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IMPACT OF INVESTMENT SUPPORT ON LABOUR PRODUCTIVITY AND ITS RESPONSIVENESS TO PRODUCTION POTENTIAL OF POLISH FARMS

Summary: Labour productivity occurs in the economic theory as one of the most important outcomes of economic growth. The agricultural policy can be distinguished as the external source of labour productivity growth. Hence, the ability to assess validity and effectiveness of policy instruments is crucial. The aim of the study was to estimate a treatment effect of investment subsidies on labour productivity growth on Polish farms. The applied research tool was quasi-experimental propensity score matching method, enabling to calculate the Average Treatment Effect on the Treated (ATT). The results were compared with a multi-criteria assessment of production potential on Polish farms. The study used regional level data from the Polish FADN (Farm Accountancy Data Network) database.

Keywords: farm, labour productivity, agriculture policy, propensity score matching.

JEL Classification: D24, Q18.

Introduction

We assume that an increase in the labour productivity is a consequence of investments made by producers. Firstly, it comes from *ex post* and *ex ante* savings. Secondly, it could be supported by adequate aid under policy instruments. In case of the Common Agricultural Policy, support for investments on Polish farms was granted, *inter alia*, under the Rural Development Programme for 2007-2013 within two measures, i.e. Setting up of young farmers (Measure 112) and Modernisation of agricultural holdings (Measure 121).

The research objective of the study is to measure the effect of support for investments made on Polish farms on the annual increase in labour productivity. The investments enhance the amount of factors of production (physical capital, land) and determine the production potential of farms. Hence, the obtained results will be discussed in the context of assessing the production potential of farms using the selected multi-criteria methods for creating rankings.

1. Increase in labour productivity as a result of the agricultural policy

In the analytical approach to the relationship between the policy instruments aimed at supporting investments and the increase in labour productivity, we assume that in case of Polish farms low level of savings is not sufficient to improve production techniques, therefore, investment needs are greater than the possibilities determined by savings [Bezat-Jarzębowska, Rembisz and Sielska, 2013]:

$$S < I$$

and

$$\Delta S < \Delta I$$

where:
S – the savings,
I – the investments.

The investment decisions of farms (agricultural producers) are additionally affected by the support from the Common Agricultural Policy. This relationship results from income of agricultural producers, which, in turn, assuming the constant employment of the labour factor, leads to the increase in the capital-to-labour ratio [Rembisz and Sielska, 2014]:

$$S_{t-1} + B_{t-1} \Rightarrow I_t \Rightarrow \frac{K_t}{L_t} \uparrow$$

where:
B – the support (political rent),
K – the capital input,
L – the labour input.

Hence, the labour productivity increases, which translates into the increase in producers' income according to the formula:

$$\frac{K_t}{L_t} \uparrow \Rightarrow \frac{y_t}{L_t} \uparrow \Rightarrow m_t \uparrow$$

where:
y – the production,
m – the producer's income.

Finally, the income determines the savings as follows:

$$m_t \Rightarrow S_{t+1}$$

2. Research method

2.1. Propensity score matching

The propensity score analysis, introduced by Rosenbaum and Rubin [1983], was used, to assess the impact of investment subsidies on labour productivity. This approach is based on the so-called counterfactual results, i.e. potential results possible to be achieved, if the status of treating the given object was different than observed [Pan and Bai, 2015]. Contrary to the naive methods (e.g. regression models) the counterfactual analysis enables to draw conclusions about the impact of policy instruments in the cause-and-effect sense and is widely use in the evaluation of the programme's effectiveness [cf. Michalek, 2012; Mary, 2013; Nilsson, 2017].

