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THE CHANGES IN PRODUCTIVITY OF PRODUCTION FACTORS IN COMMERCIAL FARMS IN POLAND IN 2004 AND 2012

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Abstract. The aim of the paper is an assessment of changes in production factors productivity in commercial farms in 2012 in comparison to 2004. An analysis concerns the flexibility of relations among production factors like: arable lands areas in hectares, human labor input in man-hours, total cost in Polish zloty in 2004 and 2012 and the effects resulted from using above mentioned factors expressed in production value. It allowed to make an assessment of changes in rural farms' economic effectiveness within eight years after Poland's accession to the European Union. In surveyed period average labor effectiveness increased of 86.5%, and land effectiveness of 29.7%. Average capital productivity decreased just like labor and land margin productivity.

Key words: agriculture, commercial farms, productivity, Cobb-Douglas production function

INTRODUCTION

Productivity is defined as the capacity of production factors for creating the effect in the form of production [Latruffe 2010]. Productivity and efficiency are often used to evaluate the competitiveness, and the European Commission considers productivity to be the most reliable indicator of competitiveness in the long term [European Commission 2008]. Analysis of productivity is a key issue in terms of the assessment and the possibility of improving the competitiveness of the company and it creates a very useful management tool at every level of economic development [Domańska et al. 2014]. Productivity, defined as the ratio between the obtained effects and the expenses, is a measure of the efficiency of the management [Floriańczyk and Rembisz 2012].

Productivity can be calculated cumulatively for all the factors involved in the production (multifactor productivity) or individually for each factor of production (partial

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productivity). Multifactor productivity of resources takes into account the impact of all factors, representing combined contribution in a given production. In turn, the partial productivity shows the impact of individual types of resources (e.g. capital, labor) on the size of the production volume and can be used for measurement in specific sectors of the national economy [Boghean and State 2013].

The foundation of productivity growth is the use of new production technologies, as well as increase in the scale of production [Floriańczyk and Rembisz 2012]. The consequence of productivity growth is, however, an increase in remuneration for ownership of capital used in agricultural production and farm management skills [Floriańczyk and Rembisz 2012]. The significance of productivity growth in Polish agriculture stems from the fact that it presents low productivity of production factors, especially labor and land [Gradziuk and Kłyż 2011, Siekierski 2014]. Taking action to improve the productivity of the production power in agriculture is also a response to the directions of agriculture development identified in the strategic documents of the European Union and Poland. With the approval of the Lisbon Strategy aimed at enhancing competitiveness, improving productivity became one of the main parameters of assessing the progress of the EU economy development [Floriańczyk et al. 2013].

The Polish agriculture, with the accession to the European Union, noted significant changes, including both structural transformations, as well as the efficiency of the use of its existing production potential, including the profitability of farms. These changes were largely the result of including the agriculture and rural areas in the EU support system. Before the integration the primary source of funding of the changes in agriculture were the owners' own resources and funds originating from the state budget. In the first period after EU accession SAPARD program was implemented until 2006, which aimed to improve the competitiveness of the food economy and sustainable development of agriculture and rural areas. However, since 2007, mechanisms of the Common Agricultural Policy (CAP) became effective, meaning new funding program for agriculture and rural areas. Then the participation in the European single market area resulted in new profitable opportunities for agriculture resulting from the higher level of demand, prices and the implementation of economic support resulting from the rules of the Common Agricultural Policy, as well as external tariff protection [Jóźwiak 2012, Wigler 2014]. Numerous studies on the impact of Polish accession to the European Union confirm the positive changes in the condition of agricultural farms after Poland joined the European Union [Poczta et al. 2012, Spicka 2013].

The aim of the study is to assess the changes that have occurred in the production factors productivity in the agricultural farms in 2012 compared to 2004. We analyzed the flexibility of the correlation between total production in Polish zloty and production factors, i.e. the area of agricultural land in hectares, expenditure of labor in man-hours and total costs in Polish zloty in 2004 and 2012. This allowed the evaluation of the changes in economic efficiency of farms during eight years after the Polish accession to the European Union.

MATERIAL AND METHODS

The study was conducted on the basis of accounting data from commercial farms participating in the Polish FADN (Farm Accountancy Data Network) from 2004 and 2012. It is a database in which data is collected according to uniform rules, and the farms form a statistically representative sample of commercial agricultural farms operating across the EU. The number of farms accepted for analysis in the examined period amounted to 10,992 in 2004 and 9,931 in 2012.

