European Research Studies Journal
Volume XXIV, Issue 1, 2021

pp. 382-394

The Impact of Fixed Asset Investments on the Productivity of Production Factors in Agriculture

Submitted 26/11/20, 1st revision 22/12/20, 2nd revision 15/01/21, accepted 16/02/21

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Abstract:

Purpose: *The study aimed to determine the impact of the fixed asset investment on farms' productivity. The study adopted a research hypothesis according to which the increase of investment in fixed assets contributes to improved productivity of production factors in agriculture.*
Design/methodology/approach: *The research was based on the Central Statistical Office data storage statistics and the study of reference books. The main source of information was the data from 4,803 farms, which consistently kept accounts within the Farm Accountancy Data Network system. The analyses were based on the productivity indicators in the researched farms. The Cobb-Douglas production function was used in the research. In addition to evaluating the effectiveness of the investment, there were used elements of marginal accounting.*
Findings: *The Polish agricultural sector's investments after 2004 led to changes in the value and structure of agricultural holdings and supported the substitution of human labor with objectified labor. The studies have shown that an increase in the level of investment in agricultural holdings contributes to labor and land productivity growth. Moreover, the examined farms in the years 2005-2013 increased the productivity of capital equity, which indicates the development of farms. The increase in the investment outlays per unit of production factor contributed to increased investment efficiency.*
Practical Implications: *The research results may be useful in economic practice in shaping investments in fixed assets in farms. They can also help to create an agricultural policy to support investment in agriculture.*
Originality/Value: *The originality of the research consists of determining the impact of investments in fixed assets on the productivity of production factors in farms based on the Cobb-Douglas production function.*

Keywords: *Investments, fixed asset, holdings, labor inputs, agricultural land, productivity.*

JEL classification: *O12, Q12, Q14.*

Paper Type: *Research article.*

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1. Introduction

The management of the production potential in agriculture is based on the existing possibilities of substituting production factors. Relations between them depend on a relative degree of their rarity, which is a market economy is reflected in the prices of production factors (Kusz and Misiak, 2017). There are two types of relationships in agriculture: between labor and capital expenditures and land resources and between the land and capital resources and labor resources. The first type of relationship is used to measure the so-called intensity of agricultural production. The second type of relationship is, in turn, the indicator of equipping the labor in land and other means of production, especially technical ones (Kusz, 2018).

According to the production theory, an undertaking seeking to maximize the profit selects a combination of production factors that will allow it to achieve its desired level at the lowest possible cost of these factors (Adamczyk, 2009). Increasing one production resource, especially labor and capital, usually takes place at the expense of reducing the other. Excessive concurrent equipment of farms in human labor and the capital can also cause inefficiency of a farm and lead to deterioration in this entity's economic performance. The phenomenon of substitution in agriculture is an integral part of any production process. Agricultural producers' decisions regarding the applied production technique, which is understood to connect the production factors like land, labor, and capital, are made based on prices and efficiency of owned resources (Heijman *et al.*, 1997).

The corresponding relationship between the production factors and their rational use is an essential condition for the production process's efficiency. High economic efficiency of existing production resources creates, in turn, opportunities for effective competition in the market (Trzeciak-Duval, 1999; Coelli and Rao, 2003; Gorton and Davidova, 2004; Rungsuriyawiboon and Lissitsa, 2006; Poczta, 2008). According to the paradigm of classical economics, business operators allocate their production resources that lead to equalization in payment for labor and other production factors in various uses. In agriculture, the flow of productive resources to higher performance applications is limited by barriers resulting from production specificity in this sector.

Among these barriers, Woś (2001) and Zegar (2004) enumerate limited mobility of production factors, especially land, natural and biological limitations, and the complexity of the farm's objectives stems from the integral relationship between a household and an agricultural holding. These factors cause that agricultural producers are deprived of the resource allocation benefits resulting from their being moved to sectors where they would have higher efficiency (Woś, 2001). The structure of the resources allocated in agriculture is also affected by external factors, especially by the state police, whose task is to stimulate a specific direction of transformations within a current paradigm, as well as bridge the gap resulting from the lack of markets and the need to ensure charges for positive externalities (Czyżewski and Kułyk, 2012).

