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EFFICIENCY ANALYSIS OF PRODUCERS' ORGANIZATIONS (CASE OF SOUTH EASTERN AND CENTRAL PLANNING REGIONS OF BULGARIA)

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Abstract: The main aim of this paper is to compare two alternative methods for estimating frontier functions and measuring efficiency in production. The application of Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) to the same data panel provides insights in estimating technical efficiency of producers' organizations in selected regions in Bulgaria.

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Introduction

Adaptation of the organizational structure is focused on market imperfections, defining them as obstacle for achieving the optimal production process and scale. Production function includes not only conventional production factors but also variables that can represent the effect of institutional changes. Comparing production function to the demand function defines sources of influence over production factors, differentiating them from those that reflect on productivity itself. This approach distinguishes market effect from the effect of government regulation and institutional policy line.

Theory on Stochastic Frontier Analysis and Data Envelopment Analysis

Stochastic Frontier Analysis (SFA) represents parametric, econometric techniques for estimating efficiency coefficients. The production function can be expressed in the following form:

$$Y_{it} = f(x_{it}) + v_{it} - u_{it} \qquad (1)$$

where Y_i is the production of the i-th producer; x_i is a vector of input quantities; v_i is the random variable; u_i is non-negative random variable which is assumed to account for technical inefficiency. The benefits of this approach result from decomposing the error term into two components - one to account for random effects and another to account for technical inefficiency.

The stochastic frontier production function to be estimated is

$$\ln (Y_{it}) = \beta_0 + \beta_1 \ln (Land_{it}) + \beta_2 \ln (Labor_{it}) + \beta_3 \ln (Production\ costs_{it}) + \beta_4 \ln (Indirect\ costs_{it}) + \beta_5 \ln (Year_{it}) + \beta_6 \ln (Land_{it})^2 + \beta_7 \ln (Labor_{it})^2 + \beta_8 \ln (Production\ costs_{it})^2 + \beta_9 \ln (Indirect\ costs_{it})^2 + \beta_{10} \ln (Land_{it}) \ln (Labor_{it}) + \beta_{11} \ln (Land_{it}) \ln (Production\ costs_{it}) + \beta_{12} \ln (Land_{it}) \ln (Indirect\ costs_{it}) + \beta_{13} \ln (Labor_{it}) \ln (Production\ costs_{it}) + \beta_{14} \ln (Labor_{it}) \ln (Indirect\ costs_{it}) + \beta_{15} \ln (Production\ costs_{it}) \ln (Indirect\ costs_{it}) + v_{it} - u_{it}$$

Technical inefficiency effects are defined by

$$u_{it} = \delta_0 + \delta_1 (Membership\ in\ Producer\ organization) + \delta_2 (Specialization\ level) + \delta_3 (Soil\ bonitet) + \delta_4 (Rainfall\ quantity) \qquad (3)$$

Likelihood ratio (LR) tests are performed to test hypothesis that there is no technical inefficiency (u_{it} = 0). Three hypotheses are formulated in order to be studied the effect from membership in producers' organizations:

1. H_0: "There is no technical inefficiency in the formulated empirical model."

In the Cobb-Douglas production function land variable includes arable land; labor variable is the total number of hired seasonally and full-time workers; production costs are represented by the value of the expenses made in the farm; indirect costs are organized by the organization itself - value of the fertilizer, manure, pesticides, machinery, marketing and administrative expenses.

2. H_0: "The technical inefficiency level of the *i*-th producer is not relevant to the inefficiency coefficients of the variables in the empirical model.

The formulated translog production function in (2) accounts for technical change and time-varying technical inefficiency effects. The variable *year* in the model specifies that joining producers' organization has direct influence over inefficiency effects.

3. H_0: "Membership in producers' organizations, specialization level, soil bonitet and rainfall quantity have no influence over technical inefficiency."

The values of the two parameters σ^2 and $\gamma (gamma) = \sigma_u^2 / \sigma^2$ are associated with the variances of the random variables v_{it} and u_{it} in the inefficiency model (3).

Data Envelopment Analysis (DEA) is a deterministic approach based on linear programming techniques. This approach introduces a piecewise linear envelopment of the data and constructs a best-practice frontier. Regarding the existence of random error DEA is very sensitive because any random error is counted as difference in efficiency. In this present analysis is used input-oriented variable returns to scale (VRS) DEA model (Färe, 1994):

$$min_{\theta\lambda}\theta \quad (5)$$

$$s.t. \quad -q_{it} + Q\lambda \geq 0$$

$$\theta x_{it} - X\lambda \geq 0$$

$$I_1'\lambda = 1$$

$$\lambda \geq 0,$$

where input and output vectors are presented by vectors x_{it} and q_{it}, respectfully for the *i*-th producer in the *t*-th time period. The data for all of the producers is denoted by input matrix X and output matrix Q. The input technical efficiency is represented by θ and has value $0 \leq \theta \leq 1$. Applying DEA is bound to preliminary condition that technical efficiency is a relative measure, because producer's technical efficiency is relative to other producers in the sample.