The relationship between the expenditures of factors of production incurred in the production process and the amount or value of the manufactured product is determined as a function of production [Gruszczyński and Podgórska 2000], where the term expenditure is sometimes narrowed down to living and objectified labor. In determining the variables for the production functions two approaches are used. One of them is the recognition of expenses in the form of resources, the second in turn consists of transferring the attention from resource aspects of the functioning of enterprises (employment and value of fixed assets) into categories having the character of streams [Kalinowski 2002]. A function with three variables was used in the study. It takes into account labor, capital and land factor. This is due to the fact that the land as a factor of production constitutes the essence of process management in agriculture [Tomczak 1983, Bezat and Rembisz 2011]. To complete the adopted aim of research, the Cobb-Douglas (C-D) type of function method was used, which is the theoretical basis for explaining the majority of the regularities of efficiency in agricultural economics [Bezat and Rembisz 2011]. The Cobb-Douglas function of production is widely used in econometric studies [Aggelopoulos et al. 2006, Ionita and Andrei 2010, Yuan 2011, Kotulič and Pavelková 2014]. It adopted the following form:

$$Y = aX_1^{\alpha} X_2^{\beta} X_3^{\delta} d$$

where: a – constant (total factor productivity);
Y – total output in Polish zloty (according to FADN-SE131)[1];
X_1 – labor input in hours (SE011)[2];
X_2 – total utilised agricultural area in hectares (SE025)[3];
X_3 – total inputs in Polish zloty[4] (SE270);
α, β, δ – the regression parameters;
d – random factor.

The calculations were performed using the software GRETL[5].

[1]Total output of crops and crop products, livestock and livestock products and of other output.
[2]Time worked in hours by total labor input on holding.
[3]Total utilised agricultural area of holding.
[4]Total inputs are the sum of specific costs, overheads, depreciation and external factors. Costs linked to the agricultural activity of the holder and relating to the output of the accounting year.
[5]ang. GNU Regression Econometrics Time-Series Library, which is a program by Allina Cottrell from Wake Forest University in North Carolina in the United States.

RESULTS AND DISCUSSION

Table 1 shows the statistical description of the variables included in the study, involving expenses on factors of production expressed as a stream (of agricultural area in hectares, workload in working hours, total costs in Polish zloty) and the effect of production expressed as total production value in Polish zloty.

Table 1. Statistical characteristics of analyzed variables in commercial farms within 2004 and 2012

Feature name	Features according Poland FADN	Symbol Variables	Measure unit	Arithmetical mean	Variability coefficient
		Year 2004			
Total production	SE131	Y	PLN	173 029.0	1.84
Total work time	SE011	X_1	h	4 614.5	0.78
Arable lands area	SE025	X_2	ha	30.8	1.54
Total cost	SE270	X_3	PLN	128 664.0	2.00
		Year 2012			
Total production	SE131	Y	PLN	351 786.0	2.65
Total work time	SE011	X_1	h	5 064.4	1.31
Arable lands area	SE025	X_2	ha	48.6	2.43
Total cost	SE270	X_3	PLN	275 012.0	3.08

Source: Own elaboration basing upon unit empirical data from Polish FADN.

The analysis in Table 1 shows that the volatility of characteristics of commercial farms admitted to this study was significantly higher in 2012 than in 2004, for all examined variables. Both in 2012 and in 2004 the highest variability can be observed in the factor of total costs, while the least diverse factor was the total work time. This is due to a family nature of Polish farms, where human labor expenses remain relatively constant due to the fact that they are determined by the number of family members.

In order to determine the productivity of land, labor and capital function models of Cobb-Douglas (CD) type were formed for small commercial farms in Poland for 2004 and 2012. The approximated models of this function express the relationship between total production in Polish zloty (Y) as the dependent variable and the labor in man-hours (X_1), expenditure of land in hectares (X_2) and the flow of capital in Polish zloty (X_3) as independent variables. In 2004 and 2012, they took the form of the following equations:

- $2004: Y = 0.8938 X_1^{0.0846} X_2^{0.0360} X_3^{0.9639}; R^2_{1.3,4} = 0.9358;$
- $2012: Y = 1.1419 X_1^{0.0420} X_2^{0.0206} X_3^{0.9750}; R^2_{1.3,4} = 0.9423.$

Statistical verification of regression coefficients in these equations was performed by using Student's t-test, assuming the level of significance at p = 0.01. The absolute level

of determination coefficients indicate that fluctuations in the value of production in 93.5–– 94.2% are explained by using three variables: labor, land and capital value expressed in total costs. A statistically significant level of multiple correlation coefficients indicates a good fit of the model function to the coordinates of researched characteristics in the studied years. The presented equations are characterized by a high degree of likelihood of regression coefficients in the test period.

