The presence of heterogeneity was examined by a variance analysis of explanatory variable values. Due to heterogeneity verification among particular subjects, the model specification of a frontier production function was based on a so-called random effects model, which stems from a presumption that there is no correlation between farm specifics and other explanatory variables in the model. The farm specifics are randomly distributed among particular cross-sectional units. The mentioned specification was used in a methodological approach published by Battese and Coelli in 1992. One advantage of this model, compared to other methodological approaches based on a specification of random effects (e.g. Pitt and Lee´s model), is quantification at time of variable rate of technical efficiency of particular farms, expressing from how many percents farm production reaches the potential level. [2]

Coelli (1995) specifies that the rate of technical inefficiency in this model is defined as exponential dependence on time:

$$u_{kt} = \{\exp[-\eta(t - T_k]\}u_k \qquad (3)$$

where: η.........estimated parameter expressing a time change in the technical inefficiency rate;

T_k........the number of periods which represent the k-th subject,
u_k........the rate of technical inefficiency of the k-th subject with supposed half-normal distribution, u_k~iid/N(0,σ_u^2).
t= 1,2,...T_k. [5]

Parameters of the above-mentioned model of a frontier production function were estimated by the method of maximum likelihood with the following log-likelihood function:

$$Log L_k = -\frac{T_k}{2}\left(\log 2\pi + \log\sigma^2\right) - \frac{(T_k - 1)\log\left(1 - \frac{\sigma_u^2}{\sigma^2}\right)}{2} -$$

$$-\frac{1}{2}\sum_{t=1}^{T_k}\frac{\sigma^2\varepsilon_{kt}^2}{\sigma^4 - \sigma_u^2} - \frac{1}{2}\log\left[1 + \frac{\sigma_u^2}{\sigma^2}\left(\left(\sum_{t=1}^{T_k} g_{kt}^2\right) - 1\right)\right] + \frac{A_k^2}{2} +$$

$$+\log\Phi(A_k), \quad (4)$$

$$A_k = \frac{-\frac{\sigma_u^2}{\sigma^2}\sum_{t=1}^{T_k} g_{kt}\varepsilon_{kt}}{\sqrt{\frac{\sigma_u^2}{\sigma^2}\left(1 - \frac{\sigma_u^2}{\sigma^2}\right)\left[1 + \frac{\sigma_u^2}{\sigma^2}\left(\left(\sum_{t=1}^{T_k} g_{kt}^2\right) - 1\right)\right]}}, \quad (5)$$

$$g_{kt} = \exp\left[-\eta(t - T_k)\right], \quad (6)$$

where: σ^2_u......dispersion of technical inefficiency rate,
σ^2 ......dispersion of estimation error,
ϕ........ a function of standard normal distribution (CDF),
k= 1,2,...K, t= 1,2,...T, j=1,2, ...J.

The conformity of the obtained estimation with empirical data was measured by the McFadden likelihood index, the so-called pseudo R2 which Green (2008) expresses in the following relation:

$$Pseudo\,R^2 = 1 - \left(\frac{\log L}{\log L_0}\right), \quad (7)$$

where: log L.....a value of log-likelihood of the estimated model,
log L_0....a value of log-likelihood of a model containing only a constant. [7]

The presence of inefficiency was tested by the Likelihood Ratio test (LR) with a zero hypothesis about the non-existence of technical inefficiency, i.e. H_0: $\lambda=\sigma_u/\sigma_v=0$. The LR test was based on testing statistics which Gujarati (2003) defines in the following way:

$$\eta = 2\,(ULLF - RLLF) \quad (8)$$

where: ULLF.... an unlimited log-likelihood function corresponding to the estimated model,
RLLF.... a limited log-likelihood function corresponding to the model which the zero hypothesis represents [8]

The testing statistics of the LR test were compared with the critical value χ^2 at a significance level of α= 5% and with one degree of freedom. The zero hypothesis was refused in exceeding the value LR statistics over the critical value χ^2 at a chosen significance level, and with a given number of degrees of freedom.

Consequently, the rate of technical farm efficiency was expressed from the quantified model, according to the relation defined by Bravo-Ureta and Pinheira (1997):

$$TE_{kt} = \exp(-u_{kt}). \quad [4] \quad (9)$$

The model of a frontier production function was also used for delimitation of factors invoking inefficiency. For the described purpose, a recursive model of the technical inefficiency rate of organic farms was specified:

$$y_{kt} = \alpha L_{kt}^{\beta_L} WU_{kt}^{\beta_{WU}} K_{kt}^{\beta_K} e^{v_{kt} - u_{kt}}$$
$$u_{kt} = \delta_0 + \delta_{LFA} LFA_k + \delta_D DEHZ_{kt} +$$
$$+\delta_O ODH_{kt} + \delta_M SPMH_{kt} + e_{kt}, \quad (10)$$

where: LFA_k............. a dummy variable expressing localization of the k-th farm in LFA area (0 = except LFA, 1= in LFA),
$DEZH_{kt}$......... the volume of obtained endowment for support of organic agriculture (EA) per hectare of managed land of the k-th subject at time t,
ODH_{kt}........... the volume of other obtained endowment per

hectare of managed land of the k-th subjects at time t,

$SPMH_{kt}$...... the real consumption of material and energy per hectare of managed land of the kth subjects at time t,

δ_0................ constant,

$\delta_{D,O,M,LFA}$...... regression parameters of the inefficiency function,

u_{kt} .... the rate of technical inefficiency with half-normal distribution u_{kt}~iidN(0,σ^2).

e_{kt}............... a random component e_{kt}~N(0,σ^2).

