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USING THE FÄRE-PRIMONT INDEX TO MEASURE CHANGES IN TOTAL FACTOR PRODUCTIVITY OF DAIRY FARMS

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Abstract

The aim of the research was to assess the changes (in dynamic terms between 2008 and 2017) in the productivity of farms specializing in milk production with the use of the Färe-Primont aggregated total factor productivity index. The total factor productivity index was divided into the efficiency change index and technological change index. The research was conducted with the use of a data panel consisting of 730 farms per annum. Data were acquired from the Polish FADN. The research adopted the dairy farm model consisting of 1 output (Y) and 9 (X) inputs. The model of dairy farm adopted for calculation purposes was a minimum input farm, assuming variable returns to scale (VRS).

Between 2008 and 2017, the Färe-Primont total factor productivity index decreased by 28% (0.720). Changes in the total factor productivity index (dTFP) were affected by a 21.6% (1.216) increase in technological changes and a 40.8% (0.592) decrease in efficiency changes (dTFPE). The research results demonstrate that the key source of productivity in Poland is the technological progress, while the efficiency changes contributed to a decrease in the Färe-Primont total factor productivity index. The larger the economic size of the farm, cow herd size, agricultural area, total labor input (AWU), and cow milk yield, the greater the changes in the Färe-Primont total factor productivity index.

Keywords: productivity, Färe-Primont index, dairy farm.

JEL codes: C61, Q13, Q14, Q18, O47.

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Introduction

The farm productivity has been studied by the scientists in different countries in the world (Coelli and Rao, 2005; O'Donnell, 2010b; Rahman and Salim, 2013; Khan, Salim and Bloch, 2014; Baležentis, 2015; Singbo and Larue, 2016; Dakpo, Jeanneaux, Latruffe, Mosnier and Veysset, 2018a; Dakpo, Desjeux, Jeanneaux and Latruffe, 2019), since an effective economic policy requires knowledge of the key factors affecting productivity growth. In agriculture, these factors include technological progress and improving technical efficiency. Technological progress leads to greater production capacity. This increase is caused by, among others, the producers building scientific knowledge and purchasing the advanced inputs. Technical efficiency may be improved by way of increasing the output-to-input ratio and by reducing errors in the production process. Various economic policies (including agricultural policy) may have a positive or negative impact on the productivity growth. One should remember that the productivity is affected also by the prices of agricultural inputs and prices from sales of agricultural products (O'Donnell, 2008).

Productivity is defined by Coelli, Rao, and Battese (1998) as a ratio of company's output(s) to used input(s). In the case of many outputs and inputs, O'Donnell (2008) defined productivity as a ratio of aggregated outputs to aggregated inputs. In production, where one input is used to make one product, the calculation of productivity is easy. In the case of many outputs and inputs, the input and output aggregation methods are used. These calculations involve different total factor productivity (TFP) indices, which enable the measurement of productivity and include all production factors. Economic studies frequently apply the DEA (Data Envelopment Analysis) methods and its variations. This method enables the calculation of technical efficiency and total factor productivity indices using, among others, the Malmquist and Färe-Primont indices. Technical efficiency indices measure the effectiveness of management and are used to assess the correctness of the operational decisions made. The total factor productivity indices determine the sources of productivity.

The issue of dairy farm productivity was addressed for two reasons. The first one is the importance of milk-producing farms in the Polish agriculture. The production of milk, bovine, and calf livestock in 2017 accounted for 21.1 and 26.5% (Statistics Poland, 2018) in the structure of global and commercial production, respectively. The second reason for addressing this issue is a knowledge gap involving a lack of current studies on changes in productivity of the Polish agriculture, including dairy farms. While the technical efficiency of these farms is relatively well researched in Poland (Marzec and Pisulewski, 2013, 2014; Marzec, Pisulewski, and Prędki, 2015; Wilczyński, Kołoszycz, and Świtłyk, 2020), no current studies on farm productivity are being conducted. The vast majority of Polish papers in this field have involved the measurement of productivity using the Malmquist index and dates back to before the Poland's accession to the European Union (among others

(Brümmer, Glauben, and Thijssen, 2002; Zawalińska, 2004; Latruffe, Balcombe, Davidova, and Zawalińska, 2005), while the latest research on the productivity of the Polish agriculture (Rusielik, 2015) is partially based on macroeconomic data. The original contribution of this paper to the existing knowledge is the determination of the Färe-Primont total factor productivity index and its two components: efficiency change index and technological change index for dairy farms in Poland.

The purpose of this research was to assess changes (in dynamic terms between 2008 and 2017) in the productivity of farms specializing in milk production, which was done with the use of the aggregated Färe-Primont total factor productivity index, divided into the efficiency change index and technological change index.

Materials and methods

The research on technical efficiency and productivity changes in agriculture with the use of non-parametric DEA method can be divided into two groups. The first group includes the regional analyses comparing the selected regions (e.g.countries). Such an approach is adopted by by Brümmer et al., 2002; Coelli and Rao, 2005; Lissitsy and Rungsuriyawiboon, 2006; Latruffe, Fogarasi, and Desjeux, 2012; Baráth and Fertő, 2016; Ziętara and Adamski, 2017, Rusielik, 2020. The second group covers the studies referring to farms of different nature (for example, by types, economic size, agricultural area) and their mutual comparisons. Examples of such studies are the papers by Zawalińska, 2004; O'Donnell, 2010b; Rusielik and Świtłyk, 2012; Marzec and Pisulewski, 2013, 2014; Marzec et al., 2015; Latruffe and Desjeux, 2016.