Power function is a function of a constant elasticity (independent of the value of individual variables) of the dependent variable and elasticity of individual variables are equal to calculations of parameters characterizing them [Czekaj 2006]. Table 2 shows the level of total elasticity coefficients of productivity factors in terms of production value, as well as a contribution of each of the analyzed factors in the overall value of the coefficient of elasticity.

Table 2. The level and structure of elasticity coefficients value production (Y) with respect to the independent variables (X_1, X_2, X_3) in the years 2004 and 2012 in Poland

Year	The level of production value's total elasticity coefficient	The share of surveyed production factors in total value of output elasticity coefficient (%)		
		X_1	X_2	X_3
2004	1.0845	7.80	3.32	88.88
2012	1.0376	4.05	1.98	93.97

Source: Own elaboration basing upon unit empirical data from Polish FADN.

The sum of the coefficients of the regression in models of C-D function was above 1 in both 2004 and 2012, which means increasing incomes from the scale. Coefficient of total elasticity measures the impact of changes in factors of production on production scale [Santeramo 2014]. The simultaneous increase in all of the analyzed factors of production by 10% while maintaining the existing proportions between them resulted in the production value increases by approximately 10.8% in 2004 and 10.4% in 2012. The coefficients of production flexibility with regard to individual factors of production indicate that the increase in the production value was shaped the most by the flow of capital. Moreover, the share of this factor in the overall value of the coefficient of elasticity increased between 2004–2012 from 88.88 to almost 94%. Also Niezgoda [2010] indicates in his research such trends in 2004–2007. At least important in total production flexibility proved to be the land factor, its impact on the incomes on the scale decreased in the research period by 1.34 percentage points and in 2012 amounted to less than 2%. Also decreased the impact of labor factor on the increase of production value decreased, with its share in the total elasticity coefficients of productivity was 7.8% in 2004 and 4.05% in 2012.

The next stage of research was to bring the above multiple regression equations to partial regression functions, which allowed to explain the relationship between production and the studied factors, i.e. labor, land and capital flow factor. Total productivity and average studied factors of production were established based on partial regression equation, while the first derivatives of the partial function were used to determine the marginal productivity of land, labor and capital. Partial regression equations in relation to each independent variables are shown below:

- for the factor of human labor

$$2004: Y'' = 85\,078.97 X_1^{0.0846}; R^2 = 0.9358;$$
$$2012: Y'' = 248\,700.67 X_1^{0.0420}; R^2 = 0.9423;$$

- for the factor of land

$$2004: Y'' = 153\,539.22 X_2^{0.0360}; R^2 = 0.9358;$$
$$2012: Y'' = 328\,416.72 X_2^{0.0206}; R^2 = 0.9423;$$

- for the factor of capital

$$2004: Y'' = 2.06 X_3^{0.9639}; R^2 = 0.9358;$$
$$2012: Y'' = 1.77 X_3^{0.9750}; R^2 = 0.9423;$$

Table 3 presents the average indices and marginal productivity of land, labor and capital on farms in 2004 and 2012.

Table 3. Average and extreme productivity of labor (X_1), land (X_2) and capital factor stream (X_3) in surveyed commercial farms in 2004 and 2012

Specification	2004	2012	Dynamics (2004 = 100)
Labor productivity			
Average productivity (PLN·h^{-1})	37.64	70.20	186.50
Extreme productivity (PLN)	3.18	2.90	91.19
Land productivity			
Average productivity (PLN·h^{-1})	5639.71	7316.80	129.74
Extreme productivity (PLN)	203.03	148.90	73.34
Capital productivity			
Average productivity (PLN·PLN)	1.35	1.30	96.30
Extreme productivity (PLN)	1.30	1.30	100.00

Source: Own elaboration basing upon unit empirical data from Polish FADN.

The relationship between the total production and expenditure of examined factors of production are shown in Figures 1–3.