The model specification stemmed from a presumption that a farm's location in a less favourable area causes an increase of efficiency compared to farming in production-favourable areas. The volume of obtained endowment per hectare of managed land works against the rational behaviour of farms, which is transferred into the technical inefficiency rate and influences it positively. The material and energy consumption per hectare shows the influence of other production factors, which affect the farm's production and the rate of its inefficiency. The mentioned model was estimated by simultaneous estimation through a maximum likelihood method, and tested by the above-mentioned tests.

A quantified frontier function was also used for a suitability analysis of organic or conventional technology in the examined enterprises. For this purpose, a procedure modification was used, designed by Kumbhakar et al. (2009), who quantify a production gap representing the difference between maximum achieved production and the potential production obtained by organic technology [12]. The size of the production gap was based on a determination of theoretical production values achievable by organic and conventional technologies. Theoretical values of potential products were obtained by installing real values of explanatory variables, from particular years of the observed time period, into quantified frontier production functions of organic and conventional agriculture. An average potential product achievable in a given subject at a given time by organic technology ($\hat{Y}_{EZ,kt}$) and a potential product achievable by conventional technology ($\hat{Y}_{KZ,kt}$) were quantified in this way.

From these potential products, maximal production values were subsequently quantified for particular subjects and periods, according to the following relation:

$$\hat{Y}_{MAX,\,kt} = \max\left\{\hat{Y}_{EZ,kt}, \hat{Y}_{KZ,kt}\right\}. \tag{11}$$

The production gap was expressed in numbers as the difference between the defined maximal production and the potential production achievable in the given subjects and the given year by organic production technology:

$$PM_{kt} = \hat{Y}_{MAX,kt} - \hat{Y}_{EZ,kt}, \tag{12}$$

where: PM_{kt}.....production gap of the k-th subject at time t.

A positive production gap in an organic farm indicated a production loss due to the use of organic production technology. In case this loss has a high value, the organic production system seems to be an inferior technology for the given enterprise, and the transition into a conventional system enables an increase of production volume while maintaining the same level of disposable resources. Vice versa, a negative production gap in eco-farms suggested the inferiority of conventional technology for the given subject. The transition into a conventional system is undesirable in the mentioned case because it would not increase the produced volume of goods. A positive value of the production gap in conventional enterprises pointed to the suitability of conventional technology; on the other hand, a negative value meant that transformation into an organic production system would increase the production volume of the observed farm.

The results of the above-mentioned efficiency analyses of organic agriculture resulted in the construction of a model which defines the basic motives for implementing an organic economic system. This model was constructed in the form of a binary choice model, constructed in the form of a probit model of implementing organic technology:

$$P(I_{kt} = |x_{kt}, w_k) = \Phi(x'_{kt}\beta + w_k), \tag{13}$$

$$\Phi(z) = \frac{1}{\sigma_z}\phi\left(\frac{z-\bar{z}}{\sigma_z}\right), \tag{14}$$

$$\phi(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{(z-\bar{z})^2}{2\sigma_z^2}}, \tag{15}$$

$$z = (x'_{kt}\beta) + w_k , \tag{16}$$

where: I_{kt}........ a binary explanatory variable representing the choice of technology of the k-th subject at time t, having a value of 0 for conventional technology and 1 for an organic method of production,

x_{kt}....... a vector of real values of factors influencing the choice of organic methods for the k-th subject at time t, with size [JxN],

β........ a vector of regression coefficients with size [Jx1], expressing the influence of explanatory variables on the likelihood of a given phenomenon occurring,

w_k....... a farm specific to the k-th subject with supposed normal distribution (CDF) $w_k \sim N(0,\sigma_u^2)$,

$\Phi(.)$...... a standardized cumulative function of normal distribution (CDF),

ϕ........ standard normal density of likelihood,

σ_z........ standard deviation of the variable z,

j = 1,2,...*J*, *n* = 1,2,...*N*, *k* = 1,2 ...*K*, *t* = 1,2,..T. [15]

Specification of the above-mentioned model of the likelihood of implementing organic technology was based on presumptions which determine the behaviour of agricultural subjects. Primarily, the positive effect of endowment support for organic agriculture on the implementation of alternative production technology was considered. Among factors explaining the choice of an organic economic system, the influence of endowment volume obtained by an agricultural subject, in the foregoing period and on one hectare of managed land, was selected. A hypothesis about the influence of the mentioned variable resulted from the following assumption: the endowment volume obtained by an organic farm exceeds the volume of endowments obtained by a conventional farm because eco-farms can draw from all subsidies available for conventional enterprises and, moreover, they are also supported by an endowment title focused only on organic agriculture. On this basis, it was assumed that the level of endowments obtained in the foregoing period had a positive effect on the implementation of organic technology in the next period.

