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Production Potential and Income of Agricultural Holdings in Poland

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Abstract

The aim of this article is to assess the impact of production potential on the income obtained by agricultural holdings in Poland. The Farm Accountancy Data Network FADN data from 2015 was used to achieve this aim. Empirical verification of factors determining the production potential and their impact on agricultural holding income was carried out using the logistic regression model. The dependent variable was taken to be the probability that the agricultural holding would achieve annual family farm income exceeding the median value of PLN 46149,18. It was established that four variables had a statistically significant positive effect on the studied phenomenon: area of agricultural land, share of leased land in the agricultural land area, total labor expenditure and technical labor infrastructure. This means that an increase in the level of these factors increases the probability of obtaining an above median value of income by agricultural holdings.

Keywords: family farm income, production potential, agricultural holdings, logistic regression

JEL: Q1, Q12, Q14

Introduction

The dominant view in the literature is that individual commodity farms are enterprises. They have a commercial character and connections with the market (Wiatrak 2005; Ziętara 2014). Family farm income is determined by the income strictly from agricultural activity (Kryszak 2017). This is the economic surplus that remains for the farmer to pay for the production factors (land, labor and capital) that are involved in the operational activity of the farm, which are his property (Goraj and Olewnik 2011). A crucial problem from the point of view of maximizing the income of an agricultural holding is to determine the factors affecting its level. The research method used to identify and assess these factors is, among others, the multiple regression model (Ibekwe et al. 2010; Kummanee et al. 2018), where the dependent variable is the income amount, and the independent variables are factors affecting its level. The logistic regression model is also applied in research, where the dependent variable is the dichotomous variable—it takes the value of either 0 or 1. It results from the obtained income in relation to a certain assumed level (e.g., the median value in the surveyed population) (Sompolska-Rzechuła and Świtłyk 2016). The purpose of such research is to identify and assess factors affecting the probability of achieving a certain level of income. In order to distinguish factors affecting the income of agricultural holdings, researched entities are grouped by type—e.g., by size or farming type (Martinovska-Stojčeska, Georgiev, and Erjavec 2008). The literature also includes research based on the use of Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA) (Hina, Tahir, and Nouman 2016) and factor analysis (Średzińska and Standar 2017). The results of current research indicate that the impact

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on the level of income obtained from agricultural activity may be exerted, among others, by the following factors: resources in possession of the given unit and rational and effective use of them (among others: Poczta, Średzińska, and Mrówczyńska-Kamińska 2009; Sadeghi, Toodehroosta, and Amini 2002; Safa 2005; Średzińska 2018; Zawadzka, Ardan, and Strzelecka 2011), specialization (production direction) (among others: Szafraniec-Siluta, Zawadzka, and Strzelecka 2011), location of the farm (among others: Orłowska 2017; Średzińska 2018), natural conditions (among others: Józwiak, Zieliński, and Ziętara 2016), and prices of production factors and sale prices (among others: Beckman and Schimmelpfennig 2015). As argued by Wysokiński (2016) and Średzińska (2017), the force and direction of the impact of particular factors (mainly factors related to the productive potential of a given unit) on agricultural holding income may vary, depending on, the type of business and the size of the entity. Undoubtedly, however, it is the resources of land, labor and capital that form the basis of the productive potential of the farm, and to a large extent determine the development opportunities of agriculture (cf.: Kaczmarek 2006; Poczta and Średzińska 2007) and influence the possible scale of operations, which determines the value of production and the level of income obtained (Zawadzka and Strzelecka 2014). The aim of this research is to assess the impact of production potential on the income obtained by agricultural holdings in Poland.

1 Materials and methods

The study was conducted using data on 12 027 individual commodity farms,[1] which in 2015 conducted agricultural accounting for the needs of the Farm Accountancy Data Network in Poland (Polish FADN). The analyzed sample of agricultural holdings is diverse in terms of the farm income level. Descriptive statistics of the continuous variable: family farm income are shown in table 1.

Tab. 1. Descriptive statistics of agricultural holding (family farm) income in Poland in 2015

Average (in PLN)	77 526,16
Median (in PLN)	46 149,18
Minimum (in PLN)	−526 930,07
Maximum (in PLN)	5 609 913,00
Range (in PLN)	6 136 843,07
Standard deviation (in PLN)	127 801,65
Coefficient of variation	164,85
Skewness	11,12
Kurtosis	338,77

Source: Own study based on FADN data
Note: [In the journal European practice of number notation is followed — for example, 36 333,33 (European style) = 36 333.33 (Canadian style) = 36,333.33 (US and British style). — Ed.]