At the level of a single observation, the treatment effect may be defined as a difference between the outcome variable values in case of being treated and the absence of this treatment [Rubin, 1974; Holland, 1986; Winship and Morgan, 1999]. However, only one of the conditions (treating or not treating) is observable, therefore, the complete empirical examination of the effect of the exogenous factor on the outcome variable is not possible in this approach. This difficulty is determined in the literature as the fundamental problem of causal inference [Trzciński, 2009]. The difference of the outcome variable values must, therefore, take into account the estimates of unobservable outcome variable, which allows us to define the treatment effect at the individual level [cf. Szulc, 2012]:

$$W_i = \begin{cases} Y_{1i} - \hat{Y}_{0i} \text{ if } D_i = 1 \\ \hat{Y}_{1i} - Y_{0i} \text{ otherwise} \end{cases}$$

where:

Y_{1i} – the outcome variable if the i^{th} object was treated,

$\hat{Y}_{1i}$ – the estimation of the potential outcome variable which would occur if the i^{th} object was treated,

Y_{0i} – the outcome variable if the i^{th} object was not treated,

$\hat{Y}_{0i}$ – the estimation of the potential outcome variable which would occur if the i^{th} object was not treated,

D_i – the binary variable that equals 1 if the i^{th} object was treated or 0 otherwise.

Firstly, the data collected are divided into two disjoint sets, i.e. the experimental group and the control group[1]. This involves the adoption of an assumption that "assigning an observation to the experimental group or to the control group takes place independently of the treatment effect" [Strawiński, 2014, p. 15]. This means that, as part of the studied phenomenon, there are no confounding variables affecting simultaneously the occurrence of treatment (exogenous factor) and its effect. For comparative groups thus constructed, as the unobservable outcome variable we adopt the outcome variable for the observation from the control group, 'similar' to the given observation from the experimental group[2].

In practice, the multidimensionality of empirical data does not enable matching treated units with non-treated units on the basis of identical (or similar) values of characteristics. The solution is to reduce the problem to a one-dimensional one by combining the observations based on the propensity score which is conditional probability of being assigned to a particular treatment given a vector of observed covariates.

At the last stage of the analysis, when we have the properly constructed control group, it is possible to determine the treatment effect in average terms. One of the effects to be calculated is the average treatment effect for the treated (ATT), in accordance with the formula[3] [Imbens, 2004; Winship and Morgan, 1999]:

$$ATT = E(Y_{1i} - Y_{0i} \mid D_i = 1) = E(Y_{1i} \mid D_i = 1) - E(Y_{0i} \mid D_i = 1)$$

1 The experimental group includes observations which have been treated while the control group includes observations which have not been treated and, at the same time, are 'similar', in terms of the selected observable characteristics, to observations from the experimental group.

2 The ways of constructing the control group and the assumptions accompanying the data matching method are described in more detail in the works by Guo and Fraser [2015] and Wiedermann and von Eye [2016].

3 The assumption on the absence of the self-selection phenomenon was adopted, thus, the ATT estimate obtained pursuant to the presented formula does not need to be adjusted by the bias [Strawiński, 2014].

This indicator allows to assess the average change taking place for treated units when compared to the observations from the control group.

To build the propensity score vector, we used the logit models to estimate the impact of all possible combinations from the set of selected 18 variables on the binary variable that express the fact of receiving (or not) investment subsidies. To specify the propensity score vector, we used the classification accuracy rate, which is a quotient of the sums of observations correctly classified to all observations. Following the suggestion by Heckman, Ichimura and Todd [1997], to specify the propensity score vector, we selected such a combination of variables for which the proper classification rate was the highest. As noticed by Trzciński [2009], the primary objective of propensity score matching is, however, to balance the characteristics of the analysed objects to ensure their similar distribution within the experimental group and control group. If it is not possible to obtain the balanced groups for the model with the highest prediction, therefore, in the study the authors selected for further analysis the logit model with the lower accuracy, but ensuring better balance.

In the propensity score matching method, we used the method of matching the data 1 to 1 with replacement and ties. Therefore, if two or more units from the control group are similar to the unit from the experimental group, each of these units is equally weighted and matched with the observation from the experimental group [Sekhon, 2011].

2.2. Creating rankings

The study used two methods to create rankings based on the multiple criteria: WSA (Weighted Sum Approach), also known as SAW (Simple Additive Weighting) [Geldermann and Rentz, 2000] and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [Hwang and Yoon, 1981]. The calculations were made in a spreadsheet with the SANNA package.