The inputs used to measure technical efficiency are: *land* - agricultural land under usage by producers, members of producers' organizations; *labor* - the number of workers, employed in a farm; *production costs* - value of expenses made in the farm; *indirect costs* - value of the fertilizer, manure, pesticides, machinery, marketing and administrative expenses in the organization. Output is represented by gross value of production by each producer and sales revenue.

Results from applying Stochastic Frontier Analysis

The present research includes data of 130 agricultural producers, members in producers' organizations that are registered in South Central and South Eastern planning regions. Maximum likelihood estimates are obtained using computer program Frontier 41 by Tim Coelli (Coelli, 1998). The upper boundaries for mixed χ^2 distribution are employed from Kodde and Palm (Kodde, Palm, 1986).

The first null hypothesis H_0 is given by Cobb-Douglas technology and implies that there is no technical inefficiency in the empirical model. The results show technical efficiency coefficients in the range between 0.530 and 0.586. The hypothesis is rejected for the four years and this means that the additional parameters of the translog function, compared to the Cobb-Douglas function will bring significant additional information about scale economies between producers.

The second hypothesis states that there is no relation between coefficients of technical inefficiency of the farmers and coefficients of technical inefficiency of the 15 parameters included in the translog model. The hypothesis is accepted for the first two years in the analysis. A conclusion can be drawn that production behavior of the farms could be adequately described by the translog function. The proportion of the inefficiency effect on the total variability of the random effect is given by the estimates of the γ parameters that are close to 1 and shows that the total variability is explained essentially by the technical efficiency. For the last two years the null hypothesis is rejected and ordinary least-squares estimates are accepted.

According to the third null hypothesis coefficients of the explanatory variables in the inefficiency model (3) have no influence over technical efficiency of the producers. For the four years in the analysis the null hypothesis is rejected. This means that the joint effect of the coefficients associated with membership in the producers' organizations, specialization level, soil bonitet and rainfall is significant, although the individual effects of the variables may not be statistically significant. This implies that there is positive effect and strong relation between technical efficiency of the farmers and variables in the inefficiency model. The main tool used for the production technology is partial output elasticities. This way is represented to what extent of the proportional input change, keeping the other inputs constant is decisive for the proportional change in the output quantity and returns.

TABLE 1. OUTPUT ELASTICITIES AND RETURNS TO SCALE

	2005	2006	2007	2008
Partial output elasticities				
Land	0.039	0.035	0.037	0.038
Labor	0.079	0.087	0.040	0.037
Direct expenses	0.316	0.377	0.303	0.298
Indirect expenses	0.207	0.371	0.503	0.480
Scale elasticities	0.641	0.870	0.883	0.853

Source: own estimations

The magnitudes of the output elasticities presented in the Table 1 indicate that the utilized proportional change of direct and indirect expenses have the highest proportional contribution to the production and revenue generation when keeping other variables constant. This implies that expenses arranged by producers' organization such as seed, chemicals, fertilizers, have positive effect on the efficiency of its members. Although the investigated period is medium-term oriented there is a pronounced tendency for more than 50% increase of the elasticity of indirect expenses. The output elasticities with respect to land and labor imply that the proportional increase of these variables results in a relatively low proportional increase in production and revenue. The low average values running up to 0.050 for land and 0.069 for labour indicate low capacity utilization of these inputs. Regarding the scale elasticities represented in Table 1, the sum of production elasticities is less than one. The proportional increase of all input will result in a lower proportional increase of revenue thus the production extension is not required. The producers are not achieving the scale optimum although there is a tendency for increase of the scale elasticities.

Results from applying Data Envelopment Analysis

Table 2 presents the average slacks for each input for the total technical efficiency. As can be seen from Table 2 the most inefficiently used input is labor. For the first year labor could be unproportionally decreased by 6%.

TABLE 2. AVERAGE SLACK FOR INPUTS (%)

	2005		2006		2007		2008	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
				Inputs				
Land	0.78	-	2.27	3.69	2.27	-	2.27	-
Labor	5.92	11.70	23.14	31.86	36.20	33.90	36.30	32.80
Production costs	0.01	0.21	-	-	-	-	-	-
Indirect costs	0.01	0.21	-	-	-	-	-	-
				Output				
Gross value of production	8.37	6.37	19.95	-	14.00	-	14.00	-
Sales revenue	0.03	0.19	-	0.69	-	13.00	-	13.00

