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EVALUATION OF TOTAL FACTOR PRODUCTIVITY CHANGE IN SERBIAN FARMS

PROMENA UKUPNE FAKTORSKE PRODUKTIVNOSTI POLJOPRIVREDNIH GAZDINSTAVA U SRBIJI

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ABSTRACT

The main aim of the research is to examine the productivity change across farms with different types of production. The study focuses on family farms in the Republic of Serbia that were part of the FADN (Farm Accountancy Data Network) sample over a seven-year period (2015-2021). The Malmquist index is used to calculate the total factor productivity (TFP) change during the observed period, in conjunction with previously applied Data Envelopment Analysis (DEA). The defined model is output-oriented with constant return to scale. On the output side, it considers total output value (crop, livestock and other outputs), while the input side includes multiple variables: labour input, utilised agricultural area, intermediate consumption and total assets value. The research results have shown that the total factor productivity of the observed farms increased by 8.0% over the analysed seven-year period. The increase in farm productivity ranges from 0.3% in specialist permanent crops (vineyards and fruits) to 11.8% in specialist field crops. All farming types experienced technical progress, but field crop farms have definitely benefited the most. Field crop farms consistently acquire new and modern equipment, enabling them to achieve better outcomes with the same inputs. This undoubtedly has a positive impact on farm productivity, eventually increasing the overall economic viability of farms.

Key words: *total factor productivity, economic viability, family farms, type of farming, FADN.*

REZIME

Cilj istraživanja je da se realno sagleda i oceni promena u produktivnosti poljoprivrednih gazdinstava različitih tipova proizvodnje. U fokusu istraživanja su porodična poljoprivredna gazdinstva u Republici Srbiji, koja su bila deo FADN (Farm Accountancy Data Network) uzorka tokom sedmogodišnjeg perioda (2015-2021). Promena u ukupnoj faktorskoj produktivnosti tokom posmatranog perioda iskazana je pomoću Malmquist indeksa, uz prethodnu primenu DEA metoda (Data Envelopment Analysis). Definisani model je izlazno orijentisan sa konstantnim prinosom na obim. Na strani autputa je vrednost proizvodnje (biljne, stočarske i ostale), dok na strani inputa figurira više varijabli: korišćena radna snaga, ukupno korišćeno poljoprivredno zemljište, ukupna međufazna potrošnja i ukupna imovina poljoprivrednog gazdinstva. Rezultati istraživanja pokazuju da je ukupna faktorska produktivnost posmatranih gazdinstava povećana za 8,0% u analiziranom sedmogodišnjem periodu. Povećanje produktivnosti gazdinstava varira od 0,3%, koliko je zabeleženo u voćarstvu i vinogradarstvu, do 11,8% zabeleženih u ratarstvu. Svi tipovi proizvodnje su ostvarili tehnički progres, međutim ratarska gazdinstva definitivno prednjače u ovome. Ratarska gazdinstva konstantno pribavljaju novu i savremeniju opremu, koja im omogućuje ostvarivanje boljih autputa uz nepromenjeno ulaganje inputa. Ovo naravno pozitivno utiče na ostvarenu produktivnost gazdinstava, što, na koncu, podiže nivo ukupne ekonomske održivosti gazdinstava.

Ključne reči: *ukupna faktorska produktivnost, ekonomska održivost, porodična gazdinstva, tip proizvodnje, FADN*

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INTRODUCTION

Agriculture is currently perceived as unattractive, with a noticeable decline in interest in agricultural work, mainly due to the low average income of farmers. Meanwhile, small family farms, which are the most prevalent, face challenges in competing with larger farms in the market. For this reason, ensuring a fair income for farmers and increasing competitiveness are identified as key objectives of the Common Agricultural Policy (CAP). Achieving these goals is also very important for ensuring the economic viability of farms, which is the main pillar of sustainable agriculture in developing countries.