Using the WSA method, the ranking is created based on aggregated assessments of individual alternatives, after comparability of results is guaranteed thanks to normalisation. This normalisation is carried out according to the following formula:

$$n_{ij} = \frac{f_j(a_i) - \min\limits_{a \in A} f_j(a)}{\max\limits_{a \in A} f_j(a) - \min\limits_{a \in A} f_j(a)} \quad \text{for the criteria to be maximised}$$

and

$$n_{ij} = \frac{\max_{a \in A} f_j(a) - f_j(a_i)}{\max_{a \in A} f_j(a) - \min_{a \in A} f_j(a)}$$ for the criteria to be minimised,

where:

$f_j(a_i)$ – assessment of the a_i alternative in view of the j^{th} criterion,

n_{ij} – normalised assessment of the a_i alternative in view of the j^{th} criterion.

The basis of the ranking is the weighted sum of the normalised ratings, according to the formula:

$$u(a_i) = \sum_{j=1}^{N} w_j n_{ij}$$

where:

w_j – weight of the j^{th} criterion.

In case of the TOPSIS method, the assessments are also normalised, however, a basis to determine the normalised value is not the interval between the assessments but their sum. Since the criterion function $f_j(a_i)$, depending on the issue examined, may take on negative values, the root from the sum of the squares of the assessments is used. Therefore, the normalisation is carried out in accordance with the formula:

$$n_{ij} = \frac{f_j(a_i)}{\sqrt{\sum_{i=1}^{n} f_j(a_i)^2}}$$

and then the normalised values are weighted with the weights of the individual criteria:

$$t_{ij} = f_j(a_i) \cdot w_j$$

An essential element differing the TOPSIS method from the WSA method is the use of two reference points for constructing the ranking. The T^+ ideal point corresponds to the best possible solution of the examined multi-criteria problem. It is defined as:

$$T^+ = (t_1^+, t_2^+, \ldots, t_n^+)$$

where:

$$t_j^+ = \begin{cases} \max_i t_{ij} & \text{when the } j^{th} \text{ criterion is maximised} \\ \min_i t_{ij} & \text{when the } j^{th} \text{ criterion is minimised} \end{cases}.$$

The other reference point reflects the least beneficial solution:

$$T^- = (t_1^-, t_2^-, ..., t_n^-)$$

where:

$$t_j^- = \begin{cases} \min\limits_i t_{ij} \text{ when the j}^{\text{th}} \text{ criterion is maximised} \\ \max\limits_i t_{ij} \text{ when the j}^{\text{th}} \text{ criterion is minimised} \end{cases}.$$

The basis for the ranking is the relative distance of the t_{ij} ratings of the analysed *a* variants from both reference points, expressed by the formula:

$$D_p(a_i) = \frac{d_p^-(a_i)}{d_p^-(a_i) + d_p^+(a_i)}$$

where:

$d_p^-(a_i)$ – distance from the negative solution,

$d_p^+(a_i)$ – distance from the ideal solution.

The study used the weights of the criteria determined in accordance with the algorithm from the study by Sielska [2010], similar to the CRITIC method [Diakoulaki et al., 1995].

$$w_i^s = \frac{\dfrac{w_i^1}{w_i^2}}{\sum\limits_{i=1}^{N} \dfrac{w_i^1}{w_i^2}}$$

where:

$$w_i^1 = \frac{|v_i|}{\sum\limits_{i=1}^{K} |v_i|},$$

$$w_i^2 = \frac{\sum\limits_{j=1}^{N} |r_{ij}|}{\sum\limits_{i=1}^{N} \sum\limits_{j=1}^{N} |r_{ij}|},$$

r_{ij} – correlation coefficient determined for the assessments in view of the i^{th} and j^{th} criteria,

$$v_i = \frac{s_i}{\bar{f}_i}$$

where:

s_i – standard deviation of the values assumed by the assessments in view of the f_i criterion,

$\bar{f}_i$ – arithmetic mean of the values assumed by the assessments in view of the f_i criterion.

This would allow to attach the greater importance of the criteria more diversified among the alternatives as well as to those less correlated.