Another factor considered was the volume of income obtained from every hectare of managed land in the foregoing period, with a presumption that the considered variable has a negative influence on the likelihood of implementing organic technology. Bio-products can achieve a higher sale price; nevertheless, this increase in income does not compensate completely for production losses within the framework of an organic economic system, relative to conventional yields. A producer, making a decision based on the income level from a hectare of managed land, will probably prefer conventional agricultural methods to organic ones.

From an analysis using a frontier production function, another variable having a potential effect on the likelihood of organic technology implementation was obtained – the technical inefficiency rate achieved by the enterprise in the foregoing period. The influence of the considered variable is conditional on the efforts made by subjects to optimize their production behaviour. For this reason, high inefficiency should provide motivation for implementing more efficient technology, which is, according to results of the previous analyses, conventional technology.

Among explanatory variable in the likelihood model of organic production technology implementation was farm size, represented on a six-point scale defining the hectare acreage of the managed land. The value „six“ represented the biggest farms, namely those managing more than 2,000 ha, while the value „one“ was assigned to enterprises managing the smallest acreage, i.e. up to 99 ha of agricultural land. It was assumed that the size of an agricultural enterprise has a negative effect on implementation of organic technology.

Formally, the examined model of technology choice can be expressed by specifying a random effect model, using the following relation:

$$P(I_{kt} = 1 \mid x_{jkt}, w_k) = \Phi\big(\alpha + \beta_V V_{kt} + \beta_{DH} DH_{k,t-1} + \\ + \beta_{NEF} NEF_{k,t-1} + \beta_{TR} TR_{k,t-1} + e_{kt} + w_k\big), \tag{17}$$

where: V_{kt}............. size of the k-th subject at time t,

$DH_{k,t-1}$...... endowment volume per hectare of managed land obtained by the k-th subject at time (t-1),

$NEF_{k,t-1}$....... rate of technical inefficiency of the k-th subject at time (t-1),

$TR_{k,t-1}$......... income level for the sale of its own products and services corresponding to the k-th subject at time (t-1),

α.............. a model constant,

$\beta_{V,DH,TR,NEF}$... regression coefficients,

I_{kt}.............. a binary dependent-variable, corresponding to the k-th subject at time t and having a value of 0 for a conventional agricultural enterprise and a value of 1 for an organic farm,

e_{kt}............ a random component of the model with supposed normal distribution $e_{kt} \sim N(0,\sigma^2)$,

w_k............ a farm specific to the k-th subject with supposed normal distribution $w_k \sim N(0,\sigma_w^2)$,

$k = 1,2,...K,\ t = 1,2,...T.$

Estimation of model parameters, providing a standardized normal division of the model's random component, $e_{kt} \sim N(0,1)$, and a normal division of farm specifics, $w_k \sim N(0, \sigma_w^2)$, was accomplished by the method of maximum likelihood using the following log-likelihood function:

$$\log L = \sum_{k=1}^{K} \log \int_{-\infty}^{+\infty} \left[\prod_{t=1}^{T_k} \Phi(\beta' x_{kt} + \sigma_w w_k)^{y_{kt}} [1 - \Phi(\beta' x_{kt} + \sigma_w w_k)]^{1-y_{kt}} \right] \phi(w_k) dw_k, \quad (18)$$

where: σ_w......dispersion of farm specifics. [6]

The conformity of obtained estimations with empirical data was evaluated using the McFadden pseudo R^2:

$$Pseudo\, R^2 = 1 - \left(\frac{\log L}{\log L_0} \right), \quad (19)$$

$$\log L_0 = N[P \log P + (1-P) \log 1 - P)], \quad (20)$$

where: log L.... a log-likelihood function of the estimated model,

P........... proportion of dependent variables which obtain a value of 1, from the total number of dependent variables of the selected collection [7].

The statistical significance of the model as a whole, based on testing of the zero hypothesis which assumes that all regression coefficients obtain a zero value, was examined by the Likelihood Ratio Test, which was also used for testing the adequacy of the model specification in the form of a model of random effects. In this case, the limited log-likelihood function represented a model estimation that did not consider any inter-farm variability. LR statistics were compared with the critical value χ^2 at 5% significance and with one degree of freedom. The zero hypothesis, assuming absence of farm variability, was refused if the value of the LR statistics exceeded the given critical value χ^2.

With the exception of the standard t-test, the statistical significance of the estimated parameters was also tested using the Likelihood Ratio Test. The zero hypothesis, supposing a zero parameter value for the examined variable, was refused according to the LR test if the LR statistics exceeded the critical value χ^2 at 5% significance and with one degree of freedom, in the case where a parameter of one variable was tested.

For estimating parameters of the above-mentioned model, the econometric software LIMDEP, version 9.0, was used.