According to Mikolajczyk (2006), investment is needed to reproduce and develop production capacity and improve Polish agriculture's profitability and competitiveness. Increasing the stock of fixed assets or improving their quality contributes to increasing the farm's potential in the future. Investment projects are mainly to substitute human labor with capital, which results from changes in the cost price of production factors, among which the most dynamic are labor costs (Ziętara, 2008). This has consequences for the economy and organization of farms, consisting of the preference for labor-saving and capital-intensive techniques and technologies (Runowski, 2009). The increasing use of capital-intensive technologies contributes to agricultural production growth by promoting land and labor input substitution with capital.

The study aimed to determine the impact of the investment on the productivity of farms. The study adopted a research hypothesis according to which the increase of investment in fixed assets contributes to improved productivity of production factors in agriculture.

2. Material and Methods

The research was based on the study of reference books in investment and resource productivity in agriculture and the CSO data storage statistics. The main source of information was the data collected within the framework of Polish FADN. Their selection was dictated by the fact that the FADN agricultural accounting data are obtained from the farms representative for the entities producing 93.03% of the Standard Production (SO) of all classified farms in Poland. Hence, the resulting conclusions can be generalized.

Detailed studies included 4,803 farms, which consistently kept accounts within the FADN accounting system. This criterion allowed us to show the continuity of changes taking place in the structure and the value and volume of production about the realized investments. The farms were divided into three quartile groups:

Q1 - 25% of farms with the lowest level of investment outlays;
Q2 - Q3 50% with an average level of investment outlays;
Q4 - 25% of farms with the highest level of investment outlays.

The research period covered the years 2005-2013. The said time range was chosen for three reasons:

- the analysed period saw the most dynamic changes in the level of investment in Polish agriculture, which allows for a reliable assessment of changes in property holdings after the Polish accession to the European Union,
- the adopted scope covers the implementation of two support programs that are important for the co-financing of investments in agriculture, namely: the Sectoral Operational Program 2004-2006 and Rural Development Programme 2007-2013,

- the condition for the continuation of accounting under the FADN system significantly reduces the sample size. In order to optimize the accuracy of inference, the study period was reduced to 9 years.

The data analysis included different statistical methods. To determine the relationship between labor and capital factors, the author used the neoclassical Cobb-Douglas production function. Commonly known is the three-factor production function, which is presented as follows:

$$Y = A * (l^{\alpha}) * (K^{\beta}) * (M^{\gamma}) = f (L, K, M), \quad (1)$$

where:
Y - product;
L– work;
K - capital;
M - raw materials and consumables;
A, α, β, γ - function parameters.

The study uses simplifications, combining fixed assets with working capital. The production function then took the following form:

$$Y = A * (n^{\alpha}) * (K^{\beta}) = f (n, K), \quad (2)$$

To assess agricultural investment's impact on agricultural holdings' productivity, the author used three basic indicators: labor productivity, land, and capital (Szymańska, 2011). Their calculation formula is as follows: labor productivity - production value (PLN) / number of full-time employees at the farm (AWU):

- land productivity - production value (PLN) / UAA (ha);
- equity productivity - production value (PLN) / value of own assets (PLN).

To express the adopted indicators in constant prices of 2005, the value of agricultural production was discounted by the price index of goods sold in agriculture. According to the Polish CSO, in the period (2005-2013), this ratio was 1,612, which means that the prices of goods sold in agriculture increased by 61.2%. Additionally, in order to present the changes in the productivity of the owner's equity in fixed prices, its value was adjusted with the indicators of changes in the prices of investment assets in agriculture (+ 28% in the period 2005-2013) published by the Polish Central Statistical Office, as well as with the indicator of changes in agricultural land prices in the private trading, published by the Institute of Agricultural and Food Economics - National Research Institute (IERiGŻ- PIB), which in the analysed period was 3.19 (+ 219%).