3. Source of data

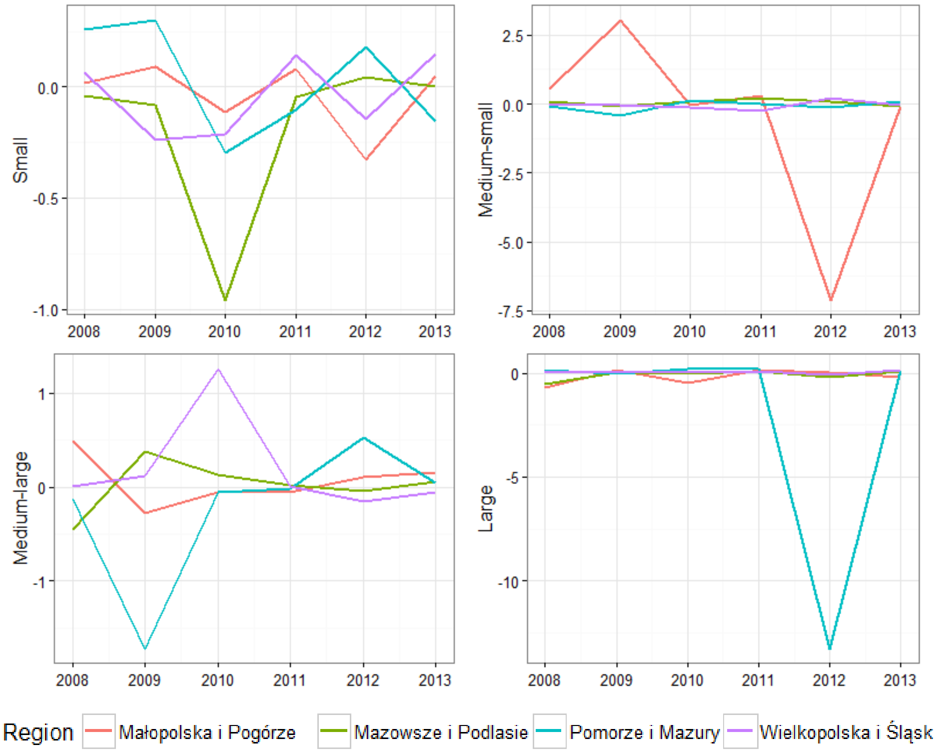
The study used the data from the Polish FADN (Farm Accountancy Data Network) regarding individual farms from the years 2006-2013, divided into four regions: *Pomorze i Mazury*, *Wielkopolska i Śląsk*, *Mazowsze i Podlasie*, *Małopolska i Pogórze* and by economic size class of farms: small (8,000 ≤ EUR < < 25,000), medium-small (25,000 ≤ EUR < 50,000), medium-large (50,000 ≤ ≤ EUR < 100,000), large (100,000 ≤ EUR < 500,000).

Using the propensity score matching method, we examined the treatment effect of investment subsidies received by farms on the increase in the labour productivity, defined as gross value added per annual work unit (GVA/AWU). It was assumed that the effects of investment support occur with some delay, therefore, some variables from the year *t* will affect receiving investment subsidies in the year *t+1*, the result of which will be an increase in the value of GVA/AWU in the year *t+2*.

4. Results

Using the propensity score matching method, we measured the treatment effect of investment subsidies on the increase in the labour productivity on the Polish farms. According to Figure 1, the farms, which in 2007-2012 received support for investments, depending on the region and economic size class recorded both the positive and negative effect of those subsidies on the increase in gross value added per annual work unit.

Figure 1. Treatment effect (ATT) of investment subsidies on the increase in the labour productivity on the Polish farms



Source: Based on the FADN data.

Among the farms which economic size did not exceed EUR 25,000 (small) the negative treatment effect of investment subsidies was dominant when compared to the units which did not receive those subsidies. The highest difference between the farms belonging to the experimental group and control group took place in the region of *Pomorze i Mazury* in 2009. Then, the farms which in 2008 received the analysed support were characterised, on average, by 30 percentage points higher annual increase in the labour productivity. In turn, the lowest (negative) difference occurred in the region of *Mazowsze i Podlasie* in 2010, when the farms not covered by support recorded double increase in the labour productivity compared to the beneficiaries of the programme. In addition, in case of the small farms, we may observe a similar direction of development, in the analysed period, of the treatment effect of support in the regions of *Wielkopolska i Śląsk* and *Małopolska i Pogórze*.