Animal farms, including dairy farms, constitute a popular area of studies on productivity and technical efficiency. Among others, they were conducted by Latruffe et al., 2005; Balcombe, Fraser, and Kim, 2006; Latruffe et al., 2012; Singbo and Larue, 2016; Darku, Malla, and Tran, 2016; Madau, Furesi, and Pulina, 2017; and by Wilczyński et al., 2020. Research on the technical efficiency of the agricultural environment, agriculture, and farms in Poland was conducted by, among others, Świtłyk, 1999; Rusielik, 2000; Rusielik and Świtłyk, 2009; Zawalińska, 2004; Góral, 2014; Marzec and Pisulewski, 2013, 2014; Marzec et al., 2015.

Source data for research purposes were obtained from the Polish FADN (Farm Accountancy Data Network). The research adopted the dairy farm model consisting in 1 output (Y) and 9 (X) inputs. The model output (Y) variable was the total revenue from sales of: cows' milk and milk products (SE216), beef and veal (SE220), and total subsidies excluding investments (SE605). The model input variables were as follows: X1 – total labor input (AWU) (SE010), X2 – total utilized agricultural area (SE025), X3 – crop-specific inputs (total of variables: seeds and seedlings (SE285), fertilizers (SE295), crop protection products (SE300), X4 – feed for grazing livestock (SE310), X5 – other livestock specific costs (SE330), X6– machinery and building current costs (SE340), X7 – energy costs (SE345), X8 – depreciation (SE360), and X9 – dairy cows (SE085). All economic values adopted in the model were expressed in PLN, dairy cows in numbers, and total labor input in AWU.

The analysis involved a panel of data from dairy farms, recurrent between 2008 and 2017. Sample size was n=730 farms. The model of dairy farm adopted for calculation purposes was a minimum input farm, assuming variable returns to scale (VRS). Given that the DEA method and Färe-Primont index were described in details in many publications, including among others the papers by: Coelli, Rao, and Battese, 1998; Färe, Grosskopf, and Lovell, 1994; Banker, Charnes, and Cooper, 1984, as well as Charnes, Cooper and Rhodes, 1978, their description was omitted due to the large volume of this paper. The DEA method was described in the Polish literature by among others: Rogowski, 1998; Rusielik, 2000; Zawalińska, 2004; Guzik, 2009; Góral, 2014., while the elaborations on the Färe-Primont index can be found in the studies by, among others, O'Donnell, 2008-2011; Rahman and Salim, 2013; Baležentis, 2015; Dakpo, Desjeux, and Latruffe, 2018; Dakpo et al., 2018a; Dakpo et al., 2019; Cilleroa and Thorneb, 2019 and Rusielik, 2015, 2020. The research uses the Färe-Primont total factor productivity index, since, when compared with the other TFP indices, it is completely multiplicable, transitive, and allows for multilateral (with the other companies) and multi-temporal (in time) comparisons (O'Donnell, 2011; Dapko et al., 2019; Rusielik, 2015, 2020).

The research used the following software: *productivity R* package version 1.1.0 (Dakpo et al., 2018) and Statistica 13.1.

The research results on the Färe-Primont index changes presented in the paper consist of two parts. The first one discusses the research results for all analyzed dairy farms. The second part presents the results for the selected groups of farms and individual classes in these groups. The results present the changes of analyzed indices. An index value below 1 means a decrease, a value equal to 1 means no changes (stagnation), while an index value above 1 means an improvement. The results are presented as a geometric mean.

The results were classified by economic size classes, according to the FADN methodology (ES6), labor input (AWU), agricultural area, milk yield and dairy cows on the farm. The group of farms selected by economic size was divided into the following classes: EUR 8,000-25,000, EUR 25,000-50,000, EUR 50,000-100,000, and EUR 100,000-500,000. The following three classes were established on the basis of total labor input: up to 1.5 AWU, 1.5-2.0 AWU, and above 2.0 AWU. In terms of agricultural area, the following classes of farms were distinguished: up to 15 ha, 15-20 ha, 20-30 ha, above 30 ha.

In terms of cow's milk yield, the farms were classified into the groups of average annual yield of up to 6,000 l, 6,000-7,000 l, and above 7,000 l/cow, while in terms of cow herd size, the farms were divided into the groups of up to 10 cows, 10-20 cows, 20-30 cows, and above 30 cows.

Results and discussion

Specification of the analyzed farms

The descriptive statistical data of the output variable and input variables of the adopted dairy farm model are presented in Tables 1 and 2. Table 1 shows information on the value of variables of the studied population of dairy farms from 2008-2017 and in the first (2008) and last year of analysis (2017). Table 2 presents the average value specific for each selected group of dairy farms. According to the data presented in Table 1, all analyzed parameters increased between 2008 and 2017. The average output volume in the analyzed period increased more than two-fold, from PLN 177,200 in 2008 to PLN 365,400 in 2017. A minor 5% increase of labor input in the analyzed farms should be noted. Average herd size increased from 23.0 in 2008 to 29.8 cows in 2017 (by 29.6%), similarly to the average agricultural area from 29.2 ha in 2008 to 34.2 ha in 2017 (by 17.1%). Crop-specific inputs, costs of purchased feed, other livestock specific costs, machinery and building current costs, and energy grew between 70 to 90%. Depreciation in the analyzed farms rose by approximately 64%, from PLN 25,100 in 2008 to PLN 41,000 in 2017.