In addition to evaluating the effectiveness of the investment, there were used elements of marginal accounting. As a result of the research on the investment technical efficiency, the study assumed the increase in productivity of elementary factors of

production (labor and land) in the analysed period. Whereas on the side of the investment, the account was taken of the value of investment outlays. To reduce the impact of market factors on the presented results, the changes in the productivity were presented in fixed prices calculated using appropriate indicators of changes in agricultural prices published by the Central Statistical Office (Table 1).

Table 1. *The price index of agricultural products and purchased goods and the price index of investment goods*

Specification	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Agricultural goods sold	1.000	1.026	1.145	1.012	0.979	1.121	1.186	1.042	1.003
Goods and services purchased for current agricultural production	1.000	1.006	1.063	1.112	1.020	1.018	1.097	1.060	1.012
Prices of investment goods and services	1.000	1.019	1.061	1.053	1.023	1.012	1.034	1.030	1.018

Source: *Central Statistical Office.*

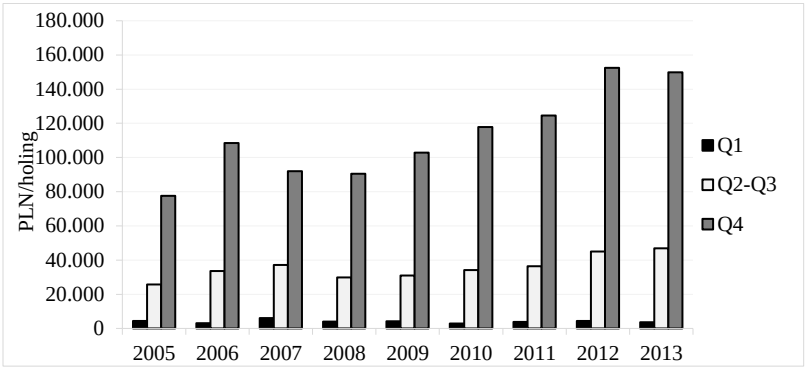
3. Empirical Results

The examined holdings were characterized by significant differences in the level of investment value. In the agricultural holdings of the highest investment (Q4), the total investment outlays in the analysed period (2005-2013) were more than 27 times higher than in households from the first group (Q1) and about 59% higher than in the second group (Q2-Q3).

The level of investment and the scale of changes in individual years were a matter of decision mainly for the farms with the highest investment. On average, in the years 2005-2013, they corresponded to 60% of the value of investment outlays in the sample agricultural holdings. Some variety also showed the volume of changes in investment outlays in the identified groups. In the farms with a medium (Q2-Q3) and high (Q4) level of investment, the investment outlays in the years 2005-2013 increased respectively by 81 and 93%, while in agricultural holdings investing the least, they decreased by 16% (Fig. 1). This means that there grew the polarization of farms about agricultural investment. While still in 2005, the holdings from the first quartile accounted for 3% of investment outlays in our sample, already in 2013, they made only 1.5%.

The comparative analysis of investment outlays in the surveyed households showed that an increase in the investment outlays implies an increase in investment intensity. In the farms from the fourth quartile, the level of investment outlays per 1 ha AL was 6.3-fold higher in 2005-2013 than in the first quartile farms, and per Average Unit Work (AWU), it was 16.7-fold higher (Table 2). With the increase in the value of investments, there increased their share in the family farm income.

***Figure 1**. Investment outlays in agricultural holdings by quartile groups in the years 2005-2013*



***Source:** Own study based on FADN data.*

The analysis shows that in the agricultural holdings with the lowest investment (Q1), the share of investments in the family farm income in the years 2005-2013 was on average 15% compared to 60 and 68% in the third (Q2-Q3) and fourth (Q4) group of farms respectively. This disparity can be explained by the existence of a minimum level of income spent on farmers' needs and does not allow for implementing investment objectives. The average income of the family farm per person employed on a full-time basis in the group of entities investing the least accounted for 51% of the National average salary in 2013, compared to 105% in agricultural holdings from the group with a medium level of investment and 275% of the agricultural holdings that invest the most.