On the farms with the economic size of less than EUR 50,000 (medium--small), the difference between supported and not supported farms was relatively small or close to zero. The only outlying observation was the region of *Małopolska i Pogórze*, where the increase in the labour productivity for the beneficiaries of the programme, when compared to the farms which did not receive investment subsidies, was in 2009 about three times higher but in 2012 – by about eight times lower.

On the farms with the economic size below EUR 100,000 (medium-large), both the positive and negative treatment effect of support on the labour productivity was recorded. The highest absolute value differences between the farms using and not using subsidies were observed in the regions of *Pomorze i Mazury* in 2009 and *Wielkopolska i Śląsk* in 2010. In the first case, the farms which made use of the programme in the preceding year achieved twice lower increase in labour productivity, while in the second case, it was about twice higher. In addition, in 2008-2011 the treatment effect of subsidies in the region of *Mazowsze i Podlasie* was opposite (symmetrically in relation to the zero point) to the region of *Małopolska i Pogórze*.

Just as before, the farms with the economic size below EUR 200,000 (large) were characterised by both the positive and negative effect of investment subsidies on the labour productivity for the beneficiaries of the programme when compared to the farms which did not receive support. The biggest difference between the farms occurred in the region of *Pomorze i Mazury* in 2012. The increase in the labour productivity was then by about fourteen times higher on the farms which did not receive investment subsidies, when compared to the farms which received them. What is more, in 2009-2013 we could observe that the increase in labour productivity was on the similar level in the regions of *Wielkopolska i Śląsk* and *Mazowsze i Podlasie*.

In order to assess the adequacy of the agricultural policy instruments to the economic and financial situation of farms, the results obtained were compared with the multi-criteria assessment of the production potential in the individual groups of farms. Using the TOPSIS method, the highest position was occupied by the large farms with the economic size exceeding EUR 100,000, while the lowest – by the small farms, with the economic size below EUR 25,000. In particular, the highest position in the ranking was occupied by the large farms from the region of *Pomorze i Mazury*, while the lowest – by the small farms from the regions of *Wielkopolska i Śląsk* and *Mazowsze i Podlasie*.

Table 1. Multi-criteria assessment of the production potential using TOPSIS method

Region	Classes of economic size	2006	2007	2008	2009	2010	2011
Pomorze i Mazury	small	13	14	13	13	13	13
	medium-small	9	9	9	10	10	10
	medium-large	5	5	5	6	6	6
	large	1	1	1	1	1	1
Wielkopolska i Śląsk	small	16	16	16	15	15	15
	medium-small	12	12	12	12	12	12
	medium-large	8	7	7	8	8	7
	large	2	2	2	3	2	2
Mazowsze i Podlasie	small	15	15	15	16	16	16
	medium-small	11	11	11	11	11	11
	medium-large	7	8	8	7	7	8
	large	4	3	3	2	3	3
Małopolska i Pogórze	small	14	13	14	14	14	14
	medium-small	10	10	10	9	9	9
	medium-large	6	6	6	5	5	5
	large	3	4	4	4	4	4

Source: Based on the FADN data.

A similar result was achieved in classifying the farms using the WSA method. Again, the production potential was rated the highest on the large farms, in particular, the farms from the region of *Pomorze i Mazury*. However, the production potential of the small farms, primarily from the regions of *Wielkopolska i Śląsk* and *Pomorze i Mazury*, was rated the lowest.