The economic size of an average farm increased by nearly 27% from EUR 59,504.4 in 2008 to EUR 7,531.9 in 2017, while cow's milk yield raised by 987 liters (by approximately 20%) from 5,028 liters in 2008 to 6,015 liters in 2017.

When analyzing data in Tables 1 and 2 on labor input and agricultural area, the research results presented by Steffen (2001) should be noted. In German conditions, the herd of 60-80 cows requires an intensive involvement of one work unit and agricultural area of approximately 70 ha. Similar results were obtained by Ziętara and Adamski (2018) in their research on, among others, the competitiveness of the Polish dairy farms compared with the farms of the selected EU Member States. The competition capacity was demonstrated by the Polish farms keeping nearly 30 dairy cows, while the fully competitive farms were the farms with an agricultural area of 60 ha keeping approximately 60 cows.

Table 1

Descriptive statistical data of the dairy farm model variables

Specification	Measure-ment unit	Average	Median	Standard deviation	Coefficient of variation	Average	Median	Standard deviation	Coefficient of variation	Average	Mediana	Standard deviation	Coefficient of variation
Number of farms	Gosp.	730				730				730			
Years		2008-2017				2008				2017			
Output variable[a]	PLN thousand	259.8	181.7	262.5	101.1	177.2	131.2	158.9	89.7	365.4	267.6	362.6	99.2
Labor inputs	AWU	2.1	2.0	0.6	30.2	2.0	2.0	0.6	27.6	2.1	2.0	0.7	31.5
Cows	number	26.3	21.4	19.1	72.4	23.0	18.7	15.1	65.7	29.8	23.5	23.3	78.3
Agricultural area	ha	31.8	25.9	20.5	64.5	29.2	24.3	18.2	62.2	34.2	27.9	22.5	65.9
Crop-specific costs	PLN thousand	24.3	16.6	25.1	103.3	17.0	12.6	16.0	94.3	30.0	21.8	30.3	101.1
Purchased feed	PLN thousand	60.5	37.8	79.5	131.4	44.8	30.9	51.2	114.3	75.8	47.1	102.9	135.8
Other livestock specific costs	PLN thousand	10.5	5.9	14.2	135.0	7.4	4.5	8.2	112.2	13.8	7.6	17.6	127.7
Machinery and building current costs	PLN thousand	13.42	9.4	13.7	102.0	10.1	7.2	9.8	96.6	18.5	13.4	17.3	93.6
Energy costs	PLN thousand	19.0	13.2	19.2	101.1	13.2	10.0	11.4	86.5	22.5	14.9	23.4	104.3
Depreciation	PLN thousand	35.1	25.2	35.4	100.9	25.1	19.7	19.9	79.5	41.0	27.6	41.4	100.8
Economic size	EUR	67,186.7	54,092.1	47,980.4	71.4	59,504.4	49,254.5	38,809.6	65.2	75,531.9	59,512.9	57,686.9	76.4
Milk yield	l	5443	5178	1717.3	31.5	5028	4840	1413.5	28.1	6015	5794	1920.0	31.9

[*] Total revenues from sales of: cows' milk and milk products (SE216), beef and veal (SE220), and total subsidies, excluding investments.

Source: own calculations based on data from FADN.

Table 2

Specification of the established groups of farms (average values for 2008-2017)

Specification	Valid *n*	Economic size (EUR)	Model input variable [a] (PLN thousand)	AWU	Cows (number)	Agricultura1 area (ha)	Milk yield (l)
Group of farms established on the basis of economic size (EUR)							
>8 000<25 000	610	18,728.4	54.5	1.6	7.5	11.6	4,021
>25 000<50 000	2,653	37,939.4	122.4	1.9	15.3	19.6	4,800
>50 000<100 000	2,853	70,304.3	261.1	2.1	27.6	34.2	5,668
>100 000<500 000	1,184	150,174.7	670.2	2.6	57.7	63.6	7,076
Group of farms established on the basis of cow herd size							
<10 cows	657	20,173.9	56.8	1.7	7.3	13.3	4,070
>10<20 cows	2,630	39,119.9	123.2	1.9	15.2	20.7	4,807
>20<30 cows	1,881	62,543.0	219.9	2.0	24.4	31.2	5,429
>30 cows	2,132	120,393.9	526.1	2.4	47.6	51.6	6,663
Group of farms established on the basis of agricultural area							
<15 ha	1,124	27,610.5	87.9	1.7	11.9	11.6	4,423
>15<20 ha	1,253	39,447.1	135.1	1.9	16.4	17.7	4,976
>20<30 ha	1,936	52,234.8	187.9	2.0	21.1	24.6	5,210
>30 ha	2,987	103,406.3	423.3	2.3	39.3	50.0	6,174
Group of farms established on the basis of milk yield							
<6 000 l	4,795	52,508.9	160.5	2.0	20.5	27.0	4,421
>6 000<7 000 l	1,127	79,812.2	320.7	2.2	31.3	37.3	6,465
>7 000 l	1,378	107,934.6	555.4	2.3	42.4	44.1	8,165
Group of farms established on the basis of labor input (AWU)							
<1.5 AWU	952	42,989.5	148.4	1.2	16.9	21.8	4,920
>1.5<2.0 AWU	2,442	53,732.5	193.7	1.8	21.4	25.9	5,107
>2.0 AWU	3,906	81,495.6	328.3	2.4	31.7	37.9	5,781

[*] Total revenues from sales of: cows' milk and milk products (SE216), beef and veal (SE220), and total subsidies, excluding investments.

