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Decomposition of Total Factor Productivity in the dairy sector: Comparative analysis of Serbia vs European Union

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Abstract

Background: In the previous period, significant changes took place in the world dairy market, and this trend did not bypass Serbia either. Serbia is facing a decline in the number of farms engaged in milk production despite significant subsidies for this production by the state. On the other hand, the abolition of quotas in the European Union led to an increase in dairy production, which certainly had an impact on the international market.

Purpose: This paper attempts to do a comparative analysis of the dairy sector in Serbia and the European Union through the analysis of the decomposition of Total Factor Productivity. In this way, we try to look at the efficiency of production through Technical Efficiency Change, and potential technological progress will also be looked at through Technological Change.

Study design/methodology/approach: In this research, the Malmquist Total Factor Productivity index is used, which relies on the previous estimation of data envelope analysis. Data from the Farm Accountant Data Network is used for 25 countries of the European Union and Serbia for the period 2015-2021.

Findings/conclusions: Based on research, there is an increase in Total Factor Productivity in the sample at a rate of 3.1%. Serbia has experienced significant productivity growth in the dairy sector, largely attributed to the exit of small and inefficient farms from production. To further enhance productivity, policymakers in Serbia should promote investments that drive efficiency and encourage dairy producers to optimize resource utilization through improved knowledge and skills development.

Limitations/future research: It is necessary to observe factors that affect the dairy sector of Serbia and the European Union in more detail, so identifying the factors that contributed to Total Factor Productivity growth will be in the focus of the future research.

Keywords
Milk; Serbia; European Union; Total Factor Productivity; Technical Efficiency Change; Technological Change.

Introduction

Milk production in Serbia is about 1.5 billion liters, with cow's milk accounting for about 97% of the total milk production (SORS, 2024). Serbia's average milk production is double that of the average CEFTA countries but only 60% of the level seen in the EU's New Member States, and six times lower than the average production in the EU-15 countries (SEEDEV, 2020), while the average milk yield of cows in Serbia is far below the European average (Radisic et al., 2021). However, Serbia is on the verge of achieving self-sufficiency in milk production (Brankov & Matkovski, 2022), but the dairy sector is far from the most competitive segment of agricultural production. Milk production in Serbia is facing a decline in the number of dairy farms, low productivity, outdated equipment and infrastructure in which inadequate hygienic practices affect milk quality. On the other hand, incentives, which represent a significant expenditure of the agricultural budget, do not contribute to investments and development but are more of a social category, which is especially concerning given that milk production is important for the survival of many small farmers and their families (Hristov et al., 2023). In addition, it is necessary to consider the diverse conditions for production in different regions of Serbia, because regional competitiveness is reflected in the quality of local conditions (Krstić & Gawel, 2023). Exports of milk from Serbia have increased in recent years, (SORS, 2024), and in the previous period, Serbia predominantly exported milk to CEFTA countries, where it achieved comparative advantages in exports (Birovljev et al., 2015). Milk trade is quite volatile, that is, affected by the overall economic situation in the country, fluctuations in supply and demand, as well as other factors (Djordjevic et al., 2023). Numerous events have shaken the milk market in Serbia, causing concern: the aflatoxin contamination scandal, the processing industry's insufficient transparency in labeling milk origin, and farm protests over the unfavorable market position (Džever et al., 2024).

In the context of global milk production, it is undergoing an expansion and consolidation, and this sector faces increased criticism and competition from non-dairy alternatives (Bojovic & McGregor, 2023). Furthermore, global food systems can be significantly affected by the increase in consumption of alternatives to animal-based products (Sun et al., 2023). A period of turbulence is currently affecting global milk production as a result of the slowdown in Chinese demand for these products, the Russian trade embargo, and the process of abolishing EU milk quotas, which existed from 1984 to 2015. Namely, the abolition of milk quotas in the EU changed the EU market significantly, as evidenced by the increase in milk production in a small number of developed countries such as Ireland, Belgium and the Netherlands (SEEDEV, 2020). Changes in the milk market in the EU certainly have an impact on the international market, including the market in Serbia. The aim of this paper is a comparative analysis of the dairy sector in Serbia and the EU, through the observation of the decomposition of Total Factor Productivity (TFP). Consequently, the change in efficiency of the dairy sector can be seen, since TFP considers the efficiency of production factors, that is, Technical Efficiency Change (TEC). Furthermore, TFP gives a good insight into potential technological progress by looking at Technological Change (TC). This research aims to fill the gap in the literature, by offering a competent comparative analysis of TFP between Serbia and EU countries in the area of the dairy sector.

