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The Relationship of Investments and Subsidies to Labour Productivity in Agriculture in Poland between 2010 and 2015

Abstract: Following the microeconomic producer theory as a framework, this paper studies the empirical relationship between investments and subsidies from the CAP and labour productivity on farms, thus also on whole agriculture sector. It refers to labour productivity as the basis of producers' income and the investments affecting the capital endowment as a major source of productivity improvement. The aim of the article is to present analytical and empirical evidence of the positive relationship to labour productivity of the growth of investments as well as subsidies on investments. The multifactor ANOVA models with interactions are used as an applied research tool to assess the differences in labour productivity, for example by investments and subsidies on investments. The results obtained indirectly suggest that agricultural producers behave rationally as far as the relationship between investment and labour productivity is concerned.

Keywords: investments, subsidies, labour productivity, farms, agricultural policy.

1. Introduction

The purpose of this paper is to identify and illustrate the empirical relationship between investment and its support from the CAP (Common Agricultural Policy) and labour productivity on farms. The analytical approach to the relationship between these variables and the empirical illustration, and in a sense also the verification, are our contributions to these issues. We refer to labour productivity because implicitly it is the basis of farmers' income from work, while investments are the most visible sign of development processes, also among agricultural producers.

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Thus it is possible to formulate a hypothesis about the possibility of observing such a positive relationship. The analysis is conducted only in close connection with the analytical approach derived.

We accept some basic theoretical and hypothetical relationships between savings, investment and physical capital and, as a result, between the technical equipment of the labour factor and its efficiency.[1] These are based in the regularities known from microeconomics related to the technical and production relationship, where the starting point for the description of the reality is the construction of the production function and the theory of production factors. We relate this to the agricultural producer as a special case of the concept of the producer from microeconomics. These relationships are presented analytically by means of identity equations and difference quotients. Theoretical deliberations about the relationship between investment and subsidies in the context of the expected change in labour productivity in agriculture, based on the microeconomic theory of the producer, were introduced, among others, in work of Rembisz, Sielska and Bezat-Jarzębowska (2014) or partially also in work of Dorward (2013).

However, so far the empirical verification of the relationship between investments or subsidies on investments within policy instruments and labour productivity has not been widely discussed in the literature. The examination of the impact of investments, and in particular payments to support investment, was carried out primarily in the context of evaluation of the agricultural policy instruments implemented. As Nilsson (2017) points out, the results presented in the literature do not give a clear answer as to the positive or negative impact of investment support on the efficiency of the production factors on farms.[2] For example, Ratinger, Medonos and Hruska (2013) demonstrate the positive impact of the CAP support on labour productivity on medium-sized agricultural holdings in the Czech Republic. The results presented by Mary (2013) suggest, in turn, that several CAP subsidies have a negative effect on productivity of crop farms in France, but, in contrast to previous studies, the impact was not significant for all CAP payments (see Latruffe 2010; Sckokai and Moro 2009; Zhu and Lansink 2010). Similar conclusions about the lack of significant differences in labour productivity between the farms either benefiting from investment support or not were also reached by Sielska and Pawłowska (2016) in a work paper researching farms in Poland.

[1] The efficiency of the labour factor (labour productivity) is defined in this study as gross value added per annual work unit.

[2] Michalek, Ciaian and Kancs (2014) emphasise that the discrepancy between the results may be due to a different methodological approach. According to Nilsson (2017), the issue of dealing with selection bias is problematic. Most of the instruments in the framework of the CAP are deliberately addressed to specific beneficiaries, whereas usually the allocation of subsidies is considered random.

The relationship of investments, capital and subsidies to labour productivity

Performing the analysis at the level of a single agricultural producer, it can be assumed that with the constant employment of the labour factor and a given land factor resource, the increase in the use of the physical capital factor should imply an increase in the technical equipment of labour:

$$\left(L = \text{const.} \wedge K \uparrow\right) \Rightarrow \frac{K}{L} \uparrow \tag{1}$$

and consequently lead to increased labour productivity:

$$\frac{K}{L} \uparrow \Rightarrow \frac{y}{L} \uparrow, \tag{2}$$

where: L is the labour input, K is the capital input and y is the production per capita.

The basis of these processes are investments made by producers (see Rembisz and Sielska 2014; Rembisz, Sielska and Bezat-Jarzębowska 2014). In simple terms, ignoring time subscripts and investment sources (e.g. loans, subsidies or savings), the following relationship exists:

$$I \Rightarrow K \tag{3}$$

where I is investment.

As Chiang and Wainwright (2005) point out, if this process is considered continuous, the increase in capital is equal, in identity terms, to the rate of the net investment stream in a given period:

$$\frac{dK}{dt} \equiv I(t). \tag{4}$$

Thus a farm's physical capital involved is a derivative of investment, hence:

$$K(t) = \int I(t)dt = \int \frac{dK}{dt} dt = \int dK. \tag{5}$$

Taking into account the nature of the capital and investments,[3] the volume of net investments made, i.e. the accumulation of the physical capital at the producer over a specified period of time, can be defined as:

$$\int_0^t I(t)dt = K(t) - K(0). \tag{6}$$

[3] Capital is treated as a "resource" and investments as a "stream".