2. Data

The efficiency analysis of Czech organic agriculture was based on panel data obtained over the years 2004 – 2008 from 143 organic and 388 conventional agricultural enterprises – legal entities. One database resource was the Creditinfo Firemní monitoring database, which came into being through the collection of accounting data from entrepreneurial subjects registered in the Czech Republic, as well as from the Companies register. The data from final accounts were further complemented by acreages of managed land obtained from the database LPIS, with the number of employees determined as the ratio of wage costs of particular subjects to the average wage earned, according to the database of the Czech Statistical Office in the region where the examined enterprises resided, and by the volume of endowment funds spent by the relevant enter-

Tab. 1: Annual average of selected indicator values of the selected collection

	Organic farming					Conventional farming				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
Production f.p. [ths. CZK]	10721	10787	12175	11294	11497	49931	50850	48153	45450	37138
Revenue from sale own products and servises [ths. CZK]	8510	7742	8205	9459	10412	43290	40864	39456	45423	38835
Subsidy [ths. CZK]	6900	7703	7902	9366	10776	4289	7310	8060	9233	7659
Average work units	16	16	18	19	22	61	57	54	53	43
Land [ha]	887	809	811	834	880	1334	1276	1261	1283	1135
Intangible fixed asset [ths. CZK]	280	679	260	132	77	286	864	1153	868	127
Tangible fixed asset [ths. CZK]	12133	13248	15354	16100	19824	42090	41845	42577	46994	43471
Financial fixed asset [ths. CZK]	1137	4755	4479	7844	1683	3197	3050	3111	3014	2030
Consumption of material and energy [ths. CZK]	4402	4230	5479	5413	5478	22951	21053	22424	24681	23109
Profit [ths. CZK]	1702	1535	1991	2704	2694	3171	1715	1871	4848	1860

Source: Own calculation

prise in particular periods, which was obtained from the database of the State Agricultural Intervention Fund. The location of farms in less favourable areas was also added, according to firm domiciles and the list of municipalities and cadastral territories ranked in LFA, issued by the Ministry of Agriculture of the CR.

The elaboration of an efficiency analysis also required a delimitation of the total production indicator of the monitored enterprises. This indicator was set as the sum of outputs and the consumption of an enterprise's own intermediate product. The influence of price development in determining production was eliminated by a transfer into real value by means of price indexes of agricultural producers, taking into account their production specialization as published by the Czech Statistical Office, with a base period of 2005.

Data obtained in the above-mentioned procedure were further purged of incomplete and remote observations. The resulting data collection, used for estimation, contained 390 observations of 129 organic farms and 1,533 observations of 379 conventional enterprises. The organic farms represented a basic collection of 52 %.

Enterprises, whose final accounts were entered in the database, can be ranked from the viewpoint of production specialization, and are engaged above all in mixed production (OKEČ 013000). In terms of size structure, farms with an average acreage of 500-999 ha prevailed, which represented 34 % of the collection of organic enterprises. In the collection of conventional farms, 32 % of subjects managed within this production range). The regional structure of this collection of agricultural enterprises copied the basic structure, because the observed organic farms managed from 15 % in the South-Bohemian region, where 13 % of Czech organic enterprises are located. Fifteen percent of the observed organic farms reside in the Zlín region, in which 11 % of Czech organic enterprises are situated. Conventional farms of the selected collection were located above all in the Vysočina region (18 %) and South-Bohemian region (13 %), where 20 % of conventional enterprises in the Czech Republic reside.

The researched organic enterprises reached on average 11,294,800 CZK of production in constant 2005 prices, with the use of 844 ha of managed agricultural land, 18 employees, and 17,136,400 CZK of constant assets, on average. The observed organic enterprises gained an average of 8,865,600 CZK from the sale of produced commodities. Almost the same sum (8,529,400 CZK) was achieved by the previously-mentioned eco-farms through endowment support of agricultural production. The observed organic enterprises terminated their economic activity with an average profit of 2,656,500 CZK. Table 1 shows an obvious growth tendency in most mentioned indicators throughout the monitored period.

Conventional enterprises, whose final accounts were entered in the research database, reached an average production in constant 2005 prices of 46,304,500 CZK. To achieve the mentioned production they used an average of 54 employees and 1,258 ha of agricultural land, with constant assets of 46,094,600. By the sale of their production they obtained, on average, 41,573,600 CZK. Moreover, their economic results were supported by a total of 7,310,100 CZK obtained by means of subsidies financed by the Czech Republic and the European Union. Finally, the economic activity of these farms was also profitable, at an average level of 2,692,800 CZK. However, from Table 1 it is obvious that selected indicators of conventional agriculture show contradictory tendencies towards organic agriculture. The apparently decreasing trend can be seen in the number of employees, the acreage of managed land, and in production in constant prices.

In Czech agricultural production, a considerable tendency to shift from a conventional production system to organic production technology can be identified. However, these tendencies seem to be a consequence of the growing volume of support for environmentally friendly production technology, rather than a strengthening of the positive relationship of agricultural producers to the environment.

3. Technical Efficiency of Organic Production Technology

The results of estimation of the frontier production function model by the method of maximum likelihood, shown in Table 2, indicate the existence of technical inefficiency in organic and conventional farms. The parameter „?“, verified by the t-test and LR test, proved that the technical inefficiency rate had a significant representation in a random component of the model. Other parameters of the estimated model also reached the level of statistical evidence, with a likelihood of 95 %. The evidence of the parameter „?“ indicated the growing rate of technical inefficiency over time. This negative trend afflicts both production systems. The technical inefficiency of organic farms in organic agriculture showed a yearly increase of 0.96 %. Similar tendencies can be identified in conventional agriculture, since the technical inefficiency rate there showed a yearly increase of 0.97 %.