A significant number of papers are available in the literature regarding milk production sector in the EU. Small specialized dairy farms are relatively important in a large number of EU countries, (Spicka & Smutka, 2014), which must be taken into account when analyzing this sector. The study by Madau et al. (2017) investigated the technical efficiency and TFP change of dairy farms in EU countries after the relaxation of the quota system. The results of this research showed that there was a drop in productivity in the milk sector, and these authors concluded that external factors in the future may play a more significant role than efficiency itself in achieving productivity and profitability. Cechura et al. (2017) investigated the catching-up and lagging processes in the European dairy sector and concluded that the Eastern European countries achieve the lowest productivity in this sector, as well as the lowest level of TFP and TFP growth, and the authors suggested that farm size is not optimal in many Central and Eastern European countries. Another study dealt with the factors affecting the technical efficiency of dairy farms in the EU using Stochastic Frontier Analysis (SFA), and suggested that farms in the EU are relatively technically efficient, but since their size is not fully optimized there is potential to achieve a better result and improve competitiveness (Naglova & Rudinskaya, 2021). Authors Latruffe et al. (2017) investigated the effects of subsidies on the technical efficiency of farms engaged in milk production in the EU and concluded that depending on the country, subsidies have a positive, null, or negative effect on technical efficiency, depending on the analyzed country. These authors concluded that decoupling within The Common Agricultural Policy (CAP) in 2003 weakens the effect that subsidies have on technical efficiency.

Previous literature shows that there is not too much research done on analyzing the agricultural sector in Serbia from the aspect of TFP decomposition, both in terms of the entire agricultural production and specifically for the milk producers. When it comes to research on this topic from the perspective of entire agricultural production, most of the authors mainly deal with the issue of technical efficiency at the level of the entire agricultural production or a particular sector. The research done by Djokic et al. (2022), which examines the technical efficiency of agriculture in EU and Western Balkan countries using SFA, indicates a significant difference in technical efficiency between the countries of the Western Balkans and the EU. According to the same authors, exogenous factors do not have a significant impact on agricultural technical efficiency. Consequently, endogenous factors must be improved, which is a signal to policy makers in the Western Balkans countries to create policies that can improve agricultural efficiency. The authors Popovic et al. (2019) investigated the technical efficiency of Serbian farms in 2017 using the Farm Account Data Network (FADN) database and concluded that farms in the Serbia North region are on average more efficient than farms in the Serbia South region. Also, the same authors concluded that when it comes to livestock production, farms focused on poultry and pig production are more efficient. When it comes to dairy farms in Serbia, the authors Milic et al. (2023) investigated indicators of technical efficiency for 104 farms engaged in milk production for the period 2015-2021 using FADN data. They found high technical efficiency for the analyzed farms, and a negative effect of subsidies on the overall efficiency. The authors justify such tendencies with the type of domestic support for milk production, where premiums for milk dominate, while a very small part of the support is directed towards investments. On the other hand, the authors Tomić et al. (2020) analyzing the economic aspects of milk production in Serbia, concluded that small farms with a maximum of 9 dairy cows dominate, and that the limiting factors of increasing the number of cows are fragmentation of households and limited resources for animal feed production. According to the authors, the introduction of appropriate processing technologies for family farms, such as various types of cheese and other dairy products, could increase the value and profitability of milk production. When it comes to TFP, the authors Djokic et al. (2022) analyzed Malmquist productivity indices in Serbian agriculture through Data Envelopment Analysis (DEA) and concluded that the annual mean TFP change after 2008 is 5%. The authors explained this tendency by technical change affected by the European integration, as well as better application of innovations, and gave recommendations to policy makers to improve investments in research and development.

In reviewing the literature, a gap in analyses of this type can clearly be observed, i.e. there are no comparative analyses of TFP for the dairy sector for Serbia and the EU. It is clear that previous analyses were limited by a lack of data for analysis, which will now be overcome using the FADN. The importance of this analysis stems from the fact that in previous years the agricultural sector was faced with significant changes in input prices, and there were significant changes in the agricultural pattern (Andrei et al., 2022). Additionally, the methodology used in the research will be presented following the introduction with a literature review. The results of the research will be presented together with a discussion, after which certain conclusions will be presented with recommendations for policy makers.