Hence, the temporal path for the physical capital is determined according to the equation (cf. Pejin 1971):

$$K(t) = K(0) + \int_0^t I(t)dt. \tag{7}$$

In discrete time, the level of the physical capital involved at the agricultural producer in a given period can be defined as the result of the accumulated investment and consumption of the capital factor (cf. Stiroh 2001):

$$K_t = I_t + (1-\delta)K_{t-1} \tag{8}$$

which, after the transformation gives us, of course:

$$I_t = K_t - (1-\delta)K_{t-1} = \Delta K, \tag{9}$$

where δ is capital depreciation factor and $\delta \in [0, 1]$.

The positive relationship between the value of fixed assets (physical capital) and investments (in cash) was confirmed in Figure 1. As can be seen, in the period analysed, the increase in the value of investments was accompanied by an increase in the value of fixed assets.

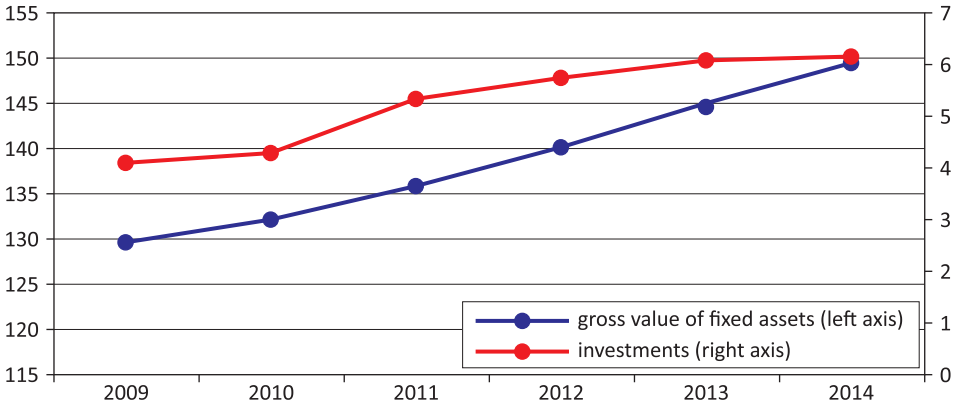

Figure 1. Gross value of fixed assets and investments in agriculture in Poland between 2009 and 2014 (in PLN million)

Source: Pawłowska and Bocian 2017, p. 19.

Investments are the basis for the occurrence of specific production techniques, i.e. specific relationships between the factors involved in production. In particular, investments determine the relationship of the capital factor to the labour factor, which can be expressed as the following implication:

$$I \Rightarrow (1-\beta)K \Rightarrow \frac{K}{L}, \tag{10}$$

where β is the degree to which investment translates into the capital factor available to the agricultural producer. This in turn results in an increase in labour productivity, which in simplified terms can be presented as the following sequence of implications:

$$I \uparrow \Rightarrow K \uparrow \Rightarrow \frac{K}{L} \uparrow \Rightarrow \frac{y}{L} \uparrow, \tag{11}$$

or as:

$$\frac{dI}{dt} \Rightarrow \frac{d\left(\frac{K}{L}\right)}{dt} \Rightarrow \frac{d\left(\frac{y}{L}\right)}{dt}. \tag{12}$$

Hence the analysis of the following relationship seems interesting:

$$\alpha = \frac{dI}{dt} \Big/ \frac{d\left(\frac{y}{L}\right)}{dt}, \tag{13}$$

as more indirect compared to the relationship of the increase in technical equipment to labour productivity. We can assume that the value of a factor equal to unity means the same growth of investments and labour productivity in a given year compared to 2009. If $a > 1$, the dynamics of investments in a given year was higher than the dynamics of the labour productivity. Conversely, when $a < 1$, the increase in the productivity of labour factor was ahead of the growth of investments over time. Of course, this allows us to assess the effectiveness, or rationality, of this process.[4] This factor will be illustrated empirically later in the paper.

