EFFICIENCY OF LABOUR USAGE BY ORGANIC FARMS IN THE CZECH REPUBLIC

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Abstract

The aim of the paper is to assess the efficiency of usage of production factor labour by organic farms in the Czech Republic. Parametric method to assess the technical efficiency, particularly Stochastic Frontier Analysis, is applied. We presume truncated normal distribution of the inefficiency term and normal distribution of the noise term. Cobb-Douglas production function is estimated using maximum likelihood approach. Then efficiency and inefficiency is calculated. Consequently it is tested by ANOVA whether micro, small, medium or large-sized companies (in terms of the employees) statistically significantly differ in the efficiency usage of labour force. Schéffe's method is applied on non-equal means.

The results show high inefficiency in labour usage among organic farms – almost from 67 %. The efficiency is very low – only 56 %. The less inefficient are large farms (33 % in average), while micro farms (70 %) and small farms (81 %) are the most inefficient. On the other hand, large farms are the most efficient (from 73 %). There are also statistically significant differences among unequally sized firms. This is in line with the theory of return to scale suggesting that larger firms are more efficient in input usage as they can benefit from their size.

Key words: organic farms, labour efficiency, Stochastic Frontier Analysis (SFA), ANOVA
JEL Code: Q18, C54

Introduction

Organic farming is different from conventional as it does not use synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. As a consequence for organic agriculture is typical higher labour usage. Pimentel et al. (2005) argue in their study that organic systems require on average 15% more labour than conventional systems. The question whether and how conversion to organic farming leads to changes in labour requirements was answered by many studies. For example analysis performed by Rapp (1998, in Jansen, 2000) showed almost doubled increase in labour use in a sample of 448 farms in Germany after converting from conventional to organic farming. Nguven and Haynes (1995) observed the labour efficiency for three pairs of conventional and alternative mixed cropping (pasture-arable) farms in Canterbury in New Zealand. They came to the conclusion that it was "higher for production of individual cereal crops under alternative management but mean annual labour inputs over the whole rotations were slightly lower under alternative than conventional management."

Jansen (2000) stated in his study that "labour requirements may impose constraints of the competitiveness and growth of the organic sector." He does not see higher labour usage negatively as he proclaimed that: "higher labour requirement are sometimes perceived as one of the merits of organic agriculture when this means higher rural employment," (Jansen, 2000). Also Fasterding and Rixen (2006) highlight positive contribution of the labour intensive agriculture to the preserving of farming job. Particularly she proclaims that: "if there is a demand for the products backed by purchasing power, support to convert farming operations to an organic system, or-generally speaking-to diversify agricultural production can contribute to creating or preserving farming jobs. Yet this merely leads to lower reduction rates of the labour input."

According to Lohr and Park (2009) „farm size and farm workers are complementary inputs." They came to the conclusion that "incentives that encourage farmers to expand employment of year-round and seasonal workers raise the marginal product and rates of return to organic acreage in relative wage payments." (Lohr and Park, 2009)

As every input, the labour should be also used efficiently, i.e. the output produced by certain number of labour force should be as high as possible. Efficiency analysis was firstly elaborated by Farrell in 1957. He defined cost efficiency and decomposed it to technical and allocative. The approach was non-parametric based on linear or quadratic linear programming. Parametric approach, on the other hand, was elaborated later and is based on the estimation of certain production function. Mostly used method is Stochastic Frontier Analysis (SFA). It presumes that the error term is divided into two parts – noise v_i and inefficiency u_i. This later enabled to derive the firm specific inefficiency u_i from the composed error term $\varepsilon_i = v_i - u_i$. To enable the decomposition, the assumption about the inefficiency term distributions has to be imposed. For example Pitt and Lee (1981) utilized truncated normal and Aigner et al. (1977) half normal. Others utilize one-parameter Gamma or exponential distribution.