***Table 2.** Selected indicators of investment in the identified groups of agricultural holdings averagely in years 2005-2013*

Specification	Quartile groups		
	Q1	Q2-Q3	Q4
Investment outlays / 1 ha of UAA	0.27	1.28	1.69
Investment outlays / AWU	2.46	18.01	41.23
Investment outlays / income from a family farm	0.15	0.60	0.68
Fixed asset renewal rate	0.02	0.07	0.09
Investment rate	0.36	1.66	2.04

***Source:** Own study based on FADN data.*

The increase in the nominal level of investment and intensity of investments resulted in the rise of the renewal rate of fixed assets. In agricultural holdings with the highest investment (Q4), its average rise was by about 9%, while in the farms from the first group (Q1) by 2%. This level in the agricultural holdings, the least active in investing, did not allow for reproducing the entire assets they owned. The average investment in this group of farms covered the depreciation of available fixed assets only by 36%. The data analysis in the sample agricultural holdings shows that the minimum rate of the renewal ratio of fixed assets, which inhibited divestment processes, was 4.3%. In turn, the rate of investment in the group of agricultural holdings with a medium level

of investment (Q2-Q3) accounted on average for 1.66%, and in the group of highest investment (Q4) - 2.04%. This means that the level of surplus investment covered the costs of depreciation in these entities. The results, therefore, indicate large disparities in the level of investment between groups.

The studies have shown that an increase in the level of investment in agricultural holdings contributes to labor and land productivity growth. The increase in productivity of these production factors, expressed in real and in fixed prices, was the biggest in the group of agricultural holdings characterized by the highest investment level. The only group in which the record showed an increase in land productivity calculated in fixed prices, with the observable decrease in the first and second groups (Table 3). In turn, labor productivity calculated in fixed prices in the group of holdings with the highest level of investment (Q4) increased in the period 2005-2013 by 24%, with less than 1% average increase in the second group (Q2-Q3) and a 12% decline in the first group (Q1). Strong growth in land productivity in farms with the highest level of investment resulted largely from substituting labor with fixed capital. On this basis, a conclusion can be drawn that investment positively impacts the production level both per 1 ha of AL and per person employed on a full-time basis.

In the analysed period (2005-2013), the owner's equity's productivity has increased in each of the analysed groups of farms. However, this increase was the highest in the group of farms of the lowest investment (Q1) and the lowest in agricultural holdings that invest the most (Q4). Such a phenomenon is a consequence of a rapidly decreasing base indicator over the period, which is the value of their own assets in the first group's holdings (Q1). A decrease in the value of fixed assets in this group of holdings has a negative character, as it indicates a divestment phenomenon, and a faster pace of change in the productivity of owners' equity does not represent, in this case, positive efficiency trends.

Table 3. *Productivity of labour, land and own capital in the surveyed households*

Quartile group	Years	Productivity - real prices			Productivity - constant prices (from 2005)		
		labour	land	equity capital	labour	land	equity capital
Q1	2005	38	4,25	0,27	38	4,25	0,27
	2009	41	4,47	0.30	36	3.84	0.33
	2013	54	5.79	0.36	33	3.58	0.34
	change (%) 2009/2005	*9%*	*5%*	*11%*	*-6%*	*-10%*	*21%*
	change (%) 2013/2005	*43%*	*36%*	*31%*	*-12%*	*-16%*	*25%*
Q2-Q3	2005	62	4.59	0.33	62	4.59	0.33
	2009	70	4.93	0.34	60	4.24	0.36
	2013	101	6.85	0.39	62	4.24	0.36
	2009/2005	*13%*	*7%*	*1%*	*-3%*	*-8%*	*9%*
	2013/2005	*63%*	*49%*	*16%*	*1%*	*-8%*	*7%*
Q4	2005	116	5.21	0.43	116	5.21	0.43
	2009	152	6.20	0.42	131	5.33	0.46
	2013	234	8.92	0.47	144	5.52	0.43
	change (%) 2009/2005	*31%*	*19%*	*-2%*	*12%*	*2%*	*7%*