The agricultural sector in Republic of Serbia (RS) faces challenges related to land reform, farm structure development, and modernization, similar to other countries in Eastern Europe that operating within transitional economies (*Baležentis, 2015*). Farm productivity is at relatively low level (*Miljatović et al., 2022*), considering business conditions and the available resources for agricultural production. Family farms, as the most dominant entities in agriculture, need to improve their efficiency and productivity in order to continue developing. This can be achieved through better utilization of the available factors of production.

Improving efficiency of production, i.e. increasing productivity levels, undoubtedly has positive implications for economic outcomes, farmers' average income, and the overall economic viability of farms. Therefore, it is crucial to enhance the productivity growth on farms and analyse the potential for further increasing their productivity levels. There are multiple approaches to measuring changes in total factor productivity (TFP). If prices are available, Laspeyres, Paasche, Fisher, Törnqvist or Hicks-Moorsteen index can be calculated (*Czyzewski & Majchrzak, 2017; Balk et al., 2020*). Conversely, the Malmquist index does not require data about prices (*Coelli & Rao, 2005*), making it widely used for calculating TFP change in agriculture (*Balcombe et al., 2008; Baležentis & Baležentis, 2016; Le et al., 2019*).

Malmquist indices are calculated using Data Envelopment Analysis (DEA) to assess technical efficiency. DEA, as a non-parametric efficiency analysis, is commonly used for evaluating technical efficiency and productivity of farms. Nevertheless, it is

not sufficient to provide decision-makers with comprehensive information about the productivity changes. In this regard, it is crucial to use the Malmquist index.

The main aim of the paper is to examine the productivity change across farms with different types of production. Additionally, by quantifying specific changes, potential agricultural policy measures could be recommended to further improve the productivity levels of farms. The paper is organised as follows. The following section presents the data and the methodology applied. Subsequently, the research results are presented, followed by a discussion. Finally, the main conclusions and recommendations are summarized in the last section.

MATERIAL AND METHOD

The analysis was conducted on Serbian farms included in FADN (Farm Accountancy Data Network) sample throughout the entire seven-year period from 2015 to 2021. The study focuses on family farms, with a total of 543 farms examined. This makes a balanced panel dataset consisting of 3,801 observations.

To analyse the productivity change, farms were divided according to type of farming (TF) into: (1) specialist field crops, (2) specialist horticulture, (3) specialist permanent crops (vineyards and fruits), (4) specialist milk, (5) specialist grazing livestock – other grazing livestock, and (6) mixed. These six farming types are dominant in RS, representing approximately 99% of all commercial farms[1] (*www.stat.gov.rs*). Unlike the official classifications based on European Union (EU) regulations (*www.ec.europa.eu*), the granivores type of farming was excluded. The main reason for excluding granivores, aside from the low share, is the specific nature of the production that is closer to industrial processes (*Coppola et al., 2022*).

Farms were also analysed at the regional level, following the nomenclature of territorial units for statistics (NUTS). This means that farms were divided into Serbia North, which includes the Belgrade region and the Autonomous province of Vojvodina, and Serbia South, which includes Šumadija and Western Serbia, as well as Southern and Eastern Serbia.

To determine changes in total factor productivity of farms, the Malmquist index was calculated. The Malmquist TFP index calculates changes in productivity by establishing the ratio of the distance of each decision-making unit (DMU) to an efficiency frontier determined usually by DEA approach (*Coelli et al., 2005*). TFP is measured as the ratio of aggregate output to aggregate input for DMU. Accordingly, formula for calculating TFP in period *t* is as follows:

$$\mathrm{TFP_t} = \frac{\mathrm{Q_t}}{\mathrm{X_t}} \quad (1)$$

where Q_t is an aggregate output in period *t*; X_t is an aggregate input in period *t*; t = 1, 2, …, T is a respective time period.