The SFA further developed with evolution of panel data estimation methods. Panel data have several advantages. Pitt and Lee (1981) named that the structure of the data enables to estimate the efficiency of individual firms and permits to evaluate whether the inefficiency of firms is time invariant and finally make possible to see the structural change in the production function. Kumbhakar and Lovell (2010) highlighted that panel data provide more reliable evidence on the performance of producers, because they enable to track the performance of each of them through a sequence of time periods.

The aim of this article is to assess the labour usage efficiency of organic farms and to test whether there are statistically significant differences among different sized farms. Firstly, the used methods – SFA and ANOVA – are described. Than the analysis on the organic farms sample is performed. The differences between smaller and bigger farms in labour efficiency are tested. The discussion follows. The last chapter summarizes the conclusions.

Methodology

We considered alternative specifications of "true" fixed effect (TFE) model to estimate the Cobb-Douglas production function in a linear form. Organic farms, which lie on the frontier of the production function, are 100 % efficient while the others are compared to those and are less efficient. Output – the production y_i is represented by the sales of own products and services and change of the stock of own activity. Subscript i (i = 1, 2, ..., N), where N is total number of farms, marks particular farm. There is only one input included as production factor – the number of employees on the full-time basis (so called AWU). One AWU (annual work unit) corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis (minimally 1 800 hours – an equivalent to 225 working days of eight hours each).

We assumed truncated normal distribution of the inefficiency term. To calculate the inefficiency of a farm the Jondrow et al. (1982) estimator was used. It produces estimates of inefficiency via conditional expected value E(u|e). The efficiency was estimated as suggested also by Jondrow et al. (1982) via exp[-E(u|e)]. Null value of u_i implies that the farm is efficient from 100 %. If the $|u_i|>0$, the farm is producing under its possibilities. In other words, it is wasting its resources.

The farms were divided according to the EU definition on micro (less than 10 employees), small (between 10 and 50), medium (from 50 to 250) and large (more than 250 employees). The null hypothesis assumed that there are no statistically significant differences among the mean values of inefficiency (or efficiency) among farms of different size.

Analysis of variance (ANOVA) was used to test the hypothesis. The formulas to calculate the between group, within group and total variance are displayed in Tab. 1.

Tab. 1: ANOVA

Variability	Sum of square	D.f.	Variance	Test criterion
Between group	$S_1 = \sum_{i=1}^{m} \frac{x_{i\bullet}^2}{n_i} - C$	m-1	$s_1^2 = \frac{S_1}{m-1}$	$F = \frac{s_1^2}{s_r^2}$
Within group	$S_r = S - S_1$	n-m	$s_r^2 = \frac{S_r}{n-m}$	
Total	$S = \sum_{i=1}^{m} \sum_{j=1}^{n_i} x_{ij}^2 - C$	n-1		

C is calculated as $C = \frac{x^2_{\bullet\bullet}}{N}$. A dot substitutes the sum symbol. Therefore, the calculations are as follows: $x_{i\bullet}^2 = \left(\sum_{j=1}^{n_i} x_{ij}\right)^2$ and $x_{\bullet\bullet} = \sum_{i=1}^{m} \sum_{j=1}^{n_i} x_{ij}$. S_1 is between group sum of square, S_r is within group sum of square, S is total sum of square, *i* is the number of rows, *j* is number of columns, *n* stays for the number of observation and *m* stays for the number of compared groups.

Calculated F test criterion is compared with table value of Fisher-Snedecor distribution with *m-1* and *N-m* degrees of freedom. If value of F criterion exceeds the critical value, the null hypothesis is rejected and we may conclude that there are statistically significant differences at least between two means. The same results can be achieved by calculating p-value, i. e. the significance level at which is possible to reject the null hypothesis.