The above-mentioned model of investment implications, the involvement of the capital factor for a given labour input and the resulting labour productivity, to some extent assumes autonomy of the process based on rationality premises. Leaving aside the deeper reference to the above, we assume, in accordance with reality, that the investment decisions of agricultural producers are also affected by payments from the Common Agricultural Policy. These payments can be defined as a kind of political rent (Rembisz, Sielska and Bezat-Jarzębowska 2014). The political rent, and as a matter of fact the income effects of the policy received by agricultural producers are likely to increase the savings and creditworthiness of agricultural producers necessary to make investments. This can be a catalyst for investment in fixed factors of production. Of course, this is facilitated by changes

[4] A growth of investment higher than the growth of the labour factor efficiency may be the consequence of irrational decisions by agricultural producers regarding investment, e.g. as a result of subsidies, as we will refer to later in this paper.

in technical relations, which mainly allow for improvement in the technical equipment of labour. This, in turn, implies an increase in labour productivity according to the above schematic analytical approach. As Rembisz, Sielska and Bezat-Jarzębowska (2014, p. 54) note, "if these subsidies would contribute to this type of investment, then it would fulfil a similar role as the savings from the outside (regardless of the form), sourced as foreign investment in the whole economy." However, it is emphasised that instruments aimed at direct investment targets, from the point of view of rational choice of an agricultural producer, make it possible to achieve a lower level of investment than political rent. This can result, for example, in an irrational choice and the use of too capital-intensive production techniques and, as a result, in irrational technical relationships on a farm. Direct payments, defined as the main form of political rent, which is an implicit source of income and savings for a producer, do not have these drawbacks.

We therefore assume that the most important fact is that the political rent allows increasing savings as a basis for investment by an agricultural producer, which in turn results in the increased use of physical capital in relation to the constant input of the labour factor, which we can illustrate as follows:[5]

$$S_{t-1} + B_t \Rightarrow I_t \Rightarrow K_t \Rightarrow \frac{y_t}{L_t}, \tag{14}$$

where: S are savings and B are subsidies.

Figure 2 shows the level of labour productivity for farms which did or did not receive support under the CAP. On farms receiving investment payments between 2007 and 2015, there was on average higher labour productivity than on farms which did not receive this support, which is to a certain extent confirmed by the adopted analytical approach.

This reasoning is based on the assumption that a characteristic situation of an agricultural producer is when the investment needs are greater than the possibilities of financing them from the savings for a given period (see Rembisz and Sielska 2014):

$$S_t < I_t \tag{15}$$

and

$$\Delta S_t < \Delta I_t. \tag{16}$$

[5] The production function underlying this reasoning is characterised by positive but decreasing marginal products (see Krugman and Wells 2013):

$$\frac{\partial Y}{\partial x_i} > 0 \text{ and } \frac{\partial^2 Y}{\partial^2 x_i} < 0,$$

where x_i is the i-th production factor.

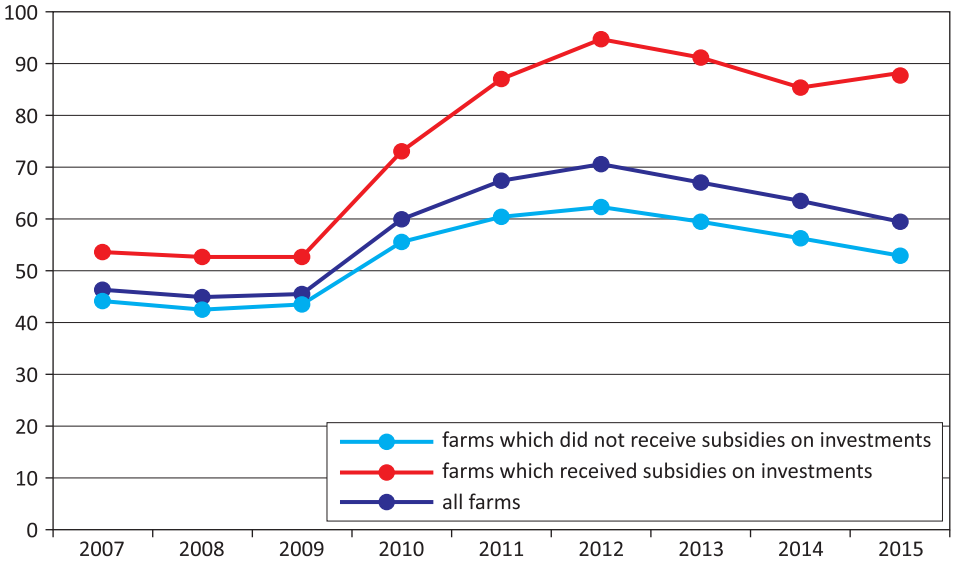

Figure 2. Average labour productivity vs subsidies on investments in Polish farms between 2007 and 2015 (in PLN thousand)

Source: Pawłowska and Bocian 2017, p. 25.