Further, the Malmquist TFP index (output-oriented) can be calculated by comparing the TFP in period *s* with the TFP in period *t* (the base period) through the following formula:

$$\mathrm{M_0} = \frac{\mathrm{TFP_s}}{\mathrm{TFP_t}} = \frac{\mathrm{Q_s}/\mathrm{X_s}}{\mathrm{Q_t}/\mathrm{X_t}} \quad (2)$$

If the Malmquist TFP index is greater than one, it indicates progressive growth in TFP during the observed period. Conversely, a value less than one indicates decline in TFP. The TFP change calculated by the Malmquist index can be decomposed as an efficiency change (EC) and technical change (TC) (*Färe et al, 1994*), through the following formula:

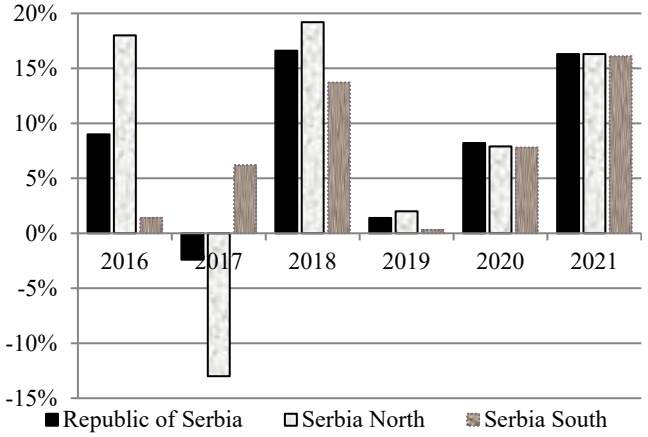
$$\mathrm{M_0} = \mathrm{EC} \times \mathrm{TC} \quad (3)$$

As mentioned above, the Malmquist TFP index is obtained based on Data Envelopment Analysis (DEA). DEA method was used to calculate an efficiency frontier, with total output value (crop, livestock and other outputs) on the output side, and total labour input, total utilised agricultural area, total intermediate consumption and total assets value on the input side. The model is output-oriented and assumes constant return to scale (CRS).

RESULTS AND DISCUSSION

The total output value, calculated as the sum of crop, livestock and others output, is used on the output side when assessing the technical efficiency of farms. Moreover, total utilised agricultural area as land factor, total labour input as labour factor, total assets value as capital factor, along with total intermediate consumption, appear as inputs in the calculation. The average total labour input was 1.95 annual working units (AWU). As expected, horticulture farms had the highest labour input, reaching 4.39 AWU. The average total utilised agricultural area was 36.47 hectares, with field crop farms having the largest average areas at 61.93 hectares. Bearing this in mind, it is evident that the analysed sample consists of relatively large farms in the context of domestic conditions.

The total factor productivity change of Serbian farms for the seven-year period from 2015 to 2021 was estimated using the Malmquist index. The average TFP index was 1.080, indicating that Serbian farms experienced an 8.0% productivity growth during the observed period. Figure 1 shows the Malmquist indices based on a comparison with the previous year. Regarding the TFP change in Serbian farms, the results obtained are quite unstable throughout the observed period. This significant variation in productivity change over the years is largely influenced by variable yields caused by unstable climatic conditions and socio-economic factors, primarily driven by fluctuating market conditions. In 2021, productivity increased by 16.3%, making it the second-best result after the one recorded in 2018 (16.6%). On the other hand, there was a 2.4% decrease in productivity in 2017, primarily due to a significant decline in the productivity of farms located in the northern region of Serbia. Subsequently, in the last four years, constant productivity growth has been recorded, ranging from 1.4% to 16.6%.



Source: Author's calculations based on FADN data

Fig. 1. Dynamics of the TFP change during the observed period

[1] Commercial farms in RS are defined as farms with a standard output value greater than 4,000 euros.

When observed regionally, farms located in Serbia North region generally record more significant productivity growth (*Fig. 1*). These farms experienced higher productivity growth than those in Serbia South in all years except for the aforementioned 2017. This is primarily due to the fact that Serbia North - Belgrade and particularly AP Vojvodina - is an agricultural area, meaning it has more favourable weather conditions, higher-quality agricultural land, as well as more experienced and knowledgeable workforce. Field crop farms are undoubtedly the most affected by the previously outlined characteristics (*Miljatović & Vukoje, 2024*). As the most dominant type of farming in domestic conditions, the results obtained from analyzing field crop farms definitely have a significant impact on overall economic outcomes.