When there were statistically significant differences found, Schéffe's (1959) method was used to observe between what means the differences are. The method reject the hypothesis $\mu_i = \mu_j$ (i, j, = 1, 2, 3, 4, i $\neq$ j) when

$$\left|\bar{x}_{i\bullet} - \bar{x}_{j\bullet}\right| > \sqrt{\left(\frac{1}{n_i} + \frac{1}{n_j}(m-1).s_r^2.F_{\alpha(m-1,N-m)}\right)}, \qquad (1)$$

where s_r^2 is residual variance. If $\bar{x}_{i\bullet} - \bar{x}_{j\bullet}$ is higher than the right side of the unequation, it implies that μ_i is significantly higher than μ_j. If $\bar{x}_{i\bullet} - \bar{x}_{j\bullet}$ is smaller than the right side of the unequation with negative sign, we can say that μ_i is significantly smaller than μ_j.

The data were obtained from Albertina database (managed by company Bisnode Česká republika, a.s.) and from Commercial register and the collection of documents. The database of organic farms contained data for 44 Czech organic farms for year 2010. The analysis was elaborated in Stata 11.2 and STATISTICA CZ 10.

Results

Because we are using the Cobb-Douglas function, the variables had to be linearized, i.e. the logarithm of each variable had to be taken. There were 44 observations for production and labour input. Basic statistics of a sample are displayed in Tab. 2. The average production value was 17 506 thous. CZK with deviation of 5 600 CZK. The average worked hours were 67 653 and variability for labour usage was 4.32 hours with minimum of 1800 (one AWU).

Tab. 2: Summary characteristics for variables

Variable	Mean	Standard dev.	Min.	Max.
y - production	17506.07	5.60	227.00	496168.07
x - labour	67653.20	4.32	1800.00	667797.32

Source: own elaboration

The variables were included into a stochastic frontier model – particularly TFE model with normal distribution of a noise term and truncated normal distribution of inefficiency term. The results of the estimation are presented in Tab. 3. Cobb-Douglas production function can be rewritten as $\ln y = 0.4115 + 0.9011 \ln x$ or $y = 0.4115x^{2.4623}$. Unlike the constant, the coefficient for input is statistically significant.

Tab. 3: True fixed effect model results

Nr. of obs. = 44; Wald chi2(1) = 86.08; Prob > chi2 = 0.0000; Log likelihood = -60.0363; AIC = 130.0726; BIC = 138.9935

H_0: No inefficiency component: z = -1.651 Prob<=z = 0.049

ln y	Coef.	Std. error	z	P>|z|	[95% conf. interval]	
Frontier						
ln x	0.9011	0.0971	9.2800	0.0000	0.7108	1.0915
cons	0.4115	1.1798	0.3500	0.7270	-1.9009	2.7239
Mu						
cons	-935.1349	10031.7300	-0.0900	0.9260	-20596.9700	18726.7000
Usigma						
cons	6.4325	10.7089	0.6000	0.5480	-14.5565	27.4215
Vsigma						
cons	-0.6869	0.4080	-1.6800	0.0920	-1.4865	0.1128
sigma_u	24.9344	133.5094	0.1900	0.8520	0.0007	900538.2000
sigma_v	0.7093	0.1447	4.9000	0.0000	0.4756	1.0580

lambda	35.1517	133.5107	0.2600	0.7920	-226.5244	296.8278

Source: own elaboration

Inefficiency term was obtained via E(u|e) using the Jondrow et al. (1982) estimator. Efficiency was estimated via exp[-E(u|e)]. 95 % confidence intervals are constructed for each group and inefficiency and efficiency value.

The mean inefficiency reached almost 66.40 % with high standard deviation of 53.80 %. Overall efficiency was low (56.28 %) with lower standard deviation (17.41 %). When we divide the inefficiency between differently sized firms, we can see (Tab. 4) that the most inefficient are the small farms (80.60 %) and the less inefficient the largest. This corresponds to the theory suggesting that larger companies are able to achieve economy of scale. Also the large farms are more efficient (from 72.06 %) that the small (51.07 %). Surprisingly micro firms use labour more efficiently (54.28 %) than small ones. However, we must keep in mind that there are only three organic farms among the largest and only seven in the group of micro farms. Therefore, the results might not have sufficient explanatory power.