The curves shown in Figure 1 illustrate the relationship between the production value and expenditures of labor in researched commercial farms in 2004 and 2012 in the range of variability of the analyzed factor. Figure 2 shows the relationship between the total production (SE131) and the agricultural land (SE025). Graphical analysis of regression equations confirms the known correctness that with an increase in the area of agricultural land the level of total production increases as well. Figure 3 shows the relationship between the total production (SE131) and the level of capital flow (SE270). Curves in

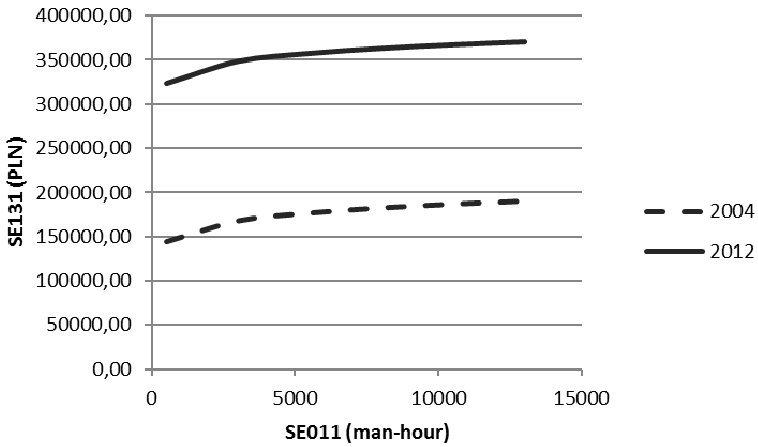

Fig. 1. The dependence between total production SE131 and labor input SE011 in surveyed commercial farms in 2004 and 2012

Source: Own study based on unit empirical data from Polish FADN.

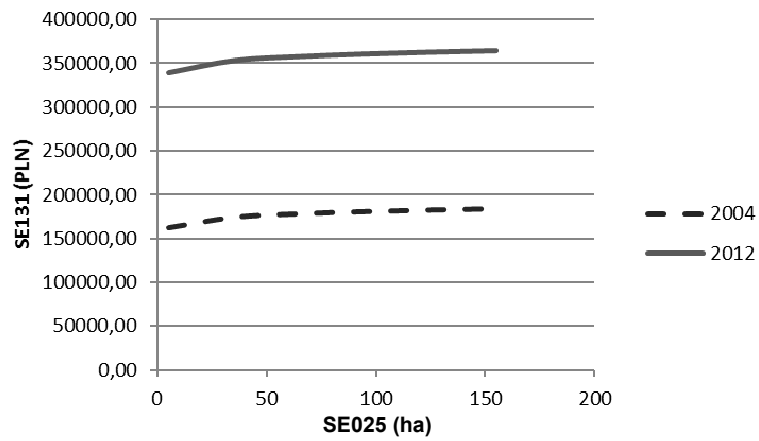

Fig. 2. The dependence between total production SE131 and arable lands area SE025 in surveyed commercial farms in 2004 and 2012

Source: Own study based on unit empirical data from Polish FADN.

Figures 1–3 run similarly to each other, confirming the lack of significant differences in the proportions of production factors in the studied years.

Analyzing the average productivity of examined production factors in two studies years, one may notice growth for both labor and land and a decrease in the case of capital flow. Work is one of the factors of production that affects all economic activities, hence remains a major factor of wealth and development of every community [Boghean and State 2013]. Labor productivity is one of the synthetic indicators of the economic activity in agriculture. The research shows that the value of production per one man-hours of

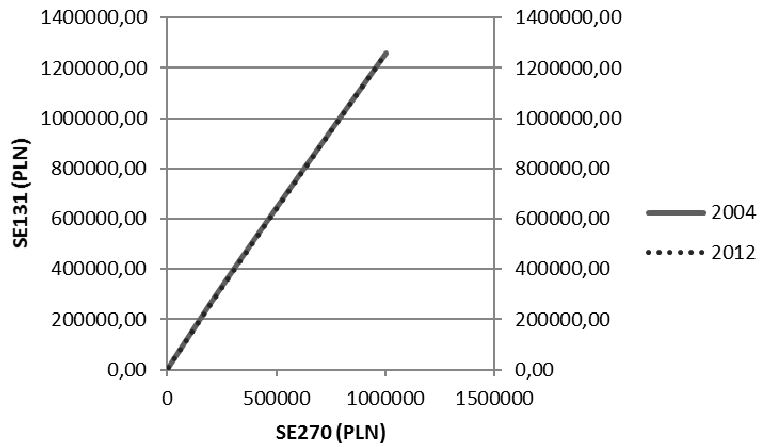

Fig. 3. The dependence between total production SE131 and total costs SE270 in surveyed commercial farms in 2004 and 2012

Source: Own study based on unit empirical data from Polish FADN.

labor in the average farm in 2004 amounted to PLN 37.64, while in 2012 increased by 86.5% reaching a value of PLN 70.20.