The following Table 1 presents the TFP change across different farming types and. As shown, each type experienced productivity growth during the observed period. The most significant increase was observed in field crop farming, where productivity grew by 11.8%. The TFP growth of other farming types ranged from 6.0% to 9.3%, with the exception of permanent crop farms, where productivity increased by just 0.3%.

Table 1. The Malmquist index and its decomposition by farming type, 2015-2021

Type of farming	Efficiency change	Technical change	TFP change
Field crops	1.063	1.051	1.118
Horticulture	1.005	1.090	1.093
Permanent crops	0.957	1.049	1.003
Milk	1.015	1.046	1.060
Grazing livestock	1.014	1.048	1.061
Mixed	1.023	1.058	1.080
Mean	**1.027**	**1.051**	**1.080**

Source: Author's calculations based on FADN data

The TFP change can be divided into efficiency change and technical change. Only permanent crop farms exhibited a decrease in efficiency by 4.3%, which significantly contributed to their poor total factor productivity growth. All other farming types have improved their efficiency, reducing their gap to the observed production frontier, i.e. to the maximum output achievable for each input level (*Coelli et al., 2005*). It is important to keep in mind that this paper examines only family farms, which predominantly rely on their own labour - the farm manager and their family members. *Balcombe et al. (2008)* argue that a higher share of family labour contributes to total factor productivity growth, as family workers control resources and technology and, as the primary income beneficiaries, have a strong incentive to be more efficient and productive.

When it comes to technical change, all faming types, without exception, experienced technical improvement. Horticulture, mixed and field crop farms exhibit higher technological progress compared to milk and grazing livestock farms. This aligns with the findings of *Baležentis & Baležentis, 2016*, who observed that technical change primarily impacted crop and mixed farms based on a sample of farms in Lithuania. Also, *Cechura et al. (2015)* claim that technological progress is a significant driver of productivity growth in the cereal sector in the Czech agriculture. Conversely, farms that invest in old, second-hand machinery face high maintenance costs on the input side (*Davidova, et al., 2005*), which considerably limit their potential for productivity growth

Crop farms in general, and field crop farms in particular, utilize new and modern equipment, enabling them to achieve better production results with the same labour and other input. Unlike other types of farming, field crop farms have greater access to subsidy applications from domestic sources and, especially, European funds for investment in assets. This is primarily because these funds are predominantly intended for purchasing modern and more efficient machinery used in crop farming. Such support undoubtedly fosters productivity growth, ultimately contributing to the overall economic viability of farms.

CONCLUSION

The calculation of TFP change in agriculture is very important part of analysing the utilization of available resources. There is definitely room to improve the utilization of the main factors of production in Serbian agriculture through productivity growth. For this reason, calculating the Malmquist TFP index could be very useful in understanding the current situation and indentifying potential areas for improvement.

The current study has shown that the total factor productivity on Serbian farms increases by 8.0%. The obtained results are highly variable over the observed seven-year period, ranging from the lowest value in 2017 (a decrease of 2.4%) to the highest value in 2018 (an increase of 16.6%). Considering the type of farming, field crop farms recorded the highest productivity growth of 11.8%, which is partly a result of their technical improvement over the years. These farms consistently apply for asset funding, enabling them to use new and modern equipment and achieve better production results with the same inputs.

In domestic literature there are not many studies focused on measuring total factor productivity change in agriculture. One of the reasons for this has been the lack of the data from farms until recently. Nowadays, FADN database enables performing such analysis at the farm level and recognizing the main obstacles to improving economic outcomes. As said above, the situation on Serbian farms is not ideal, but there is potential for improvement through better technical equipment, more efficient utilization of land resources, especially in the southern region, and overall improved farm management. Farm managers, along with agricultural policymakers and other stakeholders, need to put in effort to upgrade agriculture to a qualitatively higher level.

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