Tab. 4: Average inefficiency and efficiency for different sized farms

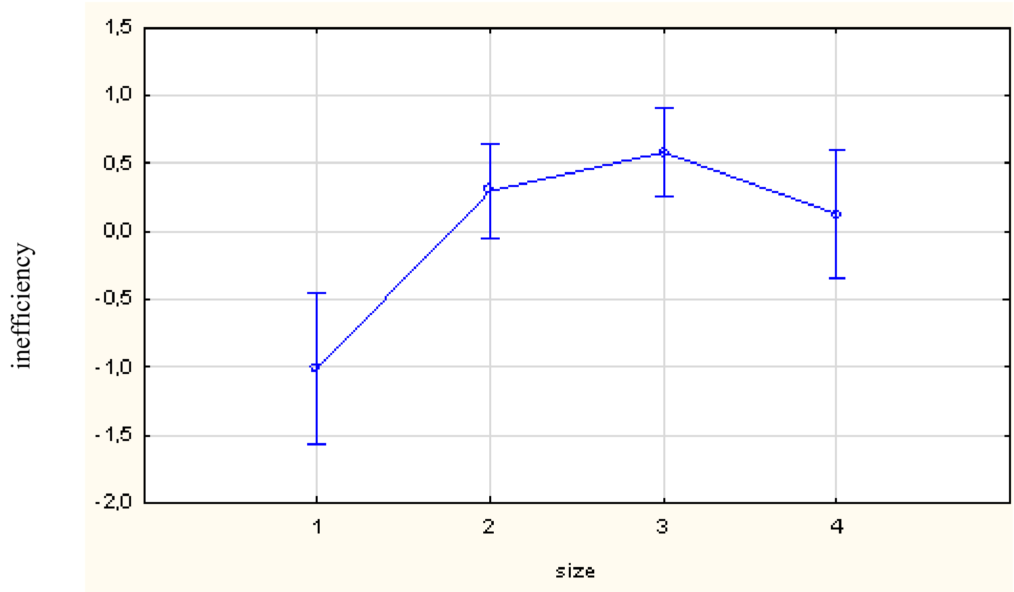
Farm size	N	Inefficiency			
		Mean	Std. dev.	95,00%	+95,00%
Large	3	0.3307	0.0972	0.0892	0.5723
Medium	16	0.5495	0.3278	0.3749	0.7241
Small	18	0.8060	0.7071	0.4543	1.1576
Micro	7	0.7022	0.4831	0.2553	1.1490
		Efficiency			
Large	3	0.7206	0.0680	0.5517	0.8896
Medium	16	0.6007	0.1411	0.5255	0.6759
Small	18	0.5107	0.1764	0.4230	0.5984
Micro	7	0.5428	0.2300	0.3300	0.7556