Source: own calculations

TABLE 3. INPUT EFFICIENCY COEFFICIENTS

	2005		2006		2007		2008	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
Land	0.67	0.72	0.78	0.74	0.80	0.64	0.77	0.60
Labor	0.31	0.70	0.20	0.68	0.64	0.68	0.20	0.65
Production costs	0.80	0.82	0.88	0.89	0.80	0.80	0.87	0.76
Indirect costs	0.80	0.82	0.88	0.89	0.80	0.80	0.87	0.76

Source: own calculations

TABLE 4. EFFICIENCY COEFFICIENT ACCORDING TO THE FARM SIZE

	2005		2006		2007		2008	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
				Land				
>5 ha	0.671	0.924	0.548	1	0.517	1	0.52	1
<5 ha	0.715	0.716	0.777	0.745	0.806	0.636	0.787	0.623
				Labor				
>5 ha	0.681	0.685	0.865	0.865	0.865	0.865	0.865	0.865
<5 ha	0.314	0.314	0.204	0.684	0.164	0.68	0.165	0.68

Source: own calculations

TABLE 5. EFFICIENCY COEFFICIENTS ACCORDING TO THE FARM OWNERSHIP TYPES

	2005		2006		2007		2008	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
				Land				
Partnership	0.478	0.689	0.556	0.556	0.721	0.920	0.730	0.897
Individual producers	0.671	0.716	0.777	0.745	0.797	0.635	0.787	0.731
				Labor				
Partnership	0.725	0.625	0.458	0.96	0.455	0.672	0.455	0.672
Individual producers	0.314	0.704	0.204	0.684	0.164	0.68	0.165	0.680

Source: own calculations

For the next three years the average percentage of labor that could be decreased and still achieve the same output is 25.4%. There are insignificant opportunities to unproportionally decrease the utilized land and the two categories of the costs without bearing negative results for the released production and sales revenue. Results from applying variable returns to scale (VRS) DEA model show that there is a potential to increase percentage of sales revenue.

Results from sensitivity analysis of the inputs are presented on Table 3.

Efficiency coefficients of production and indirect costs take values from 0.80 to 0.88 under assumption for constant returns to scale (CRS) and from 0.79 to 0.88 under assumption for variable returns to scale (VRS). Membership in producers' organizations is an opportunity for producers to adjust the usage of their inputs. The results indicate positive relation between producers' membership and relative share of producers' costs. There is a possibility to decrease the two categories cost with average 17% and still achieve the same output.

Under common definition "members in organizations" there are presented different farm types according to their size and ownership. In order to be studied the influence of institutional factors analysis is decomposed into two separate levels. The relation between size of the arable land and the efficiency coefficient is developed on the first level; and on the second level the criterion for studying producers is their form for ownership.

Efficiency coefficients of land and labor for each producer in the sample are presented by there relation with the best-practice frontier (Table 4). Under assumption for constant returns to scale the farmers with arable land less than 5 ha can decrease the used land with average 34% and still achieve the same level of the output. This suggests that intensive production technologies are not necessarily resulting in increasing of the final output. Applying variable returns to scale model results that the largest farms are more efficient.

TABLE 6. TECHNICAL EFFICIENCY COEFFICIENTS

	$DEA_{/CRS/}$	$DEA_{/VRS/}$	SFA
2005	0.884	0.914	0.733
2006	0.895	0.919	0.734
2007	0.908	0.938	0.878
2008	0.906	0.866	0.810

Source: own calculations

Labour is the other main factor that is studied in it's relation to efficiency. Values of the efficiency coefficients of labour for producers with arable land less than 5 ha significantly decreases from 0.31 for the first year to 0.16 for the year 2008. For the largest farmers the tendency is contrary and the efficiency coefficient increases with 21% for the whole period. Incensement of the land efficiency coefficients results in increasing of labor efficiency coefficients under assumption of variable returns to scale. The results show that the share of the hired labor has significant influence on technical efficiency.

On the second level of the analysis producers are divided in two categories - individual producers and partnership (Table 5).

The commonly accepted view that family farms are more efficient than wage-labor farms because of the lower transaction costs could be supported by the results. The values of the labor efficiency coefficients are decreasing for the period under assumption for constant and variable returns to scale. Under assumption for variable returns to scale for the both categories values of labor efficiency coefficients are close for the last two years of the period.

Conclusion

There are several positive signals about the future and the role of producers' organizations. The results from Stochastic Frontier analysis and Data Envelopment analysis indicate relatively high technical efficiency coefficients (Table 6).

Results from DEA under assumption for constant and variable returns to scale show very low technical inefficiency level, varying between 0.11 and 0.06. SFA results define this coefficient between 0.13 and 0.27. The difference between results is due to the different treatment of the standard error term according to the methodology of the two analyses. Producers' organizations show a satisfactory efficiency level, their productivity rose over analyzed period that might suggest managerial efficiency and technological improvements. These results indicate that the producer organizations increase their competitiveness and follow the continuous changes in consumption model by improving managerial capabilities and by investing in technology.

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