	change (%) 2013/2005	*101%*	*71%*	*9%*	*24%*	*6%*	*1%*
Total	2005	74	4.84	0.36	74	4.84	0.36
	2009	91	5.50	0.37	78	4.72	0.40
	2013	136	7.78	0.43	84	4.81	0.39
	change (%) 2009/2005	*23%*	*14%*	*2%*	*5%*	*-2%*	*11%*
	change (%) 2013/2005	*83%*	*61%*	*17%*	*13%*	*-1%*	*8%*

Source: *Own study based on FADN data.*

The notion of productivity involves the question of efficiency. In the reference book, the approach to the agricultural sector's investment efficiency is quite diverse, and it largely comes down to determining the relationship of profit to expenses incurred for investment. Manteuffel (1966) described as investment efficiency the relationship of investment benefits to investment outlays. For Czekaj and Józwiak (2009), the investment benefit was the limit (marginal) increases in the income from the production factors, the function (2) of the investment efficiency being determined in the following way:

$$E_i = \frac{\mathrm{DY_i} - \mathrm{jK_i}}{jK_i}, \tag{3}$$

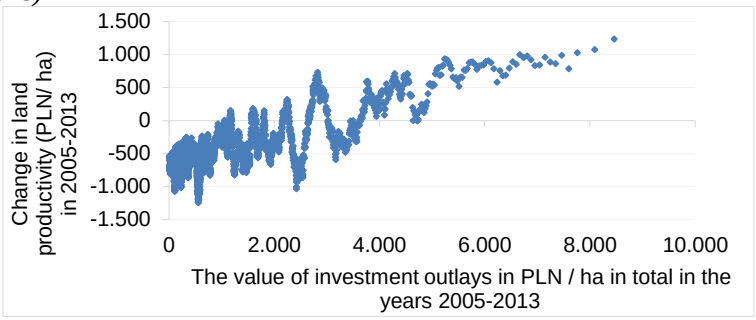
where:
E_i – investment efficiency in the i-th production factor (i = L, A or K),
DY_i – the marginal rise in the income from an increase in the i-th production factor,
jK_i – -a unit cost of the i-th production factor.

Given the research focus, the study has assumed for the analysis that the effect of the realized investment is a yearly growth of productivity measured in fixed prices per unit of the resource, land and labor. Thus, the investment efficiency was expressed as the relation of this increase to the value of investment outlays per hectare of agricultural land and a person employed on a full-time basis (weighted average) over 2005-2013. The values for both productivity gains and investment outlays were expressed in fixed prices. The analysis results are presented in a graphical manner (Figures 2 and 3), as a moving (rolling) average for a hundred consecutive observations. The moving average sought to eliminate or alleviate the random fluctuations and identify a trend out of more than 4,800 observations. The studies have shown that the increase in investment outlays per 1 ha of AL contributed to the increase in the surveyed households' investment efficiency. The increase in land productivity per one zloty of investment outlays in the examined farms showed a positive correlation with the size of investment per1 ha of AL in 2005-2013. A higher rate of investment contributed to the growth of marginal productivity gains per 1 ha of AL.