Source: own calculations based on data from FADN.

Table 3 and Figures 1 and 2 show the results of calculations for the entire studied population between 2008 and 2017. According to the data presented in Table 3, between 2008 and 2017 the average value of the total factor productivity index (dTFP) amounted to 0.720, which means that the average decrease in productivity for the entire studied population was 28%. The total productivity change index (dTFP) was affected by an increase of technological changes (dMP) by 21.6% (1,216) and a decrease in efficiency changes (dTFPE) by 40.8% (0.592).

Table 3

Changes of dTFP and its components in the analyzed dairy farms from w latach 2008-2017

dTFP change	Technological change (dMP)	Efficiency change (dTFPE)
0.720	1.216	0.592

Source: own calculations based on data from FADN.

Figure 1 presents the components of the total factor productivity index (dTFP): technological changes (dMP) and efficiency changes (dTFPE). According to Figure 1, the basic source of changes in the Färe-Primont total factor productivity index (dTFP) is technological changes (dMP), which demonstrate a clear upward trend in the analyzed period. The efficiency changes (dTFPE) contribute to a decreased total factor productivity index (dTFP). The value of efficiency change index (dTFPE) stabilized at the level of approximately 0.600. The total factor productivity index (dTFP) demonstrates an upward trend in the analyzed years.

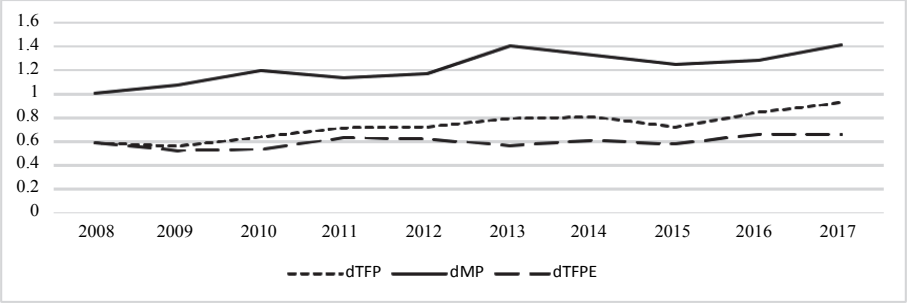

Fig. 1. Value of the Färe-Primont index (dTFP) and its components.
Source: own calculations based on data from FADN.

The research results presented in the paper can be compared with the research by Dapko et al. (2019). The research determines the Färe-Primont index and its components for five types of French farms: plant, dairy, bovine livestock, sheep, goat, and mixed. The research covered the period 2002-2015 and analyzed the total of 58, 365 observations, including 14,349 dairy farm observations.

Table 4

Results of farm productivity research in France from 2002-2015

Specyfication	Gospodarstwa					
	total	plant	dairy	bovine livestock	sheep and goat	mixed
TFP change	1.181	1.245	1.081	1.229	1.170	1.174
Technological change	0.938	0.938	0.982	1.349	1.247	1.051
Efficiency change	1.259	1.328	1.100	0.911	0.938	1.117

Source: Dakpo et al. (2019).

The results of French research demonstrated (Table 4) that the Färe-Primont total factor productivity index increased by 18.1% from 2002-2015. This increase depended on improved efficiency (by 25.9%), while the technological changes caused a decrease in the total factor productivity index by 6.2%. In each type of farms, the impact of components on the total factor productivity index is diversified. In the case of plant and dairy farms, the technological changes cause a decrease in the index value, while the efficiency changes result in an increase of the total factor productivity index. It is the opposite with the bovine livestock, as well as sheep and goat farms. On these farms, the technological changes have a positive impact on the TFP index, while the efficiency changes cause its decrease. In the case of mixed farms, a positive impact on the value of the Färe-Primont total factor productivity index is observed for both technological and efficiency changes.

In the subsequent stage of the research, an analysis of the identified research groups was performed. Figures 2 and 3 present the average values of the total factor productivity indices (dTFP) and efficiency change indices (dTFPE) depending on the economic size of farms.

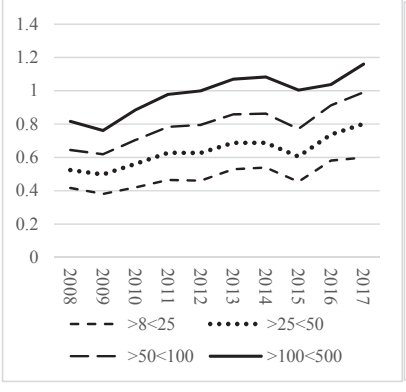

Fig. 2. dTFP value compared with the economic size of farm (EUR thousand)

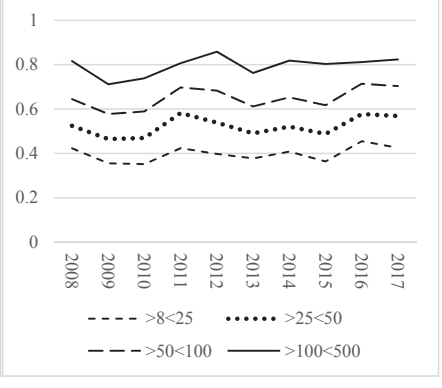

Fig. 3. dTFPE value compared with the economic size of farm (EUR thousand)

Source: own calculations based on data from FADN.