Table 2. Multi-criteria assessment of the production potential using WSA method

Region	Classes of economic size	2006	2007	2008	2009	2010	2011
Pomorze i Mazury	small	15	15	15	14	15	16
	medium-small	11	11	11	11	11	11
	medium-large	6	5	6	6	7	6
	large	1	1	1	1	1	1
Wielkopolska i Śląsk	small	16	16	16	16	16	15
	medium-small	12	12	12	12	12	12
	medium-large	8	8	7	8	8	8
	large	2	2	3	3	2	2
Mazowsze i Podlasie	small	13	13	13	15	13	14
	medium-small	9	10	9	10	10	10
	medium-large	7	7	8	7	6	7
	large	4	3	2	2	4	3
Małopolska i Pogórze	small	14	14	14	13	14	13
	medium-small	10	9	10	9	9	9
	medium-large	5	6	5	5	5	5
	large	3	4	4	4	3	4

Source: Based on the FADN data.

The farms, where in the year *t* the production potential was rated as high, in the year *t+2* differed among themselves in terms of the direction of the treatment effect of investment subsidies depending on the region. The large farms from the regions of *Pomorze i Mazury* and *Wielkopolska i Śląsk* were characterised, on average, by positive increase in the labour productivity in the analysed period. However, the negative values were recorded in the regions of *Mazowsze i Podlasie* and *Małopolska i Pogórze*. Among the farms with the lowest rated production potential, on average, the treatment effect of the programme for participating farms was close to zero or negative. In general, in 2008-2013 the highest positive treatment effect of investment subsidies occurred in the medium-small farms from the region of *Małopolska i Pogórze*, and medium-large farms from the region of *Wielkopolska i Śląsk*. The production potential on those farms, one year before receiving support, was, however, rated as average.

Conclusions

The objective of the study was to carry out the quantitative assessment of the treatment effect of investment subsidies on the increase in the labour productivity, and then to refer the results obtained to the multi-criteria assessment of the production potential on Polish farms.

Depending on the region and economic size class, the farms which used the programme in the analysed period recorded both the positive and negative effects of support. This result deviates from the results obtained at the country level, which indicates the presence of spatial diversity of treatment effects of the agricultural policy tools [cf. Sielska and Pawłowska, 2016].

The highest difference between the farms belonging to the experimental group and to the control group occurred in the region of *Małopolska i Pogórze* in 2009. Back then, the farms, which in 2008 received the analysed support, were characterised, on average, by the annual increase in labour productivity which was by about three times higher. The lowest difference between the farms using and not using support occurred, in turn, in the region of *Pomorze i Mazury* in 2012. The increase in labour productivity in the experimental group was, back then, by about fourteen times lower than that in the control group.

Comparing the results obtained with the classification of the farms by their production potential, we did not observe the expected positive treatment effect of support in the group of farms whose production potential was the lowest. In 2008-2013, the highest positive effect of investment subsidies occurred on the farms which were classified as average. This may attest to the lack of matching the implemented agricultural policy instruments in the analysed period in the context of production capacities of the farms.

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WPŁYW DOPŁAT DO INWESTYCJI NA WYDAJNOŚĆ PRACY W KONTEKŚCIE POTENCJAŁU PRODUKCYJNEGO POLSKICH GOSPODARSTW ROLNYCH

Streszczenie: Wydajność pracy jest, zgodnie z teorią ekonomii, jednym z istotniejszych źródeł wzrostu gospodarczego. Działania podejmowane w ramach instrumentów polityki rolnej mogą stanowić dla gospodarstw rolnych egzogenne źródło wzrostu wydajności pracy, dlatego też istotna jest możliwość oceny zasadności oraz efektywności narzędzi polityki rolnej. Celem badania była estymacja efektu oddziaływania dopłat do inwestycji na wydajność pracy w polskich gospodarstwach rolnych przy wykorzystaniu quasi-eksperymentalnej metody *propensity score matching*, umożliwiającej obliczenie przeciętnego efektu oddziaływania wobec jednostek poddanych oddziaływaniu (*Average Treatment Effect on the Treated*). Uzyskane wyniki porównano z wielokryterialną oceną potencjału produkcyjnego polskich gospodarstw rolnych. W badaniu wykorzystano dane na poziomie regionalnym, pochodzące z bazy Polskiego FADN (Farm Accountancy Data Network).

Słowa kluczowe: gospodarstwo rolne, wydajność pracy, polityka rolna, propensity score matching.