Too low level of savings makes it impossible for the producer to change production techniques, and thus to develop, in particular to increase the productivity of the labour factor. The political rent that directly increases savings – especially when it is a direct payment to investment – is therefore a factor reducing this limitation:

$$S + B \Rightarrow I. \tag{17}$$

In addition, through payments made under other CAP instruments, the investments made and the capital used may be greater than those that would result from "natural" savings:

$$I(K) > S \Leftarrow B, \tag{18}$$

and

$$\Delta I(K) > \Delta S \Leftarrow B, \tag{19}$$

which should ultimately effect an increase in labour productivity:

$$\frac{dS}{dt} + \frac{dB}{dt} \Rightarrow \frac{dI}{dt} \Rightarrow \frac{d\left(\frac{K}{L}\right)}{dt} \Rightarrow \frac{d\left(\frac{y}{L}\right)}{dt}. \tag{20}$$

Besides the relationship *a*, it is therefore also interesting to examine the relationship *b* defined as:

$$b = \frac{dB}{dt} \Big/ \frac{d\left(\frac{y}{L}\right)}{dt}. \tag{21}$$

Assuming that the above reasoning is correct in the sense of the cause-and-effect relationship, this factor can indirectly illustrate the impact of payments on the growth of labour productivity. We can assume that $b > 1$ refers to a situation where the dynamics of support exceeds the dynamics of labour productivity, which may be a sign of ineffective allocation of transfers. If, in turn, $b < 1$, the rate of the labour factor efficiency growth exceeds the increase in payments to investment over time, which may indicate real benefits of the implementation of the policy instrument analysed.

2. Data and methodology

This work uses balanced panel data on individual farms from the Polish FADN (Farm Accountancy Data Network) for 2010–2015. The sample consisted of farms which did or did not receive subsidies on investments during the entire period analysed. Multifactor analysis of variance was applied to examine the impact of investment and investment support on the diversity of labour productivity of Polish farms.[6] The purpose is to examine the significance of the differences between the mean values of the dependent variable (labour productivity) for the samples corresponding to the levels of the classifying variables (growth of investments, growth of subsidies, voivodeship, type of farming, economic size class and their selected interactions). This allows us to determine whether the diversity of observations due to the dependent variable is the result of diversity of the classifying factor groups or diversity within these groups.[7]

In order to verify the null hypothesis on the lack of significant differences in the value of the dependent variable between individual groups, the total variance

[6] It should be emphasised that the use of tools for the analysis of variance does not make it possible to draw conclusions about the impact of the classifying factors on dependent variable in the cause-and-effect sense, but only permits the establishment of the possible presence of statistically significant differences in the mean of dependent variable in the subgroups determined by the categories of classifying factors.

[7] The application of the analysis of variance is possible when the assumptions concerning the independence of the classifying variables and the normality of distribution and homogeneity of the variance of the dependent variable in groups determined by the levels of factors taken into account are fulfilled.

is divided into additive components referring to the inter-group and intra-group variability, and then the test statistic is calculated (cf. Gelman and Hill 2007):

$$F = \frac{q_m}{q_w} = \frac{\sum_{i=1}^{k} \left(\overline{x}_i - \overline{x}\right)^2 n_i}{\sum_{i=1}^{k} \sum_{j=1}^{n_i} \left(x_{ij} - \overline{x}_i\right)^2} \cdot \frac{n-k}{k-1}, \tag{22}$$

where: q_m and q_w are respectively variance of the group means and the mean of the within-group variances, n_i is the number of observations in the first group, n is the number of observations regardless of whether they belong to the groups determined by the categories of the factor, and k is number of levels of the classifying variable.

3. Results

3.1. The relationship between investments and labour productivity

The study of the relationship between investment and the labour productivity started from the analysis of these quantities broken down by the economic size class (Figure 3) and type of farming (Figure 4).

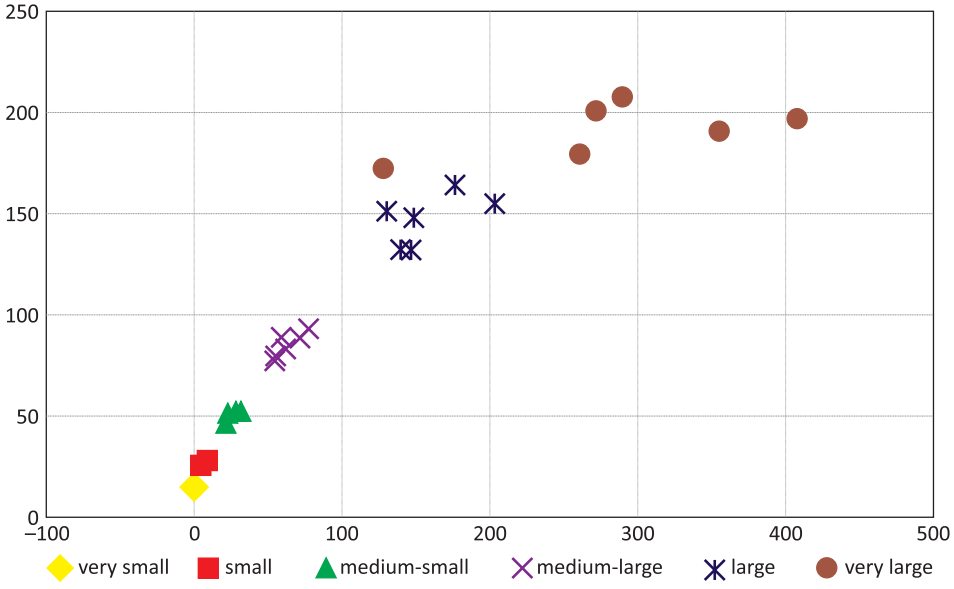

Figure 3. Average labour productivity (vertical axis) vs average investments (horizontal axis) by economic size class

Source: Own chart based on the FADN data.