2. Methodology

TFP is a measure of the efficiency of production factors such as land, labor and capital to which materials must be added, taking into account the level of production achieved. Furthermore, TFP is also often used as a measure of technological progress, since it quantifies the change in the production achieved due to the change in the used inputs. In this way, the calculation of TFP enables the comparison of the business success of different economic entities that use similar production technology or belong to the same economic activity (Caves et. al., 1982; Färe et al., 1994).

TFP is measured as the ratio of total realized output to the weighted average of input during the agricultural production process. Essentially, if the ratio of the realized output to the used inputs is greater than 1, it can be stated that the inputs are used in an efficient manner. In the economic literature, two basic approaches are distinguished when estimating TFP - parametric and non-parametric. The parametric approach is based on the principles of econometric modeling, where the assessment of realized TFP is most often performed on the basis of a stochastic frontier function model. On the other hand, the non-parametric approach is based on the principles of mathematical programming, where the DEA method and the calculation of the Malmquist TFP index are particularly distinguished (Kumbhakar et al., 2015).

In this paper, the Malmquist TFP index was used, bearing in mind that this method does not imply an assumption about the functional form of the production function. It contrasts the parametric approach, which avoids potential errors that may arise from high correlation between independent variables, which is characteristic primarily of the trans log production function. Additionally, the Malmquist TFP index, unlike the parametric approach, does not require separate data on prices per unit of used inputs and realized output, bearing in mind that based on the data used, these prices are not fully available. Also, the advantage of the Malmquist index is reflected in the fact that it does not imply the fulfillment of the assumption of constant returns to volume and enables comparative analysis between different production units in the time dimension, which is of particular importance with panel data (Fried et al., 2008). This method is widely used in the case of agriculture (most recently in Hu et al. (2024); Wan & Zhou, (2021)).

As already stated, the Malmquist TFP index relies on the previous estimate of the DEA model. The assessment of the DEA model implies the creation of an efficiency boundary by efficient production entities, while less efficient producers are below this boundary. In this regard, the Malmquist index is based on the comparison of the efficiency of production units between two time periods and includes two main components: TEC and technical progress (TC). Therefore, the Malmquist TFP index is calculated as the product of the previously mentioned two components (Färe et al., 1994):

$$Mo(y_s, x_s, y_t, x_t) = \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)} \left[\frac{d_o^s(y_t, x_t)}{d_o^t(y_t, x_t)}\right] \cdot \left[\frac{d_o^s(y_s, x_s)}{d_o^t(y_s, x_s)}\right]^{1/2}$$

If it is true that Mo>1, there is an increase in productivity, on the other hand, if Mo<1, it can be stated that productivity has decreased between the two mentioned periods.

The weighted FADN data of the EU27 countries (with the exception of data for Greece and Cyprus, which are not available) and the Republic of Serbia, for the period 2015-2021, were used as the basic data source in the analysis. In particular, the data used refer to farms specialized in dairy cattle breeding. The total value of production (SE131) expressed in EUR was used as a variable that represents the output. On the other hand, total work (SE011) in hours, used agricultural land (SE025) in hectares, depreciation value as a proxy variable for capital (SE360) in EUR and variable production costs (SE275) also expressed in EUR, were used as the variables related to production factors. The reason depreciation was used as a proxy variable for capital lies in the fact that depreciation serves as an indicator of the effective utilization of capital in the production process. Additionally, within the FADN sample, the definition of assets is not precisely specified, so it was decided to use the depreciation value, which represents the value of the capital utilized. On the other hand, variable costs, such as expenses for seeds, fertilizers, fuel, pesticides, and labor, have a direct correlation with the volume and type of production. Their inclusion allows for an analysis of how these costs are transformed into production outcomes. All the mentioned variables are divided by the number of dairy cows. Also, the variables expressed in EUR were converted into constant prices based on the HICP index. When evaluating the Malmquist TFP index along with its components, the statistical software R was used, while the Python software was used for the purposes of graphical presentation of the data.

3. Results and Discussion

As stated in the research, FADN data related to the EU27 countries (except Greece and Cyprus) and the Republic of Serbia were used. Table 1 presented below shows the results of descriptive statistics for the used variables by conditional head of dairy cows and by countries that are the subject of research. The coefficient of variation (CV) for the observed variables is presented in parentheses. The data refer to the period 2015-2021.

