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TECHNOLOGICAL AND TECHNICAL CHANGES OF AGRICULTURAL PRODUCTION IN SERBIA

SUMMARY

In this paper, the authors use the DEA methodology for the evaluation and analysis of the total technical efficiency (TE), which includes pure technical efficiency and scale efficiency, which is the result of all sizes of business. Changes in the TE were analysed using Malmquist's productivity index. This change can be broken down into the change of technical efficiency and technological change (innovation), and change in technical efficiency in itself involves changing of pure technical efficiency and scale efficiency. In the present study, data from 16 areas in Serbia were used, for data were available on investments in agriculture. The aim of this study was to analyse whether there is a technological change in these areas.

Key words: DEA methodology, Malmquist's index of productivity, technical efficiency, scale efficiency, technological changes

INTRODUCTION

Various methods are used to analyse the productivity of business and its changes during a certain period of time. The idea for defining the limits of efficiency was proposed by Farrell (1957) and since then different techniques have been used to calculate or estimate the efficiency limits. They can be classified into two groups: parametric, which are based on econometric evaluation of stochastic limit, and nonparametric, which are based on mathematical programming techniques.

The DEA (data envelopment analysis) methodology has the highest application among non-parametric methods. Its advantage, compared to parametric methods, is the fact that it is not based on assumptions about the functional relationship between inputs and outputs, as is the case with regression analysis, but it analyses the efficiency limits. In addition to determining the technical efficiency (TE) and the analysis of changes in inputs/outputs, ranking of organizations is used for its improvement, the calculation of the index for the change of efficiency coefficients, etc.

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Malmquist's productivity index (MPI) was introduced by Caves et al. (1982b). They showed that under certain conditions it is equivalent to Törnqvist's index. Färe et al. (1994) submitted in detail the methodology for calculating MPI directly based on distance function and its relationship with TE defined by Farrell (1957). For this they used the DEA output-oriented model. In addition, they explained in detail its decomposition in the technical and technological components. They used the geometric mean of the two MPI. They found that MPI is more general than Törnqvist's index because it provides inefficient performances and does not require knowledge of the functional form of the production technology. They analysed the productivity growth in 17 OECD countries during the period from 1979 to 1988 and showed the advantages and disadvantages of MPI compared to Törnqvist's index. Mohamad and Said (2012) analysed the technology changes in business in Malaysia. They analysed the change in the total technical efficiency of 106 companies in Malaysia for the period from 2008 to 2011 based on a single input (total cost of ownership) and six outputs (rates of change; turnover, profit and net assets and rates of return; turnover, profit and net assets expressed as a percentage). Based on the decomposition of the MPI, the authors concluded that the increase in total technical efficiency occurs primarily due to the growth of TE and not due to technological changes (innovations). Mohamad and Said (2012) also analysed the adoption and adaptation of small and medium-sized enterprises (SMEs) to the new technologies. They observed 42 selected economies (29 from EU countries and 13 from APEC countries) for the period from 2004 to 2008. The analysis used the input-oriented DEA distance function and MPI. For the purpose of calculating the efficiency coefficients, the observed countries were divided into three groups based on the similarity of their economies. The authors concluded that the changes of TE do not show growth in technological change, which is probably a consequence of the decrease of pure technical efficiency and scale efficiency. The SMEs were operating efficiently in only two countries.

METHODOLOGY

DEA non-parametric method is based on a linear programming model for evaluation of the efficiency limits. This method was proposed by *Charnes, Cooper* and *Rhodes* (1978) and model which they suggested was denoted with the *CCR*. According to this model, the multiple inputs reduced to a single 'virtual' input and multiple outputs are reduced to a single 'virtual' output using weights. Model for assigning weights is determined for each unit so as to maximize its efficiency on the condition that the weights must be non-negative values, and the ratio of 'virtual' input and 'virtual' output cannot be greater than 1.

Malmquist's Productivity Index (MPI) recommended by *Caves, Christensen* and *Diewert* (1982) is a productivity index based on the quotient of two distance functions. This index measures the change in productivity by comparing the observed changes in output and potential output, evaluated on the basis of production possibilities for the observed inputs. Its features are useful in empirical research because it can be used in situations where prices do not exist or when the current price has low economic impact, as used only for quantitative data and does not require assumption about efficient production. Furthermore, it can be decomposed into two components, one of which relates to technical changes, and the other on the technological changes. *Malmquist*'s index does not require any assumptions about the efficiency and functional forms.