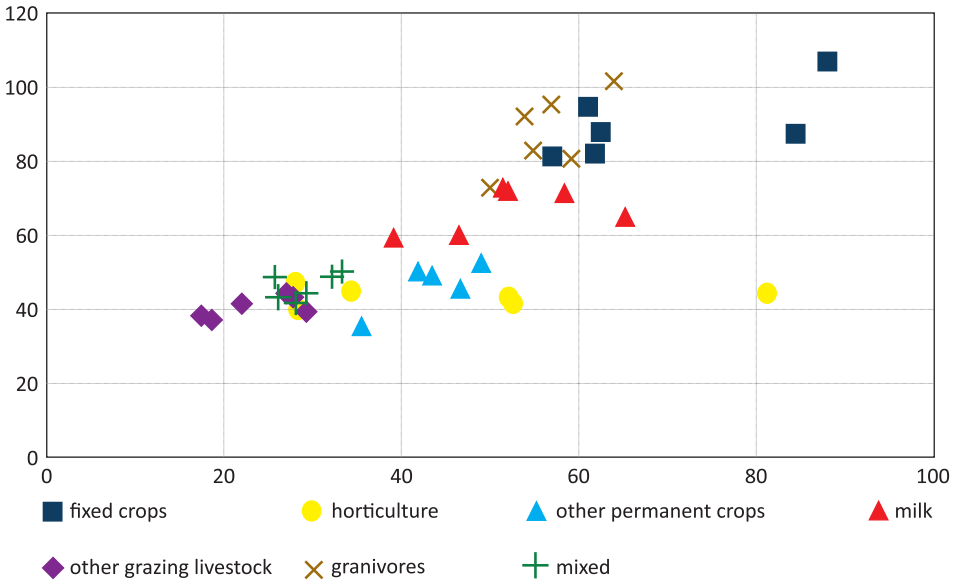

Figure 4. Average labour productivity (vertical axis) vs average investments (horizontal axis) by type of farming

Source: Own chart based on the FADN data.

Analysing farms broken down by economic size class, it can be noticed that the greater the economic size the greater the "dispersion" of the results over the years analysed. Moreover, the larger the farm, the higher is the average labour productivity and the size of investment in the holding. The exception is the relationship between the average labour productivity and investment levels in 2015 for farms with an economic size of EUR 100,000-500,000. Farms classified as "large" had lower labour productivity than "very large" farms, but with relatively higher investment.

In turn, with reference to the type of farming, farms specialising in field crops and breeding granivores were, on average, characterised both by high labour productivity and high investment. Farms specialising in permanent crops and grazing livestock achieved relatively low labour productivity with lower investment. In the years analysed, no specialised holdings on average achieved high labour productivity with low investment (or vice versa). However, it can be noted that – compared to other types of farms – between 2013 and 2014, farms specialising in horticulture achieved low labour factor efficiency with relatively high investment.

3.2. The relationship between support for investment and labour productivity

As before, the relationship between labour productivity and the amount of payments broken down by the economic size class of farms (Figure 5) and then by the type of farming (Figure 6) was presented for farms receiving investment support.