Source: own elaboration

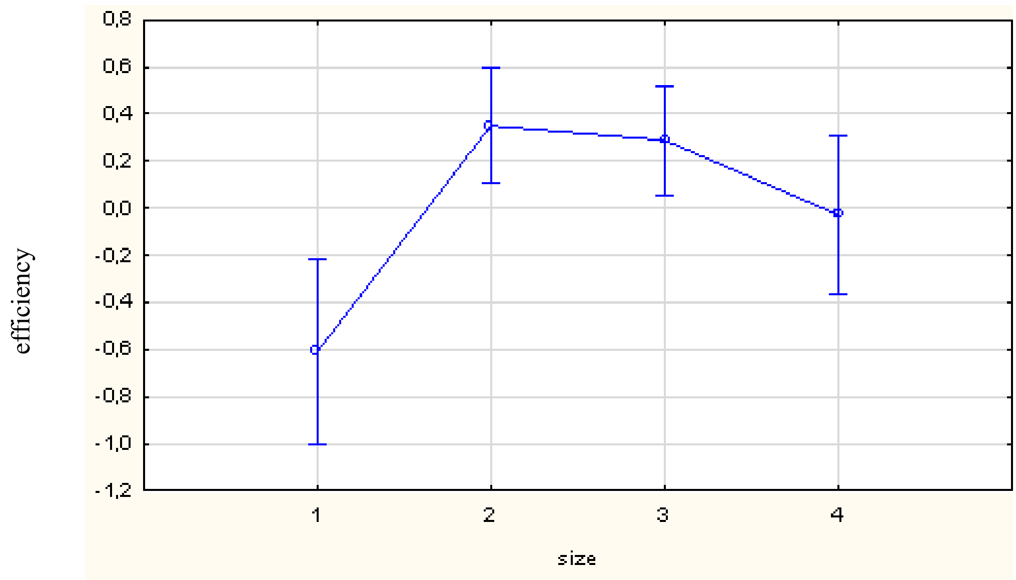
95 % confidence intervals for every mean of inefficiency and efficiency are displayed at Fig. 1. On the first side, the huge differences between particular mean values of each firm size group are visible. The p-values for ANOVA show that the null hypotheses have to be rejected in both cases. There are statistically significant differences between means of inefficiency and efficiency values among differently sized firms.

Fig. 1: ANOVA for mean values of inefficiency and efficiency

Current effect: F(3,41) =6.9231, p = .0007



Current effect: F(3,41) = 5.9029, p = .0019



Note: Vertical bars denote 0.95 confidence intervals

Source: own elaboration

Discussion

As there are statistically significant differences among mean values of inefficiency (or efficiency) across large, medium, small and micro firms, consequent analysis has to be performed. Particularly Schéffe method is used. The results of the analysis are displayed in

Tab. 5. It is obvious that the null hypothesis is rejected in every case. We can conclude that means between each pair of farms are statistically significantly different.

Tab. 5: Schéffe's Post Hoc Test for inefficiency and efficiency

Probabilities for Post Hoc Tests - inefficiency Error: Between MS = 0.2883 df = 40				
size	Large (0.3308)	Medium (0.5495)	Small (0.8060)	Micro (0.7022)
Large		0.935587	0.5746	0.8001
Medium	0.9356		0.5911	0.9409
Small	0.5745	0.5911		0.9792
Micro	0.8001	0.9409	0.9792	

Probabilities for Post Hoc Tests - efficiency Error: Between MS = 0.0289 df = 40				
size	Large (0.7206)	Medium (0.6007)	Small (0.5107)	Micro (0.5428)
Large		0.7399	0.2851	0.5194
Medium	0.7399		0.5058	0.9037
Small	0.2851	0.5058		0.9805
Micro	0.5194	0.9037	0.9805	

Source: own elaboration

Conclusion

The aim of the article was to assess the inefficiency and efficiency of usage of production factor of labour among organic farms. Besides that organic agriculture tends to use higher amount of labour, the efficiency of its usage is also lower and inefficiency higher. The average labour usage among organic farms is almost from 67 % inefficient. The efficiency is very low – only 56 %. The less inefficient are large farms (33 % in average), while micro farms (70 %) and small farms (81 %) are the most inefficient. On the other hand, large farms are the most efficient (from 73 %). ANOVA and consequent Schéffe's test proved that are also statistically significant differences among differently sized firms. This is in line with the theory of return to scale suggesting that larger firms are more efficient in input usage as they can benefit from their size.

Further research can elaborate the inefficiency and efficiency analysis for more inputs than only for labour. Also the farms can be divided according to another criterion than the size

– for example according to the location, which also significantly contributes to the efficiency of resources usage.

Acknowledgment

The paper is supported by the internal grant: "Analýza vybraných ukazatelů biodynamického zemědělství – komparace ve světovém měřítku" No. 11110/1312/3160 of the IGA of the FEM of the CULS.

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