Suppose that for each time period t = 1,2,..., T there is production technology $S^t = \{(x^t, y^t)\}$ that transforms input X^t to output Y^t. In period t, for each set of input / output corresponding to S^t, a function of distance *Färe*, R. (1988) exists for the output, which is defined as

$$D_O^t(x^t, y^t) = \inf\left\{\theta : (x^t, y^t/\theta) \in S^t\right\} = \left(\sup\left\{\theta : (x^t, \theta y^t) \in S^t\right\}\right)^{-1} = \theta^*$$

Thus defined distance function is the reciprocal value the 'maximum' possible change in output for the given inputs x^t and it fully characterizes the technology S^t. This function satisfies the condition $D_O^t(x^t, y^t) \leq 1$ only if it is $(x^t, y^t) \in S^t$. In addition, $D_O^t(x^t, y^t) = 1$ only if (x^t, y^t) is at the frontier of production possibilities of the observed technology, and it is only when the technology of production is efficiency. According to *Farrell* (1957), this means that the production is technically efficient, i.e. that the inputs are maximally used. For the definition of *Malmquist*'s index it is necessary to define a function of distance for comparison technology in period t with the technology in period $t+1$ as $D_O^t(x^{t+1}, y^{t+1})$. This distance function measures the maximum proportional changes in output (x^{t+1}, y^{t+1}). Those changes are possible with the technology in period t. If this point is outside the production possibility set in period t, then the technical change has occurred.

Output oriented *Malmquist* 's productivity index for technology in period t (S^t) is

$$MPI_O^t = \frac{D_O^t(x^{t+1}, y^{t+1})}{D_O^t(x^t, y^t)}$$

If $MPI_O^t > 1$ the productivity between periods t and t+1 is increased.
Other *MPI* can be defined if the technology from period t+1 (S^{t+1}) is used

$$MPI_O^{t+1} = \frac{D_O^{t+1}(x^{t+1}, y^{t+1})}{D_O^{t+1}(x^t, y^t)}$$

The output-oriented *Malmquist*'s index is calculated as the geometric mean of the two indices

$$MPI_O^{t;t+1} = \left[\frac{D_O^t(x^{t+1}, y^{t+1})}{D_O^t(x^t, y^t)} \cdot \frac{D_O^{t+1}(x^{t+1}, y^{t+1})}{D_O^{t+1}(x^t, y^t)} \right]^{1/2}$$

The expression for MPI_O can be divided as follows

$$MPI_O^{t;t+1} = \frac{D_O^{t+1}(x^{t+1}, y^{t+1})}{D_O^t(x^t, y^t)} \left[\frac{D_O^t(x^{t+1}, y^{t+1})}{D_O^{t+1}(x^{t+1}, y^{t+1})} \cdot \frac{D_O^t(x^t, y^t)}{D_O^{t+1}(x^t, y^t)} \right]^{1/2}$$

Term not in angle brackets characterizes the change of technical efficiency (*CTE*), i.e. how much are the observed outputs far from the manufacturing capabilities of their period

$$CTE_O = \frac{D_O^{t+1}(x^{t+1}, y^{t+1})}{D_O^t(x^t, y^t)}$$

The expression in angle brackets characterizes technological change (*CTH*)

$$CTH_O = \left[\frac{D_O^t(x^{t+1}, y^{t+1})}{D_O^{t+1}(x^{t+1}, y^{t+1})} \cdot \frac{D_O^t(x^t, y^t)}{D_O^{t+1}(x^t, y^t)} \right]^{1/2}$$

so it is $MPI_O = CTE_O \cdot CTH_O$

MPI_O with the value greater than one indicates an increase in productivity, and with the value less than one indicates the deterioration in productivity during the observed period. Naturally, the same applies to the change of its components, i.e. if $CTE_O > 1$ the technical efficiency is increased, and if $CTH_O > 1$ there is a technological advance in the use of observed inputs (education, skills, new technologies, investments, etc.). Of course, it is possible that $MPI_O > 1$ and that a single component can be less than one, while the other is greater than one. When $x^t = x^{t+1}$ and $y^t = y^{t+1}$ then there is no change in the inputs and outputs between periods, so it is $MPI=1$ In this case the components of efficiency measure are changing and they do not have to be equal to one because the change in technical efficiency can be counterweight to technological change *Färe, R.* and others (1994).