An analysis of this estimation of the organic agriculture production function allows us to quantify the technical inefficiency rate of organic farms, defined as the percentage of achievement of potential production. Therefore, the technical efficiency rate expresses the ability of ecological farms to use their disposable resources for production of the maximal input amount. In the ideal case, the technical efficiency rate reaches 100 %. A farm achieving this rate is producing at the edge of its production capabilities. Any lower value identifies an inefficient production process. In the selected collection of organic and conventional enterprises, none of the observed farms reached its full production potential. In organic agriculture, the best farm showed a 96.6 % rate of technical efficiency (see Table 3). However, in conventional agriculture it is possible

Tab. 2: Results of estimation of frontier production function

	Organic farming				Conventional farming			
	Parameter	Standard error	t-value	p-value	Parameter	Standard error	t-value	p-value
BETA0	181.3810	0.2621	19.8405	0.0000	761.8121	0.1203	55.1666	0.0000
L	0.2563	0.0435	5.8933	0.0000	0.1570	0.0117	13.4077	0.0000
WU	0.5520	0.0221	24.9701	0.0000	0.5491	0.0130	42.0951	0.0000
K	0.1553	0.0282	5.5051	0.0000	0.1226	0.0078	15.7060	0.0000
λ	3.0338	0.0418	72.5774	0.0000	5.3636	0.0103	522.2790	0.0000
σ_u	0.9501	0.1198	7.9291	0.0000	0.6750	0.0164	41.0427	0.0000
η	-0.0441	0.0108	-4.0945	0.0000	-0.0309	0.0031	-10.0289	0.0000
Pseudo R^2	0.37				0.78			
LR test [1]	199.2244			0.0000	18101.58			0.0000

Source: Own calculation

to reach a higher rate of technical inefficiency, because the most successful farm produced at a level of 99.1 % of its production capabilities. However, there are considerably inefficient farms within both production systems. In organic agriculture, one of these farms is a subject reaching only 17.7 % of its production potential. In conventional agriculture, the least efficient farm shows only a 13.2 % rate of technical efficiency.

Tab. 3: Technical efficiency rate of examined subjects

	Average	Minimum	Maximum
Organic agriculture	50.40 %	17.70 %	96.60 %
Conventional agriculture	59.70 %	13.20 %	99.10 %

Source: Own calculation

The evaluation of both models verified the statistically significant difference between organic and conventional agriculture. In terms of average values, organic agriculture can be considered less technically active, because on average it reaches 50.4 % of production potential. This represents a 15.6 % lower technical efficiency than that achieved by conventional agriculture, which has an average rate of technical inefficiency of 59.7 %.

Within the selected collection, it is possible to identify considerable variability in the technical inefficiency rate (see Tab. 4). The highest representation is shown by farms having a technical inefficiency rate from 0-50 %, a range which contains 59 % of subjects of the researched collection of organic farms. 25 % of organic farms exhibit a technical inefficiency rate higher than 70 %, but only two percent of organic farms produce at a level of more than 90 % of their production potential.

This inefficiency is determined by several factors. Results of the estimation of the technical inefficiency rate function, shown in Table 5, refer to the strongest influence of a farm's location in a less favourable area. However, the statistical significance of the parameter of this variable was not proved by an LR test at the chosen level of significance. Nevertheless, a statistically evidential influence can be identified in cases of subsidies for support of organic agriculture, according to results of the t-test and LR test, with a 95 % likelihood. These subsidies lead to an increase in a farm's technical inefficiency. The average tariff rate per hectare for the subsidies was increased during the period by 63 %, with an average annual growth of 15 %. Growth of endowment tariff rates is probably the main determinant of the decreasing tendency toward technical inefficiency of organic farms. However, there was no evidence for the influence of other subsidies. In addition to inefficiency determinants, a significant influence was also shown by

Tab. 4: Average technical inefficiency rate of organic farms

Technical efficiency rate	Abs.	%
0-20%	4	3%
21-30%	19	15%
31-40%	28	22%
41-50%	25	19%
51-60%	12	9%
61-70%	10	8%
71-80%	15	12%
81-90%	14	11%
91-100%	2	2%

Source: Own calculation

Tab. 5: Results of estimation of the technical inefficiency rate function of organic farms

	Parameter	Standard error	t-value	p-value
LFA	0.5319	0.1904	2.7931	0.0052
DEZH	0.1669	0.0442	3.7155	0.0002
SPMH	-0.0829	0.0143	-5.7817	0.0000
ODH	0.0078	0.0108	0.7205	0.4712
H_0: $\gamma_{LFA}=\gamma_D=\gamma_O=\gamma_M=0$	14.75			0.0052
H_0: $\gamma_{LFA}=0$	2.06			0.1517
H_0: $\gamma_D=0$	13.32			0.0003
H_0: $\gamma_M=0$	3.01			0.0827
H_0: $\gamma_O=0$	0.42			0.5188

Source: Own calculation

the hectare material and energy consumption, whose influence on the decrease in technical inefficiency was evidenced by the LR test, with only a 90 % likelihood.