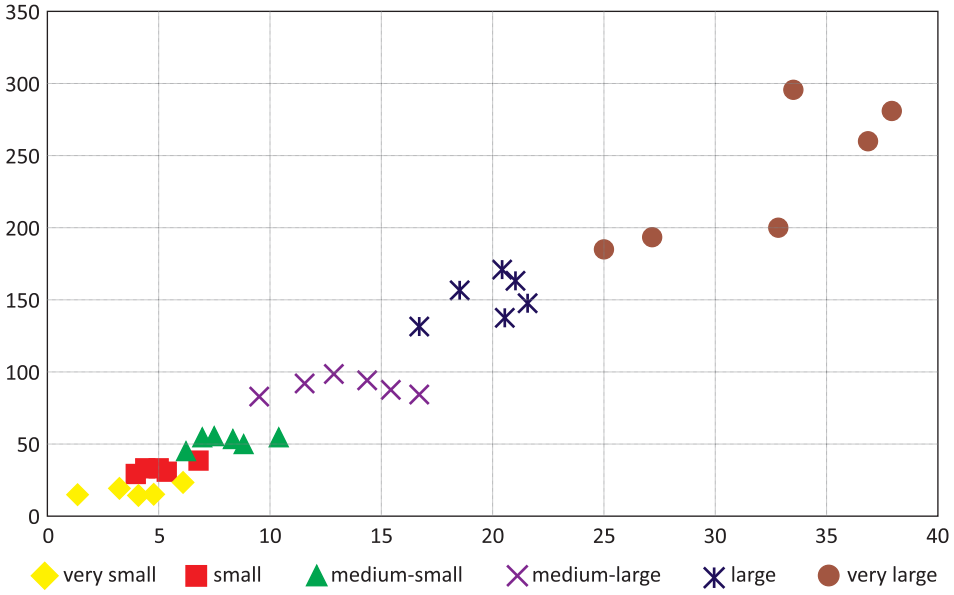

Figure 5. Average labour productivity (vertical axis) vs average subsidies on investments (horizontal axis) by the economic size class

Source: Own chart based on the FADN data.

Examining holdings in terms of their economic size, it can be noted that farms with consecutive economic size classes were characterised by higher and higher average labour productivity and on average received higher support for investment. The exceptions were holdings classified as "very small", which in 2010 and 2012, on average, achieved lower labour productivity, receiving higher levels of support (compared to "small" farms). As can be seen, in 2010-2015, relatively high average labour productivity with a simultaneously high level of support was achieved mainly by farms specialising in permanent crops and granivores. The opposite situation, i.e. low labour productivity with low support for investment, was observed in farms specialising in field crops and grazing livestock. Farms specialising in horticulture stood out against the background of the farms analysed as they received relatively high payments while achieving low average labour productivity.

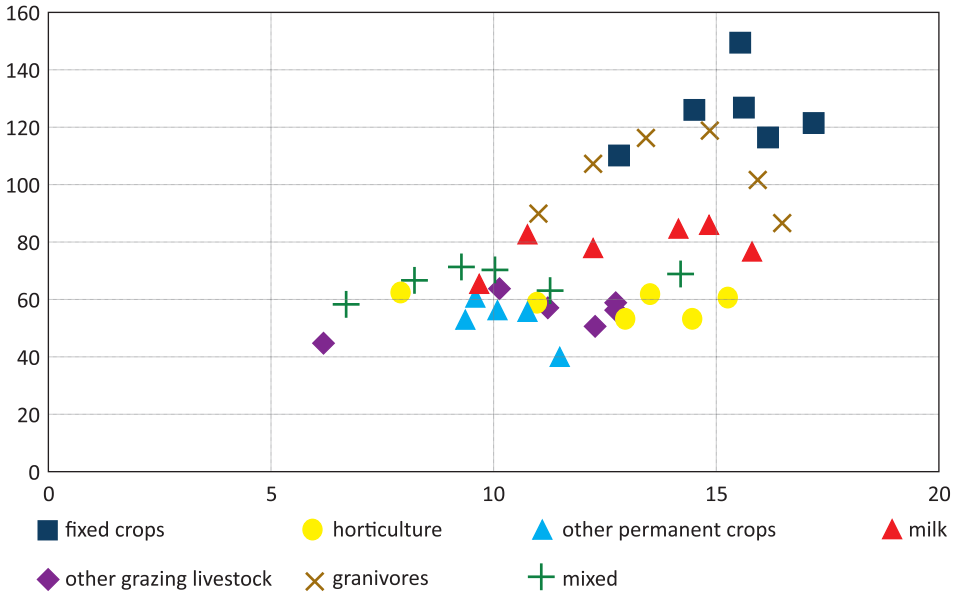

Figure 6. Average labour productivity (vertical axis) vs average subsidies on investments (horizontal axis) by the type of farming

Source: Own chart based on the FADN data.

3.3. The ANOVA model

The relationship between investment and support for investment from the CAP was verified using the analysis of variance models. The purpose of the study was to determine whether the labour productivity on farms with an annual increase in investment and/or payments for investment is really different than it is on farms where there was no such increase. Table 1 presents averages, medians and standard deviations for labour productivity in 2015, broken down into the levels of the classifying variables, and Table 2 presents the results of the ANOVA model for 2015.[8] Beside the main effects associated with the impact of investment, payments and also the economic size, specialisation and location on labour productivity, the model also took the impact of interactions between them into considerations.[9]

[8] Similar results were obtained when estimating models for previous periods.

[9] Only pairwise interactions are considered in the model, because of the difficulty of interpreting interactions of a higher order.