The *DEA* methodology can be used to calculate the *MPI*, *Färe, R.* and others (1985), and based on it is possible to follow the change in productivity of the observed *DMU* set during the time period *t*, *t* = 1,2, ..., *T*. To calculate the *Malmquist*'s *DEA* index it is necessary for each of DMU_k to calculate two measures for a single period $D_{Ok}^t(x_k^t, y_k^t)$ and $D_{Ok}^{t+1}(x_k^{t+1}, y_k^{t+1})$, and two measures for a combined period $D_{Ok}^{t+1}(x_k^t, y_k^t)$ and $D_{Ok}^t(x_k^{t+1}, y_k^{t+1})$. The output-oriented *CCR DEA* model is used for their calculation, taking into account that the output distance function is the reciprocal *Farrell* 's output measure of efficiency. For each DMU_k there are two linear problems to be solved for the observed period. For example, for *t*:

$$\left\{D_{Ok}^t(x_k^t, y_k^t)\right\}^{-1} = \max \theta_k$$

with constrains

$$\sum_{j=1}^{n}\lambda_j y_{rj}^t \geq \theta_k \cdot y_{rk}^t;\ r = 1,2,\ldots,s$$

$$\sum_{i=1}^{m}\lambda_j x_{ij}^t \leq x_{ik}^t;\ i = 1,2,\ldots,m$$

$\lambda_j \geq 0;\ j = 1,2,\ldots,n;\ \theta_k$ - has no constrains

There are also two models for the combined period, for example, for the reference technology in period *t* it is

$$\left\{D_{Ok}^t(x_k^{t+1}, y_k^{t+1})\right\}^{-1} = \max \theta_k$$

with constrains

$$\sum_{j=1}^{n}\lambda_j y_{rj}^t \geq \theta_k \cdot y_{rk}^{t+1};\ r = 1,2,\ldots,s$$

$$\sum_{i=1}^{m}\lambda_j x_{ij}^t \leq x_{ik}^{t+1};\ i = 1,2,\ldots,m$$

$\lambda_j \geq 0;\ j = 1,2,\ldots,n;\ \theta_k$ - has no constrains

With variable scale (VRS) further restriction $\sum_{i=1}^{m}\lambda_j = 1$ should be added.

In the case of mixed periods, it can be obtained that the function of distance is greater than one, because (x_k^{t+1}, y_k^{t+1}) do not belong to technology S^t so it does not have to be below the efficiency limit for period t.

For each period and for each DMU_k , the scale efficiency (*SE*) can be calculated as the quotient of distance functions obtained by *CCR* and *BCC* model. Efficiency changes can be calculated as the ratio of the distance function for that period using a variable response. Changes of technical efficiency can be calculated as the quotient of distance functions obtained by *CCR* model.

$$SE_{Ok}^t = \frac{D_{Ok}^t(x_k^t, y_k^t)_{CCR}^*}{D_{Ok}^t(x_k^t, y_k^t)_{BCC}^*} = \frac{TE_{Ok}^t}{PTE_{Ok}^t}$$

$$CTE_{Ok}^t = \frac{D_{Ok}^{t+1}(x_k^{t+1}, y_k^{t+1})_{CCR}^*}{D_{Ok}^t(x_k^t, y_k^t)_{CCR}^*} = \frac{SE_{Ok}^{t+1} \cdot PTE_{Ok}^{t+1}}{SE_{Ok}^t \cdot PTE_{Ok}^t}$$

The index CTE_O can be decomposed, *Färe, R.* (1988), to the change of pure technical efficiency ($CPTE_O$) and the change of the scale efficiency (CSE_O), so the *Malmquist*'s index can be written as follows

$$MPI_{Ok} = CPTE_{Ok} \cdot CSE_{Ok} \cdot CTH_{Ok};\ k = 1,2,..n$$

EMPIRICAL IMPLEMENTATION

The data analyzed in this paper refer to the 16 areas in Serbia for the period from 2008 to 2011. The paper includes the areas in which there was investment in new fixed assets in 000RSD in agriculture. Data were obtained from the Statistical Office of the Republic of Serbia.

Due to lack of investment in some years, the following areas: Macvanska, Raska, Sumadijska, Jablanicka, Pirotska, Pcinjska, Zlatiborska, Borska i Zajecarska were not included in the analysis.

The study focused on three inputs and one output

–I1- the ratio 'employed in the agricultural sector' and the 'active population' in %;

–I2 - utilized agricultural area (*ha*) (fields and gardens; orchards and vineyards; meadows);

–I3 - investment in new fixed assets in the 000RSD per unit of used arable land;

–O1- natural production expressed in units of wheat *(t*) (wheat, corn, sugar beet, sunflower, beans, potatoes, clover, alfalfa, meadows, pastures, apples, plums, grapes).

The coefficients in Table1. are used for translation of production into natural indicators expressed in units of wheat (Munćan, Živković, 2004).