The highest production value per conditional head of dairy cow was recorded in Sweden (5,571.3 EUR/dairy cow). In addition to Sweden, a value higher than 5,000.0 EUR/dairy cow was also recorded in the Czech Republic, Denmark, Estonia, Finland and Slovakia. The lowest production value was recorded in Bulgaria (1,486.6 EUR/dairy cow), while in Serbia the observed value for the period 2015-2021 was at the level of 3,742.7 EUR/dairy cow.

When it comes to hours of work spent per conditional head of dairy cows, the highest value was recorded in Serbia (567.4 h/dairy cow), while a slightly lower value was recorded only in Romania (517.1 h/dairy cow). The lowest value of labor used was recorded in Denmark, where it was 34.9 h/dairy cow on average.

The highest value of used agricultural land per conditional head of dairy cows was recorded in Slovakia (4.4 ha/dairy cow), while the lowest value was recorded in Spain, 0.5 ha/dairy cow. In Serbia, that value is 1.6 ha/dairy cow. The highest value of depreciation was recorded in Austria (1,142.2 EUR/dairy cow), which can be interpreted as the fact that farms from this country have the highest value of capital per conditional head of dairy cows. On the other hand, the lowest value was recorded in Spain (136.4 EUR/dairy cow), while in Serbia it was at the level of 179.6 EUR/dairy cow. Finally, the highest values of variable costs were recorded in countries where the value of production was at the highest level. Finland stood out in particular (4,655.6 EUR/dairy cow), while the lowest average value for the observed time period was recorded in Bulgaria at 933.0 EUR/dairy cow. In Serbia, the average value of variable costs was 1,959.2 EUR/dairy cow.

Table 1 Descriptive statistics (means and CV) for included variables

Country	Value of production (EUR/dairy cow)	Labour (h/dairy cow)	Utilized agricultural area (ha/dairy cow)	Depreciation (EUR/dairy cow)	Intermediate costs (EUR/dairy cow)
Austria	4,539.6 (10.0%)	196.3 (7.7%)	1.4 (0.8%)	1,141.2 (8.7%)	2,622.0 (4.6%)
Belgium	3,492.7 (13.9%)	64.8 (1.2%)	0.8 (4.0%)	467.3 (6.1%)	2,030.0 (8.5%)
Bulgaria	1,486.6 (13.6%)	172.4 (17.3 %)	0.8 (12.6%)	160.5 (12.0%)	933.0 (11.5%)
Croatia	3,772.1 (10.6%)	298.6 (4.0%)	1.6 (1.9%)	408.2 (6.5%)	2,551.8 (9.0%)
Czechia	5,685.0 (16.8%)	212.5 (2.7%)	2.9 (8.7%)	707.1 (12.5%)	4,100.3 (11.8%)
Denmark	5,445.2 (10.3%)	34.9 (2.5%)	0.9 (3.1%)	465.2 (2.2%)	3,636.8 (4.1%)
Estonia	5,009.3 (18.9%)	120.6 (2.9%)	2.8 (3.4%)	599.4 (17.2%)	3,502.0 (11.1%)
Finland	5,307.9 (8.8%)	111.9 (7.8%)	1.8 (5.5%)	1,125.0 (5.2%)	4,655.6 (4.2%)
France	3,689.7 (11.1%)	49.5 (1.7%)	1.6 (2.0%)	672.1 (6.2%)	2,444.7 (6.9%)
Germany	4,216.4 (15.9%)	68.5 (1.9%)	1.2 (4.5%)	561.1 (11.2%)	2,669.6 (11.1%)
Hungary	4,499.1 (17.6%)	167.0 (5.6%)	1.6 (13.0%)	342.6 (18.2%)	3,156.7 (9.1%)
Ireland	2,693.4 (8.9%)	46.7 (4.4%)	0.8 (4.0%)	187.7 (9.1%)	1,652.8 (9.3%)
Italy	4,119.5 (8.5%)	76.3 (3.7%)	0.6 (2.5%)	198.5 (6.1%)	2,243.8 (9.5%)
Latvia	2,995.5 (15.1%)	213.0 (5.1%)	2.9 (2.7%)	427.8 (10.8%)	2,166.3 (7.6%)
Lithuania	2,866.2 (18.5%)	295.2 (13.5 %)	2.8 (2.5%)	689.3 (9.4%)	1,792.7 (9.7%)
Luxembourg	3,887.5 (11.1%)	48.6 (8.7%)	1.3 (2.1%)	1,079.9 (3.8%)	2,572.4 (7.0%)
Malta	3,947.0 (9.8%)	89.1 (7.1%)	0.1 (7.1%)	209.2 (3.0%)	3,169.6 (6.4%)
Netherlands	4,192.7 (12.4%)	44.9 (5.2%)	0.6 (6.5%)	515.5 (7.2%)	2,580.7 (7.4%)
Poland	2,642.6 (21.6%)	226.9 (4.6%)	1.3 (2.1%)	387.0 (4.2%)	1,432.7 (15.2%)
Portugal	3,075.6 (9.9%)	95.7 (15.1 %)	0.6 (6.2%)	243.0 (4.9%)	2,271.1 (9.7%)
Romania	2,412.5 (18.5%)	517.1 (18.7 %)	1.3 (13.8%)	231.6 (17.9%)	1,258.7 (22.7%)
Serbia	3,742.7 (19.9%)	567.4 (3.2%)	1.6 (8.2%)	179.6 (21.3%)	1,959.2 (6.7%)
Slovakia	5,672.6 (12.5%)	238.8 (6.8%)	4.4 (7.6%)	770.2 (8.1%)	4,181.2 (14.2%)
Slovenia	3,597.6 (11.0%)	169.4 (8.3%)	1.0 (1.7%)	838.4 (5.8%)	2,421.2 (5.4%)
Spain	3,354.3 (14.4%)	61.1 (7.0%)	0.5 (7.2%)	136.4 (10.2%)	2,271.8 (10.7%)
Sweden	5,571.3 (11.4%)	68.4 (2.7%)	1.8 (6.7%)	682.7 (9.7%)	4,135.7 (5.8)