Table 1. Averages, medians and standard deviations for labour productivity in 2015

Independent variables		Labour productivity in 2015		
		Mean	**Median**	**SD**
Growth of investments	Negative or zero	55.36	37.89	58.00
	Positive	67.12	47.31	66.85
Growth of subsidies	Negative or zero	57.93	39.27	60.78
	Positive	82.24	66.25	58.98
Type of farming	Field crops	94.07	66.04	86.81
	Horticulture	49.84	39.50	53.56
	Other permanent crops	48.04	39.25	36.10
	Milk	57.85	42.68	53.85
	Other grazing livestock	40.22	27.54	32.97
	Granivores	67.95	53.54	64.81
	Mixed	45.36	31.55	44.92
Economic size class	Very small (EUR 2,000-8,000)	23.91	10.26	32.13
	Small (EUR 8,000-25,000)	27.60	21.14	26.99
	Medium-small (EUR 25,000-50,000)	47.70	38.14	42.07
	Medium-large (EUR 50,000-100,000)	80.08	65.55	58.25
	Large (EUR 100,000-500,000)	126.87	107.04	95.66
	Very large (over EUR 500,000)	164.27	141.65	91.54
Voivodeship	Dolnośląskie	85.86	61.68	81.32
	Kujawsko-pomorskie	72.13	55.11	65.32
	Lubelskie	50.62	35.84	48.72
	Lubuskie	89.97	65.80	88.79
	Łódzkie	42.54	30.63	38.56
	Małopolskie	47.10	30.20	61.37
	Mazowieckie	44.48	30.25	42.59
	Opolskie	70.49	49.99	64.61
	Podkarpackie	52.00	38.51	51.68
	Podlaskie	53.78	37.61	60.81
	Pomorskie	73.98	51.13	77.50
	Śląskie	53.75	37.88	47.30
	Świętokrzyskie	59.20	39.27	61.45
	Warmińsko-mazurskie	57.20	43.46	56.97
	Wielkopolskie	55.01	39.42	56.16
	Zachodniopomorskie	84.32	55.33	81.57

Source: Own table based on the FADN data.

Table 2. ANOVA model

Independent variables	F	p-value
Growth of investments	64.886	$9.68e^{-16}$ ***
Growth of subsidies	3.523	0.0606 *
Voivodeship	26.741	$< 2e^{-16}$ ***
Type of farming	99.796	$< 2e^{-16}$ ***
Economic size class	394.661	$< 2e^{-16}$ ***
Growth of investments * voivodeship	1.061	0.3880
Growth of investments * type of farming	1.501	0.1734
Growth of investments * economic size class	4.476	0.0013 ***
Growth of subsidies * voivodeship	1.600	0.0654 *
Growth of subsidies * type of farming	1.351	0.2308
Growth of subsidies * economic size class	5.545	$4.23e^{-05}$ ***

*** – p-value < 0.01, ** – p-value < 0.05, * – p-value < 0.1

Source: Own table based on the FADN data.

The results of the multifactor analysis of variance show that the diversity of labour productivity of Polish farms is influenced independently by four main effects, i.e. an increase in investment, location, type of specialisation and economic size class of the farm.[10] The average labour productivity on farms with a positive annual increase in investment in 2015 was over PLN 67,000 compared to PLN 55,000 on holdings where the increase did not occur or was negative. Considering the type of a farm, on average, in 2015, the highest labour productivity was observed on farms specialising in field crops (about PLN 94,000) and lowest on farms specialising in grazing livestock (about PLN 40,000). In the case of the economic size of the farms, again, greater size was accompanied by higher average labour productivity. Thus the highest labour productivity was found on farms whose size exceeds EUR 500,000 (about PLN 164,000), the lowest – on farms of size below EUR 8,000 (about PLN 24,000). In addition, in 2015, along with the economic size class of the farm, the interaction between investment growth and the increase in payments for investment turned out to be the factors differentiating labour productivity. This means that the impact of investment growth or support for investment in labour productivity depended on the economic size, as shown in Figure 7 and Figure 8.

[10] In the ANOVA models constructed for the previous periods, an important main effect was also the annual increase in payments to investment.

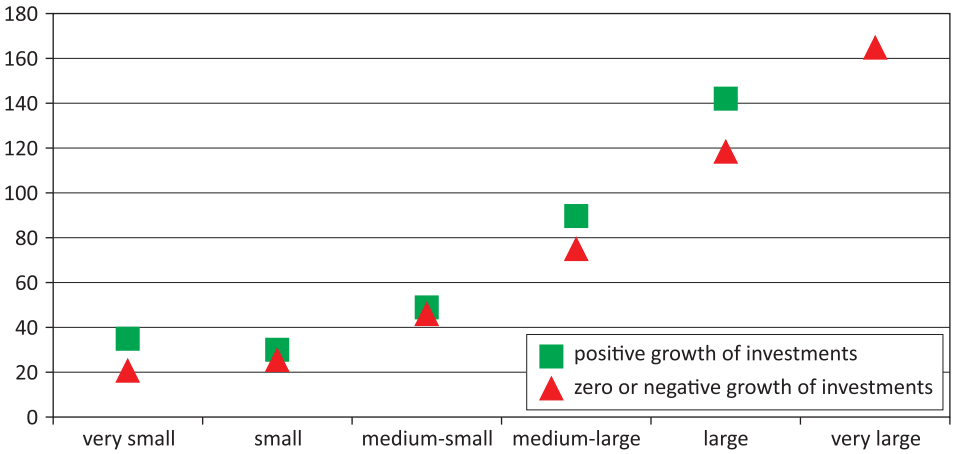

Figure 7. Impact on labour productivity of interaction between growth of investments and economic size class

Source: Own chart based on the FADN data.