Table1. The coefficients for translation into wheat units

Product	Coefficient
Wheat	1,00
Corn	1,00
Sugar beet	0,25
Sunflower	2
Soy	1,50
Grains(all kinds)	1,00
Potatoes	0,25
Beans	1,20
Stone fruit	0,25-0,50
Fruit(average)	0,25
Raspberries,blackberries, currants	0,75
Meat (live weight)	6,00
Milk	0,30
Hay, clover, alfalfa	0,5
Pasture, meadows less	0,33

The averaged data for the observed period are given in Table 2. and the descriptive statistics of the observed inputs and outputs per year are given in Table 3.

Table 2. Averages inputs and outputs from 2008 to 2011

DMU	*I*1	*I*2	*I*3	*O*1
Belgrade	0,5525	213766	6,34925	499362,1
West Backa	2,46	200598,5	7,564	972869,6
South Banat	1,9625	336142	1,87475	1382418,0
South Backa	1,57	320192,3	5,56275	1248603,0
North Banat	1,68	203480,8	0,91625	695444,8
North Backa	2,22	159158,8	4,919	787652,3
Central Banat	2,09	274351,8	2,7875	1038670,0
Srem	1,225	254465,8	3,074	1051266,0
Kolubara	0,5675	170205,8	0,66775	240935,9
Moravica	0,575	179334,8	0,0645	193079,0
Pomoravlje	0,595	163132,5	0,513	380878,7
Rasina	0,4775	162349	0,15225	308220,2
Branicevo	0,6875	239911	0,20525	466931,4
Nišava	0,3225	173379	0,03725	239800,6
Podunavlje	0,3875	102112,3	0,2635	272999,9
Toplice	0,635	117140,5	0,01225	117496,1

Source: *These data were obtained as the result of author's calculations of the original data from the Statistical Office of the Republic of Serbia, Belgrade and from the State Statistics of Municipalities in Serbia 2008-2011, by Statistical Office of the Republic of Serbia, Belgrade*

Table 3. Descriptive statistics from 2008 to 2011

Year		*I*1	*I*2	*I*3	*O*1
2008	Max	2,78	336425	25,816	1257546
	Min	0,41	102479	0,001	121139,9
	Average	1,2775	204271,7	4,123438	598575,5
	SD	0,801261	64373,04	6,47847	378198,9
2009	Max	2,44	336127	10,358	1316435
	Min	0,37	102059	0,002	121532,8
	Average	1,17375	204428,3	2,117375	603450,4
	SD	0,727589	64031,4	3,00631	370275,8
2010	Max	2,26	336008	4,928	1553177
	Min	0,35	101870	0,006	119516
	Average	1,090625	204449,8	1,363813	642332,3
	SD	0,681776	64316,73	1,535229	425616,7
2011	Max	2,36	336008	3,575	1402512
	Min	0,16	102041	0,001	107795,7
	Average	0,96	204280,4	1,136188	629798,6
	SD	0,70382	63987,76	1,270663	421271,6

The geometric mean for *Malmquist*'s index and its components is given in Table 4.

Table 4. The average of the calculated coefficients for the period from 2008 to 2011

DMU	MPI	CTH	CTE	CPTE	CSE
Belgrade	1,110569	1,116041	0,995095	1,000001	0,995097
West Backa	1,064198	1,064199	1	1	1
South Banat	1,082073	1,082073	1	1	1
South Backa	1,099337	1,081727	1,016279	1	1,016285
North Banat	1,118812	1,063692	1,051818	1,031014	1,020175
North Backa	1,016933	1,019675	0,997311	1	0,997311
Central Banat	1,054487	1,066908	0,988362	0,989603	0,998746
Srem	1,094609	1,094689	0,999927	1	0,999927
Kolubara	1,105185	1,107606	0,997813	0,999675	0,998136
Moravica	1,071178	0,944208	1,134475	1,146038	0,989907
Pomoravlje	1,261575	1,175199	1,0735	1,070705	1,002614
Rasina	1,050969	1,001178	1,049732	1,046461	1,003127
Branicevo	0,904337	0,960561	0,941476	1	0,941476
Nisava	1,154957	1,154958	1	1	1
Podunavlje	1,198173	1,198171	1,000003	1,000003	1
Toplice	0,982189	0,895806	1,096432	1	1,096427
Mean	1,061034	1,020359	1,017006	1,003297	1,082635

Based on the *MPI* it can be concluded that in all areas there was an increase in productivity except Branicevo and Toplice. This increase ranged from 1.7% in North Backa to 26% in the Pomoravlje. For Branicevo it was reduced by 10% and in Toplice by 2%. The 11 fields have *MPI* index above average. Large differences in labor productivity (0.90 to 1.26) were a consequence of economic changes and business orientation in the past. At the moment this is a problem that must be solved at level of the whole state because the balanced development is a prerequisite for economic stability.