Test results by Wójcik and Nowak [2014], covering the period 2004–2009, also indicate the positive trend in the average labor productivity in farms in Poland. They indicate that labor productivity increased by 9.1% during this period and in 2009 reached the value of PLN 40.79 per 1 man-hour. The average productivity of the land means the value of production attributable to 1 ha of agricultural land. Its growth in the studied period was lower than in the case of labor factor and amounted to 29.74%. In 2012, the average commercial farm production value reached the average of PLN 7,316.80 for 1 ha of agricultural land. The negative growth was recorded in the average productivity of capital in the form of total costs. The present rate decreased from PLN 1.35 in 2004 to PLN 1.30 in 2012. This is attributable to a higher rate of growth in costs (213.7%) than the value of production (203.3%) in the researched period.

Analyzing the marginal productivity of specific factors of production one may notice a decrease in its value in relation to the factor of labor and land, while in the case of total costs it remained at the same level in both 2004 and 2012. An increase in the workload of 1 man-hour caused a rise in the value of total production by an average of PLN 3.18 in 2004 and PLN 2.90 in 2012. Assuming that the economic standard of efficiency of human labor expenditure factor was parity rate amounting to PLN 8.33 in 2004 [Skarżyńska et al. 2006] and PLN 12.82 in 2012 [Skarżyńska et al. 2014], it can be concluded that the average farm has not reached its level in tested years. The increase about 1 ha in land contributed to the increase in production value, PLN 203.03 in 2004 and PLN 148.90 in 2012. The coefficient of marginal productivity of capital in the examined period amounted to PLN 1.30 which should be considered a positive trend, indicating that an increase of costs by PLN 1 contributed to the increase in the production of PLN 1.30.

CONCLUSIONS

On the basis of the estimated Cobb-Douglas function it was established that there had been significant changes in the efficiency of production factors in commercial farms in 2012 in comparison to 2004. On the basis of elasticity coefficients reflecting the degree of proportionality of revenue in regard to analyzed factors it can be stated that there were increasing returns from production scale in both studied years. Lower value of flexibility in production in 2012 (1.0845) compared to 2004 (1.0376) indicates that increasing efficiency of combined expenditures was lower in 2012 compared to the base year. The biggest impact on the increase in value of production and the one showing a rising tendency had the capital flow, while the importance of labor and land factors diminished.

The research showed significant changes in the efficiency of management of labor and land factors, and small changes in productivity capital expressed in terms of total costs. Average labor productivity showed a higher growth (86.5%) in the studied years than the productivity of the land (29.7%) and the efficiency in the use of total costs decreased by 3.7%. These changes were accompanied by increased investment in all analyzed factors of production in an average farm. It was economically justified, because the analysis of marginal productivity of factors of production indicates that in 2012 the increase in the workload of 1 man-hour caused a rise in the value of total production by an average of PLN 2.90, an increase of land resources by 1 ha contributed to the increase in production value of PLN 148.90, while the increase in costs by PLN 1 contributed to the increase in the production of PLN 1.30.

Therefore it is highly probable that continued structural changes in Polish agriculture arising from the participation in the European economic area of the single market and the use of economic support mechanisms offered by the Common Agricultural Policy will lead to more efficient use of involved production factors. Among the instruments of Common Agricultural Policy implemented after 2013, which may have a potential impact on improving the efficiency of farms in Poland one can list more opportunities of implementing innovations than ever before, measures promoting the transfer of knowledge, advisory services, investment in physical assets and cooperation.

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ZMIANY PRODUKTYWNOŚCI CZYNNIKÓW PRODUKCJI W TOWAROWYCH GOSPODARSTWACH ROLNYCH W POLSCE W LATACH 2004 I 2012

Streszczenie. Celem opracowania jest ocena zmian, jakie zaszły w produktywności czynników produkcji w towarowych gospodarstwach rolnych w 2012 roku w stosunku do 2004 roku. Analizie poddano elastyczność związków między czynnikami produkcji, tj. powierzchnią użytków rolnych w hektarach, nakładami pracy ludzkiej w roboczogodzinach oraz kosztami ogółem w złotych w latach 2004 i 2012, a uzyskanymi w wyniku ich zastosowania efektami wyrażonymi wartością produkcji. Pozwoliło to na ocenę zmian, jakie zaszły w efektywności gospodarowania towarowych gospodarstw rolnych w ciągu ośmiu lat po akcesji Polski do Unii Europejskiej. W badanym okresie przeciętna produktywność pracy zwiększyła się o 86,5%, a ziemi o 29,7%. Przeciętna produktywność kapitału zmniejszyła się, podobnie jak krańcowa produktywność pracy i ziemi.

Słowa kluczowe: rolnictwo, gospodarstwa rolne, produktywność, funkcja produkcji Cobba-Douglasa

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