The model of a frontier production function also allowed for an analysis of the adequacy of organic or conventional technology for the examined subjects. For this purpose, construction of a production gap was used, defined as the difference between the maximal production potentially attainable from disposable resources of the analyzed subjects, and the potential production obtained by application of organic technology in the given subject. This production gap reached positive values for all enterprises, which indicates the fact that organic production technology in all examined farms does not enable maximization of the volume of production from disposable resources. The organic economic system can be considered globally as an inferior production system, relative to production volume.

In the organic as well as the conventional economic system, considerable variability in the production gap can again be identified (see Tab. 6). On average, the collection of organic enterprises shows 47 % of the production gap of conventional farms. From a time perspective, it is possible to identify an increase in the production gap by an annual average of 4 %, caused primarily by a deepening of the maximal values of the production gap, which grow by an average of 11 % annually. On the other hand, in conventional agriculture the average production gap shows a decreasing tendency over time, with an average yearly decrease of 4 %, which occurs due to a fall in the minimal and maximal values of the production gaps of conventional farms. This development indicates a widening difference between the efficiency of organic and conventional technologies.

Given the level of these values, the growing inefficiency of organic production technology in comparison with conventional technology is obvious. The above-mentioned loss of production potential in the organic economy is also accompanied by an increase in production gap variability among particular subjects within the monitored period. From the extreme values, it is also obvious that there has been an increase in the maximal values of the production gap, which has led to the above-mentioned strengthening of the inferiority of organic technology.

Tab. 6: Descriptive statistics of the production gap of organic and conventional farms

Year	*Production gap - organic agriculture [thous. CZK]*				*Production gap - conventional agriculture [thous. CZK]*			
	Average	Standard deviation	Minimum	Maximum	Average	Standard deviation	Minimum	Maximum
2004	9700.63	6646.93	1352.86	30134.1	23091.4	8988.08	2452.07	48211.3
2005	9442.86	6695.56	1345.5	30372.7	22277.8	8881.79	1408.4	44913.8
2006	10166.5	7551.04	1326.16	32205.8	21674.7	8666.67	1165.53	41950.4
2007	10590.7	7927.88	1363.49	46599,00	21521.3	8450.4	2810.76	44521.6
2008	11332.2	8670.31	1184.02	44750,00	19098.5	8529.82	3113.62	36427.3
Total	10194.4	7477.21	1184.02	46599,00	21903.7	8776.62	1165.53	48211.3

Source: Own calculation

4. Inclination Toward Organic Technology

The above-mentioned information regarding the inefficiency of organic technology for agricultural production suggested the construction of a binary choice model, which defines the basic determinants for implementing organic as opposed to conventional technology. The construction of this model was primarily based on delimiting and quantifying those factors which could significantly influence the decision of an agricultural producer to implement organic production technology. Out of a wide range of factors, some of which it was not possible to quantify in terms of the existing database, seven basic determinants were defined:

- subsidies for the support of organic agriculture,
- price allowance of bio-products towards conventional products,
- technical inefficiency rate,
- size of the agricultural enterprise,
- location of the agricultural enterprise,
- income from the sale of its own products and services.

The estimation of a binary choice model in the model specification of random effects with the above-mentioned explanatory variables did not give appropriate statistical results. Therefore, the number of explanatory variables was reduced. The only variables included were those characterized by a variability between the cross-sectional and time components of panel data, i.e. the volume of granted subsidies per hectare of managed land, including subsidies for support of organic agriculture, the rate of technical inefficiency, income from the sale of its own products and services per hectare of managed land, and the size of the agricultural enterprise.

The reaction of agricultural enterprises to the working of these determinants was not assumed without a time delay; therefore, the delayed influence of the above-delimited variables, except for the size of the agricultural enterprise, was considered.

The results of estimation of binary choice model with an explanatory variable, having a value of one for the implementation of organic technology, and a zero value for a conventional economic system, are shown in Table 7.

The accuracy of the defined specification of a probit model was tested by an LR test, first with a zero hypothesis, assuming the existence of only a constant as an explanatory variable, and subsequently with a zero hypothesis about omission of another explanatory variable, in the form of income from operations over an accounting period per hectare of managed land. In both cases, LR statistics exceeded the critical value χ^2, at a 5% level of significance and with one degree of freedom, which allowed for a conclusion to be made concerning an adequate model specification.

Tab. 7: Results of estimation of binary choice model in model specification of random effects

	Parameter	Standard error	t-value	p-value
BETA0	-0.5501	0.2073	-2.6538	0.0080
V	-0.2452	0.0398	-6.1659	0.0000
TR_{t-1}	-0.0466	0.0033	-14.2598	0.0000
DH_{t-1}	0.2350	0.0147	16.0440	0.0000
NEF_{t-1}	-0.1891	0.2285	-0.8280	0.4077
ς	0.0431	0.0485	0.8878	0.3747
Log-likelihood function	-332.71			
Pseudo R^2	0.4569			
LR[1]	559.74			0.0000
$LR_{om}[1]$	26.38			0.0000
$H_0{:}\varsigma=0$	541.67			0.0000
$H_0{:}\beta_{DH}=0$	213.10			0.0000
$H_0{:}\beta_{TR}=0$	247.28			0.0000
$H_0{:}\beta_{V}=0$	24.33			0.0000
$H_0{:}\beta_{NEF}=0$	125.10			0.0000

Source: Own calculation

The adequacy of specification of this model in the form of a random effect model was tested by an LR test with a zero hypothesis about the absence of farm specifics:

$$H_0: \varsigma = \frac{\sigma_w^2}{\sigma_w^2 + \sigma_e^2} = 0 \qquad (21)$$

The hypothesis was refused, at a 5% level of significance with one degree of freedom, in favour of an alternative hypothesis confirming the statistical significance of inter-farm variability.