When analyzing the changing of components of *MPI* it can be noted that in some areas there was a technological changes with reduced technical efficiency, such as Beograd, North Backa, Central Banat and so on, while in others there has been technological change and increased technical efficiency as South Backa, North Banat, etc. In areas West Backa, South Banat and Nisava there was only technological change, and the overall technical efficiency remained the same. Deeper study would confirm the hypothesis that after technological changes and restructuring of farms and companies in the food industry there is increased intensity of production and labor productivity (very small differences of *MPI* and *CTH*).

In Toplice area technical efficiency increased by 9.6%, but due to the reduction of technological changes the total productivity decreased by 2%. In this district the largest business systems stopped working and made a technological step backwards since private farms with limited resources cannot maintain the level of production from the previous period.

It is similar in Branicevo administrative district. Lower values for all indicators (the only district with all negative values) were also consequence of the structure of production. This district used to be recognizable as an area with developed food industry which, apart from some exceptions, stopped working some ten or more years ago. This pulled with them large farms, and caused a decrease in agricultural production, migration and refocused investments in other areas.

Total Technical efficiency was increased in 6 areas. The most in Moravica, by 13.47%, and lowest in the South Backa by 1.6%. In all other areas the total technical efficiency was unchanged or insignificantly reduced. The greatest decline was in the area Branicevo by 7.86% and Central Banat area for 1.2%.

Regarding the change in pure technical efficiency and scale efficiency in some areas, such as South Backa, North Backa, Srem, Branicevo and Toplice, pure technical efficiency (*PTE*) was not changed, only scale efficiency (*SE*).

CSE values indicate negative trends in 9 administrative districts. If one takes into account that the number of employees in agriculture decreased, that the used agricultural area is reduced, then the only solution is to increase investments. In the present circumstances only a small number of agricultural enterprises and farms are capable to invest, especially from their own sources. Huge financial expenses that would be incurred based on borrowed capital would further burden the production so that the solution for the crisis must be sought in cooperation with other enterprises or state measures that should take into account specificities of agricultural production.

Trends in total productivity and other specified components must be considered not only from the point of inputs in the study period, but in a slightly longer period. Probably the best example is the North Banat because the investment in the period before 2008 provided a good basis to achieve good results. Besides, reducing the number of workers in agriculture with undiminished capacities logically leads to increased productivity.

It is interesting that for all the indicators the mean is more than one, so that for the observed areas in the period from 2008 to 2011 productivity increased by 8%, while the technological change increased by 6.1% and the technical efficiency by 2.04%. Increase in total technical efficiency is the result of increase of pure technical efficiency by 1.7% and scale efficiency by 0.33%.

CONCLUSIONS

In this paper we analyzed the changes in productivity in 16 areas in Serbia who had investments in the period from 2008 to 2011.The geometric mean of *Mulmqust*'s productivity index and its components was used in analysis. Productivity increased in 14 districts, but technological changes that have been noted in most districts were not followed by increasing technical efficiency. The current situation requires a wide range of measures to change the business environment and create conditions for greater investment in agriculture, which would result in greater output in physical and value terms.

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TEHNIČKE I TEHNOLOŠKE PROMENE POLJOPRIVREDNE PROIZVODNJE U SRBIJI

SAŽETAK

Predmet ovog rada je korišćenje DEA metodologija za ocenu i analizu ukupne tehničke efikasnosti (*TE*) koja u sebi uključuje čistu tehničku efikasnost (*PTE*) i skala efikasnost (*SE*) koja je posledica različitih obima poslovanja. Promene ukupne tehničke efikasnosti (*CTE*) analizirana je korišćenjem *Malmqust*-ov indeksa produktivnosti (*MPI*). Ova promena može se dekomponovati na promenu tehničke efikasnosti (*CTE*) i tehnološku promenu (inovacija) (*CTH*), a promena tehničke efikasnost u sebi uključuje promenu čiste tehničke efikasnosti (*CPTE*) i promenu skala efikasnost (*CSE*). U radu su korišćeni podaci 16 oblasti u Srbiji za koje postoje podaci o investicionim ulaganjima u poljoprivredu. Cilj rada je da se analizira da li postoji tehnološka promena u ovim oblastima.

Ključne reči: *DEA* metodologija, *Malmqust*-ov indeks produktivnost, tehnička efikasnost, skala efikasnost, tehnološke promene