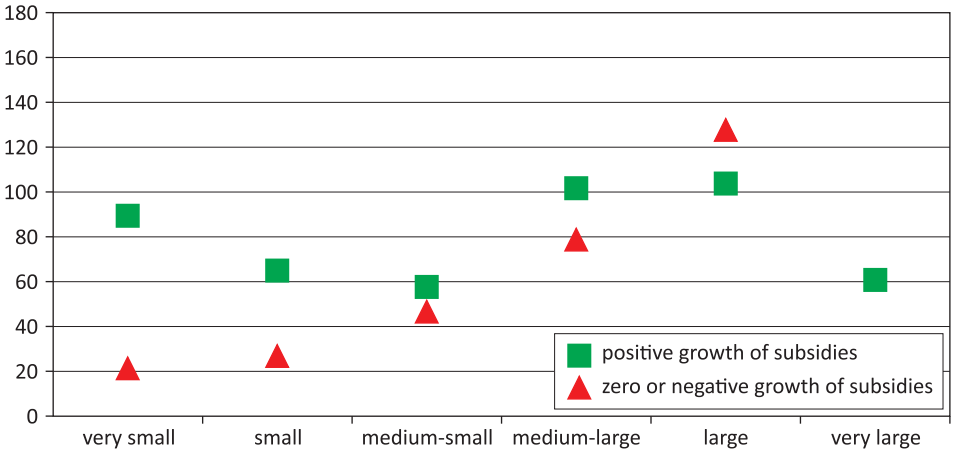

Figure 8. Impact on labour productivity of interaction between growth of subsidies on investments and economic size class

Source: Own chart based on the FADN data.

The highest average labour productivity occurred on farms with the economic size over EUR 500,000, and the lowest on farms with the economic size below EUR 8,000, with no increase in investment or payments for investment.[11] For

[11] In studying the interactions between investment growth and the economic size class, the sample did not include farms classified as "very large", for which the increase in investment would be positive.

all economic sizes classes, higher labour productivity was observed on farms with a positive annual increase in investment. However, it is worth noting that higher labour productivity occurred on farms where the increase in payments for investment was positive, but the economic size did not exceed EUR 100,000.

4. Summary and discussion

The purpose of this paper was to empirically verify the analytical relationships between investment and subsidies on investments and labour productivity on farms. The starting point was the microeconomic theory of the producer, the basis of which is the construction of the production function and the theory of production factors.

The study indicates that between 2010 and 2015 average labour productivity was significantly higher for farms where the increase in investment and payments for investment was positive, compared to farms where the increase was zero or negative. This can prove the catalysing effect on labour productivity of investment and investment support and indirectly also the efficiency of management of agricultural producers.

A distinguishing feature of this paper is the empirical study of the impact on labour productivity of investment and related subsidies, however, not in order to evaluate specific CAP measures, but to verify the analytically derived relationships based on microeconomic foundations. However, it should be noted that the analysis of variance models could only be used to indirectly identify the relationship between investment and payments and labour productivity. The recommended extension of the analyses conducted is the use of tools that make it possible to study the so-called "true causation" relationship in non-experimental conditions, e.g. the propensity score matching method.

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Związek między inwestycjami i dopłatami do inwestycji a produktywnością pracy w rolnictwie w Polsce w latach 2010–2015

Streszczenie: W artykule dokonano analizy zależności między inwestycjami i dopłatami do inwestycji w ramach Wspólnej Polityki Rolnej a wydajnością czynnika pracy zarówno na poziomie pojedynczego gospodarstwa rolnego, jak i dla całego sektora. Odwołano się do wydajności pracy jako podstawy dochodów producentów rolnych oraz inwestycji wpływających na zasób czynnika kapitału jako źródła poprawy wydajności. Celem artykułu jest prezentacja analitycznych i empirycznych dowodów na pozytywną relację zachodzącą między wzrostem inwestycji oraz wsparcia dla inwestycji w ramach instrumentów polityki na wydajność czynnika pracy. Jako narzędzie badawcze zastosowano modele wieloczynnikowej analizy wariancji (ANOVA) z interakcjami do oceny zróżnicowania wydajności pracy ze względu na inwestycje oraz dopłaty do inwestycji. Uzyskane wyniki sugerują katalizujący wpływ inwestycji i wsparcia o charakterze inwestycyjnym na wydajność pracy, a pośrednio również racjonalność gospodarowania producentów rolnych.

Słowa kluczowe: inwestycje, dopłaty, wydajność pracy, gospodarstwa rolne, polityka rolna.