An analysis of the results presented in the figures demonstrates that the average level of changes in the total factor productivity was determined by the economic size of a farm. The group of the largest farms in terms of economic size (> EUR 100,000<500,000) score the highest index, while the smallest farms have the lowest total factor productivity index. The group of the largest farms in terms of economic size (Table 2) from 2008-2017 accounted for 16.2% (1,184 farms) of the studied population and displayed the following features: average labor input (AWU) of 2.6, herd size of 57.7 cows, agricultural area of 63.6 ha, milk yield of 7,076 liters. The group of farms of the lowest economic size (>EUR 8,000 <25,000) accounted for 8.4% of the studied population (610 farms) and its average features were as fol-

lows: labor input (AWU) of 1.6, herd size of 7.5 cows, agricultural area of 11.6 ha, milk yield of 4,021 liters. In all identified classes, an upward trend is observable for this index. The total factor productivity index (dTFP) in three classes of economic size up to EUR 100,000 were below 1. The total factor productivity index (dTFP) for the >EUR 100,000<500,000 class of farms in 2008-2011 was below 1, while in the subsequent research years it was higher than 1. The total factor productivity index (dTFP) for the >EUR 8,000 <25,000 class of farms fell within the range of 0.381 (2009) and 0.599 (2017), while in the >EUR 25,000 <50,000 class of farms the value of the analyzed index varied from 0.498 (2009) to 0.802 (2017). In the >EUR 50,000 <100,000 economic class of farms, the value of the total factor productivity index (dTFP) ranged from 0.619 (2009) to 0.991 (2017), while in the class of the highest economic size, the values of dFTP varied from 0.762 (2009) to 1.160 (2017). The average level of the total factor productivity indices in the analyzed years amounted to 0.480 in the >EUR 8,000 <25,000 economic class of farms, 0.630 and 0.786 in the >EUR 25,000 <50,000 and >EUR 50,000 <100,000 classes, respectively, while in the >EUR 100,000 <500,000 class, the average value of the total factor productivity index was 0.972.

Similar interdependencies related to the level of changes can be observed when analyzing the efficiency change index. The efficiency change index (dTFPE) was below 1 in all economic size classes. Also in this case, in the group of the largest farms, the average value of this index is the highest, with the lowest occurring in the smallest farms. The values of efficiency change index (dTFPE) in the class of farms of the smallest economic size, i.e. >EUR 8,000 <25,000 fell within the range of between 0.352 (2010) and 0.455 (2016), while in the economic size class of >EUR 25,000 <50,000 they were from 0.465 (2009) to 0.577 (2016). In the economic size classes of >EUR 50,000 <100,000 and >EUR 100,000 <500,000, the index value amounted to: from 0.578 (2009) to 0.714 (2016) and from 0.711(2009) to 0.824 (2016), respectively. The average level of efficiency change indices (dTFPE) for the studied group in the analyzed years amounted to 0.395 in the >EUR 8,000 <25,000 economic size class, 0.518 in the >EUR 25,000 <50,000 economic size class, and 0.647 in the >EUR 50,000 <100,000 economic size class, while in the class of >EUR 100,000 <500,000 the average productivity change index was 0.800. The level of changes in the average efficiency change indices (dTFPE) is similar in eachyear and features a slight upward trend.

Figures 4 and 5 present the total factor productivity index (dTFP) and the economic efficiency change index (dTFPE) on the farms depending on the cow herd size. The average level of changes in the total factor productivity index (dTFP) depends on the size of cow herd. The farms with the smallest cow herds (<10 cows) record the lowest values of the analyzed index. These ranged between 0.388 (2009) and 0.605 (2017), while the average for the research period was 0.492. These farms accounted for 9.0% of the sample (657 farms) (Table 2), and their average labor input (AWU) amounted to 1.7, the herd size was 7.3 cows, the average agricultural area amounted to 13.3 ha, with a milk yield of 4,070 liters. On the farms with

a herd size of >10<20 cows, the total factor productivity index (dTFP) varied from 0.494 (2009) to 0.815 (2017), with an average of 0.634. In the following class of herd size (>20<30 cows), the total factor productivity index (dTFP) fell within the range from 0.610 (2009) to 0.945 (2017), with an average of 0.750 for this class. In the case of farms keeping the largest cow herds (>30 cows), the total factor productivity index changed from 0.728 (2009) to 1.116 (2017), with an average of 0.917 for this group. The farms with herds above 30 cows accounted for 29.2% (2,132 farms) of the studied group. These farms featured the following parameters (Table 2): labor input of 2.4 AWU, 47.6 cows, agricultural area of 51.6 ha, milk yield of 6,663 liters. The changes in the total factor productivity index (dTFP) in all analyzed herd size classes demonstrated an upward trend. It should be noted that in the three herd size classes (<10, >10<20, >20<30 cows) the total factor productivity index (dTFP) was below 1, while in the group of farms with the largest cow herds (>30 cows) in 2014 and 2017, the total factor productivity index was higher than 1.