The assumption of normality of income was rejected on the basis of Lilliefors test ($p < 0{,}01$). The distribution of the income has a high coefficient of deviation and high skewness and kurtosis. It was also established that the average family farm income in 2015 amounted to PLN 77 526,16 (arithmetic mean); however, half of the units achieved income not higher than or equal to PLN 46 149,18 (median), thus lower than the average value. That why in order to verify empirical factors affecting the income of these entities the logistic regression model was used (Gruszczyński 2010; Stanisz 2007). The dependent variable was assumed to be the probability that the agricultural holding would achieve annual family farm income exceeding PLN 46 149,18 in 2015. This is a dichotomous variable (Zawadzka and Ardan 2011), which takes two values: 0 — lack of a given trait (6 014 cases), 1 — having a given trait (6 013 cases). The selection of variables to estimate the parameters of the model defining the impact of production potential on farm income in Poland was

1. For the purposes of this study, those units in which no agricultural land was used (total agricultural land = 0 ha) or their area was less than 1 ha were eliminated from the population of individual agricultural holdings, which participated in the Polish FADN system in 2015 (12 105 farms). They belong to a group of entities that differ significantly (in terms of production and economic results) from the average units (cf. Wrzaszcz and Prandecki 2015).

Tab. 2. Hypothetical impact of independent variables assumed for the model determining the influence of production potential on the agricultural holding income in Poland in 2015

	Variable characteristics[a]	Expected impact of the variable on farm income
Y	A zero-one variable determining whether the annual family farm income in 2015 exceeded PLN 46 149,18 (median for the population included in the survey). If yes, the variable assumes the value = 1, otherwise it takes the value = 0.	
	Land	
x_1	Total area of agricultural land (ha)	The area of agricultural land is a measure of the scale of activity. The larger the area of land used for agriculture, the larger the scale of operations and the higher the income that can be obtained. The sign of the parameter in this variable should be positive, according to the assumptions of the model.
x_2	The share of leased area in total agricultural land area; is applicable to leases for a period of at least 1 year (%)	Lease of land enables us to increase the scale of production. The larger the possible scale of operations, the higher the income that can be obtained. The sign of the parameter in this variable should be positive, according to the assumptions of the model.
x_3	The share of arable land in total agricultural land area (%)	Arable land forms the production potential of a farm. The higher the share in the total area of agricultural land, the larger the possible scale of production. The larger the scale of operations, the higher the income that can be obtained. The sign of the parameter in this variable should be positive, according to the assumptions of the model.
	Labor	
x_4	The total amount of human labor (own and paid labor) as part of the farm's operational activity (AWU)[b]	The workload in a family farm is a measure of the scale of activity. The larger the scale of operations, the higher the income that can be obtained. The sign of the parameter in the discussed variable should be positive, according to the assumptions of the model.
	Capital	
x_5	The value of fixed assets less value of land, permanent crops and quotas owned by the farmer, used for the needs of agricultural activities (PLN thousand)	The fixed assets less value of land, permanent crops and quotas, used in the production process constitute the production potential of the farm. The higher this potential, the greater the possible scale of production. The larger the scale of operations, the higher the income that can be obtained. The sign of the parameter in this variable should be positive, according to the assumptions of the model.
	Relation between production factors	
x_6	The equipment of labor in land (relation of agricultural area to total labor expenditure) (ha/AWU)	Equipment of labor in land constitutes production potential of the farm. The higher this potential, the greater the possible scale of production. The larger the scale of operations, the higher the income that can be obtained. The sign of the parameter in this variable should be positive, according to the assumptions of the model.
x_7	The technical land infrastructure (the relations of fixed assets to agricultural land area) (PLN thousand / ha)	Technical land infrastructure constitutes production potential of the farm. The higher this potential, the greater the possible scale of production. The larger the scale of operations, the higher the income that can be obtained. The sign of the parameter in this variable should be positive, according to the assumptions of the model.
x_8	The technical labor infrastructure (the relations of fixed assets to the number of full employees) (PLN thousand / AWU)	Technical labor infrastructure constitutes production potential of the farm. The higher this potential, the greater the possible scale of production. The larger the scale of operations, the higher the income that can be obtained. The sign of the parameter in this variable should be positive, according to the assumptions of the model.

[a] Basic characteristics of variables according to FADN system, based on Floriańczyk, Osuch and Płonka (2016).

[b] AWU (Annual Work Unit) — work unit, equivalent to 2120 working hours a year (Floriańczyk, Osuch, and Płonka 2016).

Source: Own study based on Floriańczyk, Osuch and Płonka (2016), Orłowska (2017), Poczta and Średzińska (2007), Poczta, Średzińska and Mrówczyńska-Kamińska (2009), Poczta, Średzińska and Standar (2008), Średzińska (2017, 2018), Średzińska and Standar (2017), Zawadzka, Ardan and Strzelecka (2011)

based on the analysis of the current research results in terms of determinants of agricultural income. On the basis of substantive premises and data availability, in order to assess the probability of obtaining income exceeding PLN 46 149,18 by an agricultural farm, a set of independent variables was assumed and their hypothetical impact on the examined phenomenon was determined, which is presented in table 2. The basic descriptive statistics of the independent variables adopted for the model determining the impact of production potential on agricultural holdings income in Poland are presented in table 3.