A basic presumption of the binary choice model was that subsidies for support of organic agriculture have a positive influence on the choice of organic technology. The LR test, realized within the framework of the probit model, proved with a likelihood of 95 % that the subsidy volume, obtained by the given enterprise in the foregoing period for a hectare of managed land, should be included in the model specification of the likelihood of choosing organic technology. The statistical significance of the parameter of this variable was also confirmed by a t-test at a 5% level of significance. The correct sign of the parameter was declared also by results of VIF-test which did not verified multicollinearity between any explanatory variables. As a result of this statistical verification, subsidies can be considered as a factor which positively influences the implementation of organic technology.

Given this fact it is possible, through agricultural policy, to effectively influence the number of organically managing farmers, as well as the acreage of organically managed land.

Contrary to subsidies, other considered factors decrease the likelihood that an organic economic method will be implemented. The parameter of incomes obtained in a foregoing period from a hectare of managed land shows a negative influence, which can be considered as evidential with likelihood 95 %, according to both the LR and t-tests. Higher incomes per hectare of managed land, which conventional agriculture reaches due to higher hectare yields, and which are not sufficiently compensated for by a price allowance for bio-products, provide a disincentive to transition to an organic economic method.

A statistically significant negative influence was also evidenced with likelihood 95 % in a variable representing the size of agricultural enterprises. A farm characterized by a high acreage of managed land will probably not be motivated to implement the less efficient organic technology.

The influence of the technical inefficiency rate from a foregoing period was evidenced only by the LR test with likelihood 95 %; the t-test did not confirm the statistical significance of this parameter. Therefore, the technical inefficiency rate can be considered as only one of the important determinants in choosing organic technology. Nevertheless, we cannot reach any conclusions regarding the working direction of the variable in question. On the other hand, the omission of mentioned variable could cause bias of other estimated parameters.

It can be confidently stated that subsidies are a strong stimulus for the transition to, and implementation of, an organic economic system. However, the effects of this tool for supporting organic agriculture negatively influence the efficiency of organic production.

Conclusion

In most of the examined enterprises, an organic method of production was identified as an inferior production system. Farms implementing this production technology showed, on average, a 15.6 % lower rate of technical efficiency than conventional agricultural subjects. This inefficiency of organic agriculture is significantly influenced by subsidies, which were verified to be a determining factor in the growth of technical inefficiency on organic farms. Subsidies supporting this alternative economic system provide ecological producers with sufficiently high incomes, which even correspond in size to the revenue obtained by the sale of their own products and services. Given this fact, organic producers are not motivated to optimize their production behaviour, which implies an irrational use of production factors, and an inability to achieve potential production.

However, subsidies which support organic agriculture also provide an important stimulus for agricultural producers to adopt an organic production system, which is done not only by producers with a positive relationship to the environment, motivated by their own organic agriculture technology, but also by inefficient and unpromising producers for whom organic agriculture is only an easy way of gaining sufficient financial resources. However, the conversion of producers lacking a direct relationship to organic production can be one of the basic determining factors in the decrease of organic production.

These results imply several recommendations for changes in the endowment policy for organic agriculture in the Czech Republic. It would be appropriate to provide support for organic agriculture only in the period of conversion, when the support can be justified by how it compensates for the decrease in natural yields and efficiency, as well as the cost growth resulting from the insufficient experience of agricultural producers with new production technologies, and how it compensates for possible losses arising through unfamiliarity with the new market environment. At the same time, this support should be appropriately complemented by the financing of organic farming courses. After the period of conversion, it is possible to support organic agriculture indirectly, by means of market-oriented tools aimed at developing the knowledge level of consumers regarding bio-foods, and supporting the possibilities of selling organic products.

Pieces of knowledge introduced in this paper resulted from execution of an institutional research intention, MSM 6046070906 „Economics of resources of Czech agriculture and their efficient use within the framework of multifunctional agri-food systems".

References

[1] AIGNER, D.J., LOVELL, C.A.K., SCHMIDT, P. Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics, 1977,* Iss. 6, pp. 21-37. ISSN 0304-4076.

[2] BATTESE, G.E., COELLI, T.J. A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics*, 1995, Iss. 20, pp. 325-332. ISSN 0377-7332.

[3] BRAVO-URETA, B.E. et al. Technical Efficiency in Farming: A Meta-regression Analysis. *Efficiency Series Paper* [online]. 2005, Iss. 1, 31 p. [cit. 2009-12-20]. Available from: <http://www.uniovi.es/economia/edp.htm>.