Therefore, it can be concluded that having more asset resources, both in terms of quantity and quality, promotes the growth of productivity. Low investment, not covering the depreciation costs, may contribute to the weakening of the farm's production capacity and thus cause a decline in production per unit of land. It is worth noting that the average level of investment in the amount of less than 1 thousand

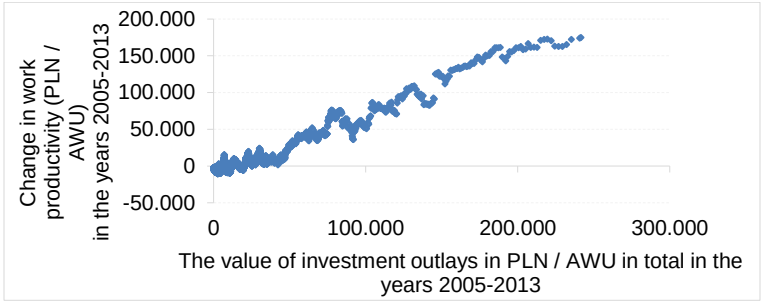
PLN/ha in the analysed period contributed to the decline in land productivity in most of the surveyed agricultural holdings.

Figure 2. *Changes in the land productivity in relation to investment outlays per 1 ha of AL in total in the analysed period - the moving average (1 point = 100 observations)*



Source: *Own study based on FADN data.*

Figure 3. *Changes in labour productivity in relation to investment outlays per 1 AWU*



Source: *Own study based on FADN data.*

Similar trends were observed in terms of labor productivity. The increase in the investment level about the available labor resources brought benefits in the form of increased production value per person employed on a full-time basis (AWU). Note, however, that the increase in the investment efficiency, in either case, is the result of not only increasing the amount of investment itself, but it also depends on the nature of the investment and its quality. A large share of replacement investments, which consist of restoring fixed assets to their previous state, do not bring such significant effects as development investments or even modernization. The studies on the substitution of human labor with objectified labor were extended to the study of changes in labor and capital relations each year. Because the relationship between the amount of spending and the volume of production results is usually expressed using the production function (Błażejczyk-Majka and Kala, 2010), the changes in the levels of labor and capital factors in each group of agricultural holdings were determined using the Cobb Douglas neoclassical function (a three-way function) (Tokarski, 2011).

The process of creation of the production function for the analysed groups of farms omitted the land factor. This was because the variability of this factor in the whole economy is limited. According to Klein (1965), the land is a constant production factor and can be ignored as a variable in most studies. However, examining individual farms, where there is a possibility of increasing its resources, the changes in this factor may translate into farm production's size and value. Therefore, taking account of the analysis's main objective, i.e., the determination of changes in the formation of production concerning labor and capital, the calculations were referenced to 1 ha of AL. The result value of the achieved production function is, therefore, the profitability of a farm per 1 ha of AL, and the function variables include the value of labor input expressed in AWU per 1 ha of AL, the value of fixed assets (without land) per 1 ha of AL and the direct costs per ha of AL. Parameters of the production function were estimated for the years 2005 and 2013 in fixed prices of 2005. The estimated production function models showed a good fit to the empirical data, as evidenced by high determination coefficients (R^2) ranging from 0.79 to 0.93, which means that by the adopted explanatory variables used in the model, the variance of income was explained in 79-93% (Table 4). In each model, the function parameters in the examined quartile groups and the analysed years proved to be statistically significant with the p-value lower than the assumed confidence level $\alpha = 0.05$.

Table 4. *Estimated parameter values of the Cobb-Douglas production function in 2005 and 2013*

Year	Parameter	Q1		Q2-Q3		Q4	
		Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
2005	L/ha	0.23	0.00	0.24	0.00	0.26	0.00
	C/ha	0.20	0.00	0.21	0.00	0.23	0.00
	D/ha	0.63	0.00	0.60	0.00	0.57	0.00
	Intersection	2.27	0.00	2.60	0.00	2.76	0.00
	R^2	0.84		0.83		0.93	
2013	L/ha	0.31	0.00	0.25	0.00	0.24	0.00
	C/ha	0.12	0.00	0.13	0.00	0.16	0.00
	D/ha	0.63	0.00	0.63	0.00	0.63	0.00
	Coefficient	3.16	0.00	3.01	0.00	2.96	0.00
	R^2	0.79		0.83		0.92	