Tab. 3. Descriptive statistics of independent variables adopted for the model determining the impact of production potential on agricultural holdings income in Poland in 2015

	Average	Median	Minimum	Maximum	Range	Skeweness
x_1	36,05	24,44	1,00	703,43	702,43	5,15
x_2	22,59	15,63	0,00	100,00	100,00	0,87
x_3	79,97	89,35	0,00	100,00	100,00	−1,44
x_4	1,93	1,81	0,11	29,65	29,54	7,49
x_5	515,57	348,96	0,00	9 648,81	9 648,81	3,79
x_6	20,01	14,47	0,04	283,00	282,96	3,25
x_7	43,71	35,31	0,00	5 172,34	5 172,34	31,93
x_8	675,82	504,10	0,00	7 573,39	7 573,39	2,89

Source: Own study based on FADN data

In the analyzed agricultural holdings, the average area of agricultural land in 2015 was 36,05 ha. These entities were characterized by a wide range of land used for agricultural purposes, amounting to 702,43 ha. The share of leased land in the total area of agricultural land amounted to 22,59%. The vast majority of land used was arable land (average of 79,97%). In more than half of the farms from the surveyed group, the share of arable land in the total area of agricultural land amounted to 89,35%. The value of production assets was characterized by a large range. The average fixed asset less value of land, permanent crops and quotas amounted to PLN 515,57 thousand. The own labor expenditure of farm owners, their family members and hired employees amounted to 1,9 AWU on average. The technical land infrastructure index was on average at 43,71 PLN thousand/ha. Technical equipment per one employee employed on the farm, expressed by means of technical labor infrastructure, amounted to an average of 675,82 thousand PLN/ha.

In order to find the best combination of factors significantly affecting the probability of obtaining an annual income exceeding the minimum level assumed in the study by the agricultural holding, the method of backwards elimination was applied. A Wald test was used to verify the significance of each model's parameters. The AIC (Akaike Information Criterion) was analyzed as the criterion of the model's optimality. The construction of the model was completed after obtaining the minimum AIC value. The assessment of the model's fit to the observed data was based on R-squared Cox-Snell statistics, R-squared Nagelkerke statistic, and R-squared McFadden statistics. The AUC (Area Under Curve) value was also used to assess the goodness of the fit of the obtained model, which was calculated on the basis of the ROC curve (Receiver Operating Characteristic). Atypical observations were eliminated on the basis of the analysis of standardized residuals. The odds ratio was used to interpret the obtained results of the logistics model. The calculations were made using the Statistica 13 program and the Statistica Plus package.

2 Research results

When estimating the parameters of the logistic regression model, the correlation between the variables included in the study was examined first. The results of estimation of the correlation coefficients are presented in table 4. Subsequently, all of the independent variables were considered in the initial model determining the impact of production potential on agricultural holding income in Poland. Then, based on the adopted research assumptions, using the backwards elimination

Tab. 4. The correlation coefficients of the variables in the model defining the impact of production potential on agricultural holdings income in Poland

	Y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
Y	1,00								
x_1	0,35	1,00							
x_2	0,17	0,23	1,00						
x_3	0,06	0,17	0,07	1,00					
x_4	0,25	0,25	0,04	−0,06	1,00				
x_5	0,33	0,55	0,12	0,07	0,43	1,00			
x_6	0,30	0,78	0,25	0,21	−0,11	0,37	1,00		
x_7	0,01	−0,09	−0,14	−0,03	0,25	0,27	−0,12	1,00	
x_8	0,26	0,53	−0,06	0,21	−0,10	0,56	0,74	0,04	1,00

Source: Own study based on FADN data

method, subsequent predictors were eliminated from the initial model and the assessment of change in the value of the criteria adopted for the evaluation of the model quality was made. At each step, the variable that was least significant (the one with the largest p-value)[2] was removed. On the basis of the above, four independent variables (with $p > 0{,}001$) were eliminated: x_3—the share of arable land in the area of agricultural land (z-square Wald test: 0,206; $p = 0{,}650$), x_7—technical land infrastructure (z-square Wald test: 1,231; $p = 0{,}267$), x_5—fixed assets less value of land, permanent crops and quotas (z-square Wald test: 6,374; $p = 0{,}012$), and x_6—equipment of labor in land (z-square Wald test: 8,211; $p = 0{,}004$). Removal of these variables improved the adopted measure of fit (decrease of the AIC value). On the basis of the residuals' analysis, outlying points were identified and these cases were eliminated, which contributed to the improvement of the values of accepted measures of goodness of fit. Finally, four independent variables were included in the final model. Table 5 presents the results obtained for the final model defining the impact of production potential on agricultural holdings income in Poland.