Source: the authors

Table 2 presents the results of the Malmquist TFP index, together with its constituent components (TEC and TC). Based on the DEA Malmquist analysis, there is a noticeable increase in total productivity at the level of all observed countries at a rate of 3.1%. Here, the period 2016-2017 stands out, where the increase amounted to 13.7%. The increase in productivity can be explained first by technical progress, which is an average of 2.5%, and then by an increase in technical efficiency at a rate of 0.8% for the observed period. A noticeable change in technical progress was recorded in the period 2016-2017, when it amounted to 10.5%. On the other hand, the biggest change in technical efficiency was recorded in the period 2020-2021 (3.5%). These results are similar to research conducted by Cechura et al. (2017). Their results showed an increasing trend for TFP in selected EU counties, but TEC was identified as a leading source of growth. Different results were probably achieved because of the smaller sample, as data was collected from 12 EU countries.

Table 2 Malmquist index summary of annual means

Period	Malmquist TFP	TEC	TC
2015-2016	0.990	0.968	1.023
2016-2017	1.137	1.030	1.105
2017-2018	0.988	1.004	0.986
2018-2019	1.021	1.017	1.005
2019-2020	1.028	0.993	1.039
2020-2021	1.027	1.035	0.994
Geometric mean	**1.031**	**1.008**	**1.025**

Source: the authors

Table 3 presented below shows the results of the Malmquist TFP index, together with the constituent components (TEC and TC). Observing the realized TFP index at the country level, it is noticeable that Spain records the highest average TFP value for the observed period (1.057), while the lowest value is recorded by Portugal and Slovakia (1.001). The value of the TFP index for the Republic of Serbia was 1.043 and it can be stated that it is entirely conditioned by technical progress, because changes in technical efficiency were not recorded (TEC=1.000). Changes in technical progress in the Republic of Serbia can be explained as a result of the modernization of machinery during the observed period, as well as an increased and improved supply of inputs on the market compared to the previous period.

Table 3 Malmquist index summary by States for period 2015-2021

Country	Malmquist TFP	TEC	TC
Austria	1.026	1.012	1.014
Belgium	1.033	1.019	1.013
Bulgaria	1.024	0.997	1.027
Croatia	1.006	0.988	1.018
Czechia	1.027	1.016	1.011
Denmark	1.042	1.000	1.042
Estonia	1.038	1.025	1.013
Finland	1.027	1.009	1.018
France	1.023	1.002	1.020
Germany	1.038	1.020	1.017
Hungary	1.037	1.029	1.008
Ireland	1.018	0.997	1.021
Italy	1.014	1.000	1.014
Latvia	1.039	1.020	1.018
Lithuania	1.049	1.022	1.026
Luxembourg	1.025	1.003	1.022
Malta	1.049	1.000	1.049
Netherlands	1.022	1.000	1.022
Poland	1.041	1.015	1.026
Portugal	1.001	0.985	1.015
Romania	1.011	0.977	1.035
Serbia	*1.043*	*1.000*	*1.043*
Slovakia	1.001	0.990	1.011
Slovenia	1.026	1.013	1.013
Spain	1.057	1.010	1.046
Sweden	1.032	1.007	1.025