The value of efficiency change indices (dTFPE) also depends on the cow herd size. In the case of farms with the smallest cow herds (<10 cows), the values of efficiency change index (dTFPE) are the lowest and range from 0.363 (2009) to 0.462 (2017), with an average of 0.404 for this class in the analyzed period.

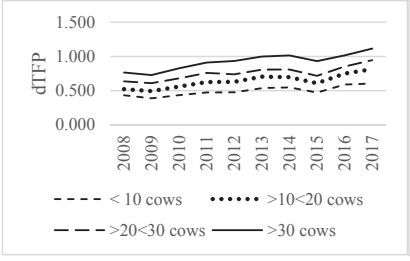

Fig. 4. dTFP value compared with cow herd size.

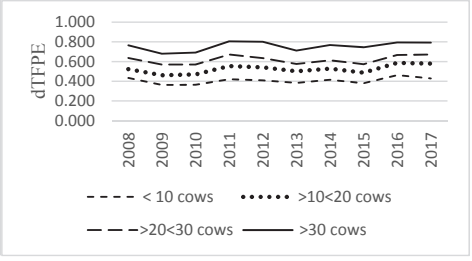

Fig. 5. dTFPE value compared with cow herd size.

Source: own calculations based on data from FADN.

In the case of farms with herds of >10<20 cows, the dTFPE index ranged from 0.461 (2009) to 0.586 (2016), with an average of 0.521. For farms keeping herds of <20<30 cows the index was from 0.569 (2009) to 0.671 (2017), while the average for the analyzed period amounted to 0.617. The farms with the largest cow herds (>30 cows) recorded the highest efficiency change indices (dTFPE), which ranged from 0.680 (2009) to 0.805 (2011), 0.754 on average. In the analyzed group of farms, the efficiency change index (dTFPE) in all analyzed years and in farm classes was below 1, and its trend can be regarded as slightly upward.

Figures 6 and 7 present the relationship between the total factor productivity index (dTFP), economic efficiency change index (dTFPE), and the agricultural area of the analyzed dairy farms.

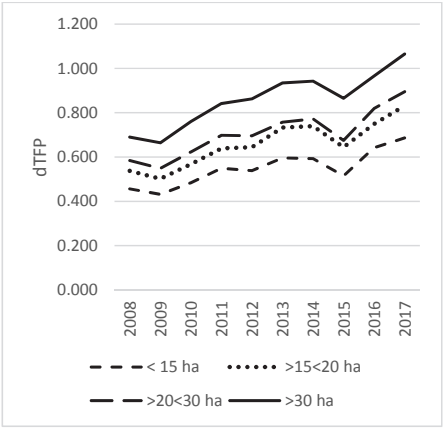

Fig. 6. dTFP value compared with agricultural area.

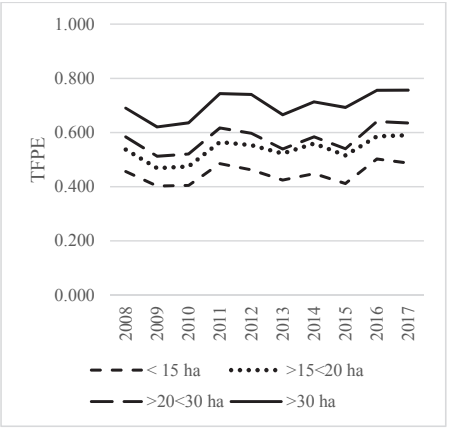

Fig. 7. dTFPE value compared with agricultural area.

Source: own calculations based on data from FADN.

The total factor productivity index (dTFP) in this group of farms, excluding the largest farms (> 30 ha) in 2017, was below 1 and demonstrated a clear upward trend. The total factor productivity index (dTFP) depended on the agricultural area. In the case of the smallest farms (<15 ha), the total factor productivity indices (dTFP) were the lowest and ranged from 0.431 (2009) to 0.687 (2017), while the average for the analyzed period was 0.544. These farms accounted for 15.4% (1,124 farms) of the analyzed group (Table 2) and featured the following parameters: labor input of 1.7 AWU, herd size of 11.9 cows, agricultural area of 11.6 ha, milk yield of 4,423 liters. In the case of farms with an area of >15<20 ha, the dTFP indices ranged between 0.502 (2009) and 0.832 (2017), and the average value of the analyzed indices amounted to 0.651. Farms with an area of >20<30 ha had a total factor productivity index (dTFP) from 0.549 (2009) to 0.895 (2017), and the average index value was 0.700. The largest farms with an area of >30 ha recorded the highest values of the dTFP index values, which fell within the range from 0.665 (2009) to 1.065 (2017), 0.851 on average in the analyzed period. This group (Table 2) of farms accounts for 40.9% (2,987 farms) of the analyzed population and records the following average values: labor input of 2.3 AWU, herd size of 39.3 cows, agricultural area of 50.0 ha, milk yield of 6,174 liters.