Tab. 5. Results of the estimation of model parameters determining the impact of production potential on agricultural holdings income in Poland—logistic regression (final model)

	Parameter	**Standard error**	***z*-square Wald**	***p*-level**	**Odds ratio**
x_1	0,036	0,002	424,076	< 0,001	1,037
x_2	0,006	0,001	32,545	< 0,001	1,006
x_4	0,940	0,039	594,529	< 0,001	2,561
x_8	0,001	0,000	101,202	< 0,001	1,001
Intercept	−3,382	0,089	1 444,565	< 0,001	0,034
AIC = 12 924,426					
Cox-Snell $R^2 = 0{,}2677$; Nagelkerk's $R^2 = 0{,}3570$; McFadden's $R^2 = 0{,}2248$					
AUC = 0,825; LR = 3 744,67 (df = 4; $p < 0{,}001$)					

Source: Own study based on FADN data

The final estimated model defining the impact of production potential on agricultural holdings income in Poland has the following form:

$$\text{Prob}(Y = 1) = \Lambda(0{,}036x_1 + 0{,}006x_2 + 0{,}940x_4 + 0{,}001x_8 - 3{,}382), \tag{1}$$

where $\Lambda(x) = e^x/(1 + e^x)$ is cumulative logistic distribution function.

Based on the estimated parameters of the final model, it was found that four independent variables had a statistically significant positive impact on the probability of obtaining an annual income

2. The significance threshold was set at 0,001.

exceeding PLN 46 149,18 in the agricultural holding: x_1 — agricultural area, x_2 — share of leased land in total agricultural land, x_4 — total labor expenditure, and x_8 — technical labor infrastructure. The direction of impact of these variables on the probability under testing is consistent with the assumptions adopted in the model (see tab. 2), therefore an increase in the level of factors included in the final model favors the probability of obtaining the minimum assumed level of income by an agricultural holding in Poland. The model is significant at the 0,001 significance level (the likelihood-ratio statistics value is 3 744,67, the critical value of this statistic for 4 degrees of freedom is 13,277). The quality assessment of the constructed model was based on the Cox-Snell R^2 coefficient (0,268), Nagelkerk's R^2 coefficient (0,357), McFadden's R^2 coefficient (0,225), as well as using the ROC curve, which is presented in figure 1.

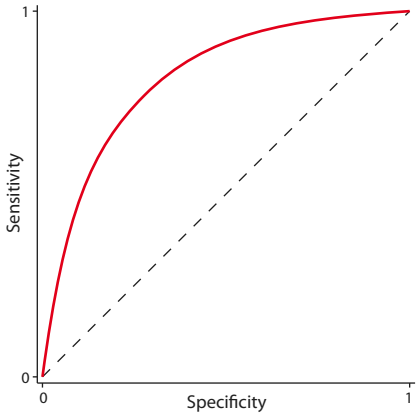

Fig. 1. ROC curve for the model determining the impact of production potential on agricultural holdings incomes in Poland — logistic regression (final model)

Source: Own study based on FADN data

The area under the ROC curve (AUC) is 0,825. Because a field larger than 0,5 and close to 1 was obtained, this indicates a good quality of the constructed model. About 74,25% of the outcomes were correctly predicted by the final model determining the impact of production potential on agricultural holding incomes in Poland. Assuming the remaining factors included in the final model remain unchanged (ceteris paribus), the chance (odds ratio) for the agricultural holding to obtain income exceeding PLN 46 149,18: will increase by 3,7%, if the area of agricultural land grows by 1 hectare (x_1); will increase by 0,6% if a theoretical increase in the share of leased land (x_2) will take place; will increase by 156,1% with an increase in labor expenditure by 1 AWU (x_4); will increase by 0,1% if the farm will increase the level of technical labor infrastructure by one unit (x_8).

Final conclusions

The article presents research on the impact of production potential on agricultural holding income in Poland. Based on literature studies and the availability of data, explanatory variables were selected for the model. The analysis included 8 diagnostic variables characterizing the production potential of agricultural holdings in Poland in 2015. The analysis showed that four variables had a significantly positive impact on obtaining income above the average level recorded for the group of agricultural holdings included in the study: area of agricultural land, share of leased land in total agricultural area, total labor expenditure and technical labor infrastructure. These variables refer to the size of the farm expressed by its area and work effectiveness. The obtained results may provide implications for public activities, which should support the growth and stabilization of agricultural income by enabling farmers to increase the area of agricultural land, mainly through the appropriate policy of regulating agricultural land trade. Furthermore, activities undertaken as part of consultancy in the field of agricultural production and effective use of production resources are important as well.

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