Source: the authors

The interpretation of TFP/TC change is delicate, especially in the case of aggregated data, and there is a debate in academic circles on this topic, which is best illustrated by Mahadevan, (2003). The high level of TFP growth in Serbia is undoubtedly a positive trend. However, it is necessary to observe the dairy sector in Serbia in more detail and discover the potential factors that influenced this result. According to the Green Book published by the Ministry of Agriculture, Forestry and Water Management (2024) and the data available within the Statistical Office of the Republic of Serbia, significant changes occurred in the period between the two agricultural censuses that were conducted in 2012 and 2023, and which are best illustrated by the following data:

- The number of farms engaged in milk production has significantly decreased. In 2012, 155,859 farms were engaged in milk production; in 2023, only 62,940 farms stayed active.
- The number of dairy cows decreased from 434,290 to 335,996 cows.
- The average number of cows per farm has increased from 2.8 to 4.8, indicating a shift towards larger, more efficient farms.
- The share of small farms with 1 to 2 cows decreased from 77% to 44%.

These trends suggest that one of the most significant factors contributing to TFP growth is actually the exit of small and inefficient farms from production, that is, the survival of farms with modern technology and the ability to effectively compete with foreign competition, especially from the EU, which receives special subsidies through CAP. The EU dairy sector must follow strict regulations on hygiene, animal health, and welfare, while also benefiting from CAP instruments like market organization, public intervention, direct payments, and producer organizations that help stabilize prices and support farmers (Augère-Granier & Vinci, 2024). On the other hand, support for the dairy sector in Serbia is far simpler and is based mainly on premiums. According to Staniszewski and Borychowski (2020), the impact of subsidies on efficiency depends on the size of farms, and the most significant, stimulating effect of subsidies was identified only in the group of the largest farms. The EU's milk production relies heavily on medium and large-sized highly specialized intensive farms, as emphasized by Poczta et al. (2020). Certainly, TFP growth was achieved with a decrease in the total number of dairy cows, which potentially endangers milk production, if there is no increase in the volume of production at the most efficient farms. As noted by

Bórawski et al. (2020), the most important changes in the dairy sector that should occur after the abolition of quotas in the EU include increased milk yield per cow, increased total milk production, decreased number of cows, and decreased milk consumption, that is, an increase in efficiency and productivity with reduced direct payments. Serbia also faces this problem. With the liberalization of the EU, the opportunities for applying adequate foreign trade policies have been largely reduced. Therefore, the only remaining solution to agricultural policy is to encourage investments that will increase productivity, as well as to help milk producers use existing resources as optimally as possible. The importance of enhancing the knowledge of milk producers was also confirmed by a study done by Ule et al. (2023), who investigated the relationship between dairy farmers' knowledge and breeding tools and genomic selection and concluded that farmers with more knowledge have a more positive outlook towards genetic and genomic selection, which indicates the need for educational programs that can encourage the adoption of innovations in milk production.

Conclusion

Based on the results of this research, a few conclusions could be made:

- Based on the DEA Malmquist analysis, there is an increase in TFP in the sample at a rate of 3.1%.
- The productivity growth can be explained mainly by technical progress and then by an increase in technical efficiency for the observed period.
- While the Serbian dairy sector has experienced significant productivity growth, the reasons behind this trend are challenging to be fully explained. It could be concluded that one of the most significant contributions to TFP growth is actually the exit of small and inefficient farms from production.

The primary focus of future research will be to identify the additional factors, such as farm size, education, subsidies, climate change, etc., that contributed to TFP growth. Identifying the factors that contributed to TFP growth will be the primary focus of future research. The dairy sector in Serbia, as well as in the EU, is undergoing significant changes. Therefore, policymakers must be cautious when creating a support system for this sector, considering the potential risks and uncertainties.

The study's main limitation is a relatively short observed period of TFP growth due to the availability of FADN data in Serbia. Therefore, similar research must be repeated in a few years to better understand TFP changes in the Serbian dairy sector. Hopefully, new datasets will be available, like satellite data on land use, climate change, and the use of chemical inputs, which will improve TFP change analysis.

Declarations

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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