The efficiency change index (dTFPE) in the analyzed group of farms was below 1, and its trend should be regarded as slightly upward in all analyzed area classes. In the case of farms with the lowest share of agricultural area (<15 ha), the level of efficiency change index (dTFPE) was the lowest and ranged from 0.403 (2009) to 0.502 (2016), 0.447 on average. In the case of farms with an area of >15<20 ha, the dTFPE index coefficients ranged from 0.468 (2009) to 0.590 (2017), 0.536 on average. In the case of farms with an agricultural area of >20<30 ha, the efficiency change indices (dTFPE) fell within the range from 0.512 (2009) to 0.641 (2016),

0.575 on average in the analyzed period. In the case of farms with an agricultural area of >30 ha, the dTFPE index was the highest and varied from 0.620 (2009) to 0.756 (2016, 2017), 0.700 on average.

Figures 8 and 9 present the relationships between the total factor productivity index (dTFP), economic efficiency change index (dTFPE) and total labour inputs in the farm (AWU). Figure 8 presents the relationship between the total factor productivity index (dTFP) and total labor inputs.

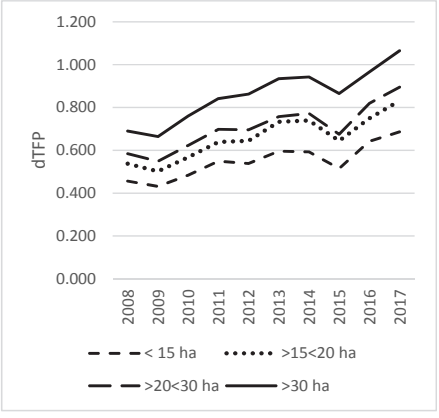

Fig. 8. dTFP value compared with labor inputs (AWU/farm).

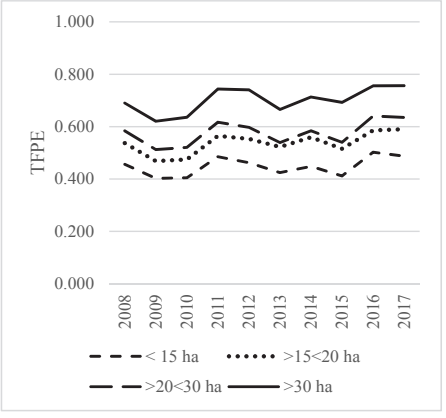

Fig. 9. dTFPE value compared with labor inputs (AWU/farm).

Source: own calculations based on data from FADN.

The total factor productivity indices (dTFP) in all labor input classes were below 1 in all analyzed years and the dTFP indices demonstrated an upward trend. It should be noted that farms with the highest labor inputs (>2 AWU/farm) recorded the highest coefficients of the total factor productivity index (dTFP), ranging from 0.582 (2009) to 0.955 (2017), while the average value of dTFP for this class of farms was 0.757. These farms (Table 2) account for 53.5% (3,906 farms) of the analyzed groups and are described by the following average values: total labor inputs of 2.4 AWU, herd size of 31.7 cows, agricultural area of 37.9 ha, cow milk yield of 5,781 liters. The total factor productivity index (dTFP) coefficients in the remaining two classes (<1.5 AWU/ farm and >1.5<2.0 AWU/farm) were similar (excluding the >1.5<2.0 AWU/farm group in 2015 and 2016) and ranged from 0.535 (2009) to 0.842 (2017) for the <1.5 AWU farms, 0.670 on average. In the case of farms with labor inputs of >1.5<2.0 AWU, the dTFP index fell within the range from 0.533 (2009) to 0.907 (2017), 0.683 on average.

The efficiency change index (dTFPE) demonstrates the same properties as the total factor productivity index (dTFP) that is the higher the labor input expressed in AWU, the higher the efficiency change index coefficients. In all analyzed years and classes of farms, the efficiency change index was below 1 and its trend can be regarded as slightly upward. In the case of farms with labor inputs of <1.5AWU,

the efficiency change index (dTFPE) was the lowest and ranged from 0.484 (2010) to 0.602 (2016), while the average index value was 0.551. In the subsequent class of farms (>1.5<2.0 AWU), the dTFPE index fell within the range from 0.498 (2009) to 0.644 (2017), 0.562 on average. In the case of farms in the >2.0 AWU class, the index value was the highest and ranged from 0.543 (2009) to 0.689 (2016), 0.623 on average. Figures 10 and 11 present the relationships between the values of dTFP and dTFPE indices and the cow's milk yield.

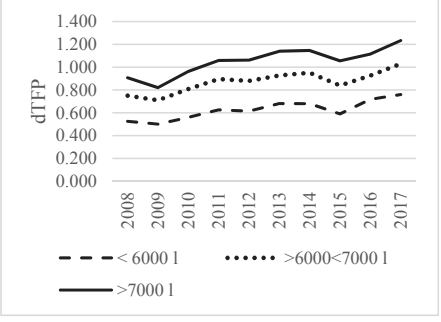

Fig. 10. dTFP compared with cow's milk yield.

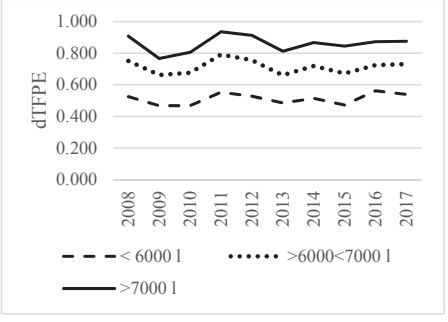

Fig. 11. dTFPE compared with cow's milk yield.

Source: own calculations based on data from FADN.