Note: *L - labor inputs expressed in AWU, C - capital value - non-current assets without land, D - value of direct costs.*
Source: *Own study based on FADN data.*

When using the model's estimated parameters, there can be seen quite significant differences in the formation of the production function in agricultural holdings with different levels of investment in the two limit years of analysis. The studies have shown an increase in the importance of labor in production levels in the farms of the lowest investment (Q1). In 2005, the increase in the labor input per 1 ha of AL by 1% would increase production per hectare value by 0.23%, and in the year 2013 by 0.31%. At the same time, a decrease was recorded for the importance of the capital.

The increase in its value by 1% in 2005 would increase land productivity by 0.2%, and in 2013 only by 0.12%.

In the agricultural holdings with the highest level of investment, the relations have evolved in a similar direction but much slower. The decrease in the importance of capital formation in agricultural production was only slight. This means that a low level of investment makes the production more and more dependent on labor, which, with declining resources at the country level, can mean a big threat to the continuity of farms that have a low investment activity. The lack of investment largely inhibits the progressive processes of substitution in the agricultural sector. What draws attention is the growing importance of the direct costs in the production function models from the years 2005 and 2013 in each of the identified groups, which confirms the increasing intensity of production in the examined farms and the entire agricultural sector in the country.

4. Summary and Conclusions

The agricultural holdings in Poland are characterized by large differences in the level and rate of investment changes. Larger changes in the level of expenditures relate to farms with higher investment outlays due to their financial capabilities. In farms with a medium and high level of investment, the investment outlays in the period 2005-2013 increased by 81 and 93%, respectively, while in the farms with the lowest investment, they decreased by 16%. These results, therefore, indicate a deepening imbalance in the level of investment between farms.

The increase in investment outlays implies an increase in the investment intensity. In the years 2005-2013, in agricultural holdings with the highest investment, the average level of investment per 1 ha of AL was 6.3 times higher than in farms with the lowest investment, and in terms of AWU, it was 16.7 times higher. The increase in the level of investment and investment intensity increased the renewal rate of fixed assets. In turn, in the farms, the least active in investment, the investment did not cover depreciation costs. This means a growing polarization of farms regarding investments.

The studies have shown that an increase in the level of investment in agricultural holdings contributes to labor and land productivity growth. Strong land productivity growth on farms with the highest level of investment resulted largely from substituting labor with fixed capital. On this basis, it can be concluded that investment has a positive impact on the production levels both per 1 ha of AL and per person employed on a full.-time basis. In this way, the working hypothesis of this article has been positively verified.

In each of the analyzed groups in the years 2005-2013 increased the productivity of capital equity, which indicates the development of farms. However, this increase was the highest in the group of farms investing the least and the lowest in farms with the highest investment. This resulted from a rapidly declining value of owned assets in

the agricultural holdings with the lowest investment level. A decrease in the value of fixed assets in this group of farms has a negative character, as it indicates the divestment phenomenon and a faster pace of changes in the capital equity productivity do not represent, in this case, positive efficiency trends. In the examined farms, the increase in the investment outlays per unit of production factor contributed to increased investment efficiency. This is confirmed by a positive correlation of the productivity gains per one zloty of investment outlays to the investment size. Similar trends were observed in terms of labor productivity.

However, it must be noted that the increase in the investment efficiency, in either case, is the result of increasing the amount of investment itself and depends on the nature of the investments and their quality. In order to improve the competitiveness of Polish agriculture and increase the income of agricultural producers, it seems reasonable to seek to increase the productivity of capital, which can be done in two directions: by reducing the volume of inefficient fixed assets, primarily in economically weak farms, also as a result of consolidation processes, by raising real productivity of fixed assets through greater investment in modern and efficient technologies and modernization of existing fixed assets, which means improving the quality of owners' equity. Low level of investment makes the production more and more dependent on labour, which, with declining resources at the country level can mean a big threat to the continuity of farms that show a low investment activity.

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