[4] BRAVO-URETA, B.E, PINHEIRO, A.E. Technical, Economic, and Allocative Efficiency in Peasant Farming: Evidence from the Dominican Republic. *The Developing Economies* [on-line]. 1997, Vol. 35, Iss. 1, pp. 48-67. [cit. 2009-11-20] Available from: <http://www.ide.go.jp/English/Publish/Periodicals/De/pdf/97_01_03.pdf>.

[5] COELLI, T.J. Recent Developments in Frontier Modelling and Efficiency Measurement. *Australian Journal of Agricultural Economics* [online]. 1995, Vol. 39, Iss. 3, pp. 219-245. [cit. 2009-09-30]. Available from: < http://ideas.repec.org/a/ags/ajaeau/22681.html>.

[6] GREEN, W.H. *Limdep Version 9.0 - Reference Guide.* New York: Econometric Software, Inc., 2007.

[7] GREEN, W.H. *Econometric Analysis.* 6th ed. New Persey: Pearson Prentice Hall, 2008. 1178 p. ISBN 978-0-13-513740-6.

[8] GUJARATI, D.N. *Basic Econometrics.* 4th ed. New York: Mc Graw Hill, 2002. 1002 p. ISBN 0-07-112342-3.

[9] CHAVEZ, D.M. *Production Technology and Production Risk in Organic and Conventional Arable Dutch Farming* [online]. [cit.2009-12-01]. Available from: <http://www.inta.gov.ar/salta/info/documentos/Economia/produc.tech.pdf>.

[10] JÁNSKÝ, J., ŽIVĚLOVÁ, I. Ekonomické hodnocení výroby vybraných rostlinných bioproduktů. (Economic evaluation of production of selected plant bio-products) In *Agrární Perspektivy XVI.* Prague: Czech University of Life Sciences, 2007, pp.173-179. ISBN 978-80-213-1675-1.

[11] KROUPOVÁ, Z. et al. Organic Farming in Less Favoured Areas. In *Think Together 2009* [CDROM]. Prague: Czech University of Life Sciences, 2009. ISBN 978-80-213-1906-6.

[12] KUMBHAKAR, S.C., TSIONAS, E.G., SIPILÄINEN,T. Joint Estimation of Technology Choice and Technical Efficiency: an Application to Organic and Conventional Dairy Farming. *Journal of Productivity Analysis*, 2009, Vol. 31, Iss. 3, pp.151-161. ISSN 0895-562X.

[13] MEEUSEN, W., VAN DEN BROECK, J. Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review*. 1977, Iss. 18, pp. 435-444. ISSN 1468-2354.

[14] TZOUVELEKAS, V., PANTZIOS, CH.J., FOTOPOULOS, CH. Economic Efficiency in Organic Farming: Evidence from Cotton

Farms in Viotia, Greece. *Journal of Agricultural and Applied Economics* [online]. 2001, Vol. 33, Iss. 1, pp. 35-48. [cit. 2009-12-21] Available from: <https://ageconsearch.umn.edu/bitstream/15288/1/33010035.pdf>.

[15] WOOLDRIDGE, J.M. *Econometric Analysis of Cross Section and Panel Data.* Cambridge: Massachusetts Institute of Technology, 2002. 752 p. ISBN 0-262-23219-7.

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Doručeno redakci: 8. 2. 2010
Recenzováno: 17. 6. 2010, 21. 6. 2010
Schváleno k publikování: 18. 1. 2011

ABSTRACT

EFFICIENCY ANALYSIS OF CZECH ORGANIC FARMING

Zdeňka Malá

Organic agriculture is the fastest developing branch of Czech agricultural production. Nevertheless, foreign research indicates that it is not being dealt with using efficient production technology. This research has not yet been undertaken in the Czech Republic, and therefore the aim of the proposed paper is to evaluate the technical efficiency of Czech organic farms, including determining which factors are causing the inefficiency. A partial aim is also to identify the determining factors in choosing organic production technology.

The primary methodological tool for achieving these aims is an analysis using a frontier production function estimated by the maximum likelihood method. The determinants for choosing organic production technology are analyzed by means of an estimation of a probit model, which is also quantified by the maximum likelihood method.

These analyses are conducted on the basis of unbalanced panel data from 129 organic and 379 conventional enterprises obtained over the time period 2004 – 2008. Farms, whose data was entered into this database, represent legal entities concentrated primarily on mixed agricultural production.

Results of the analyses indicate the inferiority of organic production technology, because they document that conventional producers operate, on average, closer to the frontier production function than organic producers. Moreover, conventional production technology enables all organic producers to increase their production.

This inefficiency is determined by the endowment policy of the Czech Republic and the European Union. The completed research documents that subsidies for support of organic agriculture deepen the technical inefficiency of organic producers. However, at the same time, those subsidies are an important stimulus for converting producers to organic production technology. In reaction to these conclusions, the submitted paper suggests changes in the endowment policy which would enable organic producers to increase their efficiency.

Key Words: *Organic farming, stochastic frontier analysis, technical efficiency, production gap, probit model.*

JEL Classification: *Q12, Q18.*