The total factor productivity index (dTFP) depending on cow's milk yield in the following analyzed years demonstrates an upward trend, provided that this index was above 1 in the >7000 liters yield class from 2011 and in the >6000<7000 liters yield class from 2017. The farms in this class accounted for 18.9% (1,378 farms) of the analyzed group and were described by the following parameters: labor input of 2.3 AWU, herd size of 42.4 cows, agricultural area of 44.1 ha, and milk yield of 8,165 liters. The total factor productivity index (dTFP) in the case of farms with the lowest milk yield (<6,000 liters) were the lowest and varied from 0.501 (2009) to 0.760 (2017), while the average value for the class was 0.621. This class of farms accounted for 65.7% of the analyzed group (4,795 farms) and was described by the following values: total labor input of 2.0 AWU, herd size of 20.5 cows, agricultural area of 27.0 h, milk yield of 4,421 liters. In the case of farms with milk yield of >6000<7000 liters, the total factor productivity index (dTFP) was from 0.710 (2009) to 1.030 (2017), with an average of 0.867 for the analyzed milk yield class. Farms with the highest milk yield (>7,000 liters) had the highest total factor productivity index (dTFP), which ranged from 0.821 (2009) to 1.233 (2017), with an average of 1.044 for this class.

Similarly to the total factor productivity index (dTFP), the value of efficiency change index (dTFPE) depended on the milk yield. The trend of this index is diversified. In the case of farms with a yield of < 6,000 liters and >7,000 liters, it is slightly upward.

In the case of farms with a yield of >6,000<7,000 liters, it can be described as stable (no trend). With regard to farms with a yield of <6,000 liters, this index was the lowest and varied from 0.468 (2009) to 0.562 (2016), with an average of 0.511 for this class. Farms with a yield of >6,000<7,000 liters had the efficiency change index (dTFPE) from 0.661 (2013) to 0.792 (2011), 0.713 on average. In the class of farms with the highest yield (>7,000 liters) the dTFPE index was the highest. It ranged from 0.766 (2009) to 0.936 (2011), with an average of 0.858 for this class.

Conclusions

The research of dairy farms in Poland covering the period 2008-1017, which aimed to determine the level of changes in total productivity and its sources in the form of technological and efficiency changes with the use of the Färe-Primont total factor productivity index, allows for drawing the following conclusions:

1. From 2008-2017, the average value of the Färe-Primont total factor productivity index decreased by 28% (0.720). The total factor productivity (dTFP) was affected by an increase in technological changes (dMP) by 21.6% (1,216) and decrease in efficiency changes (dTFPE) by 40.8% (0.592).
2. The changes in the Färe-Primont total factor productivity index (dTFP) and efficiency change index (dTFPE) were linked with the scale of production of the analyzed farms and increased along with the economic size, cow herd size, agricultural area, labor input (AWU), and cow's milk yield.
3. It should be noted that the total factor productivity index (dTFP) was, in the vast majority of cases, below 1. Only in a few cases (in the highest classes of the researched groups), the Färe-Primont total factor productivity index was higher than 1. The efficiency change index (dTFPE) in all analyzed groups of farms and established classes was below 1.
4. Low efficiency change indices (dTFPE) of the analyzed farms may indicate that the farmers make inappropriate operational decisions and the values of index components need to be analyzed, i.e.: technical efficiency change index, scale efficiency change index, and residual mixed efficiency change index.

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ZASTOSOWANIE INDEKSU FÄRE-PRIMONTA DO POMIARU ZMIAN PRODUKTYWNOŚCI CAŁKOWITEJ GOSPODARSTW MLECZNYCH

Abstrakt

Celem badań była ocena zmian (w ujęciu dynamicznym w latach 2008-2017) produktywności gospodarstw rolnych specjalizujących się w produkcji mleka, której dokonano stosując zagregowany indeks produktywności całkowitej Färe-Primonta. Indeks zmian produktywności całkowitej został zdekomponowany na indeks zmian efektywności i indeks zmian technologicznych. Badania wykonano na panelu danych liczących 730 gospodarstw rocznie. Dane do badań pozyskano z Polskiego FADN. W badaniach przyjęto model gospodarstwa mlecznego, który składał się z 1 efektu (Y) i 9 (X) nakładów. Przyjęty do obliczeń model gospodarstwa mlecznego był ukierunkowany na minimalizację nakładów, przy założeniu zmiennych efektów skali (VRS).

W latach 2008-2017 indeks zmian produktywności całkowitej Färe-Primonta zmniejszył się o 28% (0,720). Na wielkość zmian indeksu produktywności (dTFP) wpłynął wzrost o 21,6% (1,216) zmian technologicznych (dMP) oraz spadek o 40,8% (0,592) zmian efektywności (dTFPE). Wyniki badań wskazują, że głównym źródłem produktywności w Polsce był postęp technologiczny, natomiast zmiany efektywności wpływały na zmniejszenie indeksu zmian produktywności całkowitej Färe-Primonta. Zmiany indeksu produktywności całkowitej Färe-Primonta są tym większe, im większa była: wielkość ekonomiczna gospodarstwa, wielkość stada krów, powierzchnia użytków rolnych, nakłady siły roboczej (AWU) i wydajność mleczna krów.

Słowa kluczowe: produktywność, indeks Färe-Primonta, gospodarstwa mleczne.

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