ROMAN SASS

DETERMINANTS OF TECHNICAL EFFICIENCY OF PRODUCTION FACTORS AT FAMILY FARMS

Summary: The main objective of the research was to determine the impact of selected endogenous factors, as well as the amount of subsidies from EU funds on the technical efficiency of production factors in family farms. The research included farms from Bydgoszcz subregion which before pre-accession of Poland to the European Union (1996-2003) benefited from preferential loans. At the same time, in the years 2004-2011, they kept accounting in the Polish FADN system. Using the regression calculus, the impact of particular factors on the technical efficiency of farms was determined. The structural parameters of linear and non-linear models with many independent variables were estimated. As a result of the conducted analyzes, it was found that they improved efficiency: capital expenditure before and after accession, land area increase before accession, production intensity, increase in equity after accession, asset debt and external costs. However, they worsened efficiency: work expenses, pig stocking, debt of equity, fixed costs as well as additional investment activity and the share of subsidies in income.

Key words: technical efficiency of production factors, DEA method, regression calculus, efficiency determinants.

1. INTRODUCTION

The economic purpose of family farming is to obtain the highest farming income possible. The value of this income determines the potential remuneration for the labour inputs and investment expenditures incurred on farm development. The amount of farming income is affected by a number of factors. They include internal (endogenous) factors, e.g. the amount of production resources, relations between the factors of production, the efficiency of the factors of production, the manner of using production resources, and the features of the farmer and the farmer's family (human capital).

The amount of farming income is also highly influenced by external (exogenous) factors, which are related to the agricultural policy. Nowadays, it is not possible

to separate the agricultural policy from the macroeconomic one. The development of agriculture is increasingly determined by the macroeconomic policy. And this covers a number of factors influencing the growth of production, restructuring and modernisation of agriculture, as well as the costs of production. The factors having a direct impact on the farmers' income include the prices of agricultural products, means of production and services purchased by farmers, as well as fund transfers from agriculture (taxes and other charges) and fund transfers to agriculture, which have grown in importance after Poland's accession to the European Union and including Poland's agriculture into the Common Agricultural Policy.

The farming income is highly influenced by the macroeconomic policy and Poland's development in general; demand for agricultural products, labour demand, opportunities of state budget support for agriculture and the social policy (social transfers) are of particular importance here [Zegar 2008, p. 99-105].

After the accession of Poland to the European Union, there has been a definite increase in agricultural income (a leap in income). This leap in income was caused mainly by the implementation of direct payments. The main source of income should be an improvement of efficiency and an increase of production.

There is even coercion to look for improvement of production efficiency as a source of income [Zegar 2008, p. 64], and to maintain competitiveness, but this coercion is being reduced by the agricultural policy, as efficiency is substituted with political rent, which means that efforts towards efficiency improvement are substituted with benefits from specific solutions under the agricultural policy, including, in particular, direct payments [Bezat-Jarzębowska, Rembisz 2013, p.29-41].

Production efficiency is a producer dependent microeconomic category, according to which something may be profitable to one producer and not profitable to another under the same circumstances. On the other hand, it is becoming increasingly common to say that development of agriculture is less dependent on internal conditions and mainly on external ones. The producer is mostly responsible for improving the efficiency of manufacture in a variety of its categories, i.e. improvement of technical or economic efficiency.

The basic aim of this analysis is to define the impact of selected endogenous factors, as well as the amount of EU subsidies on technical efficiency of the factors of production at family farms.

2. RESEARCH MATERIAL AND METHODOLOGY

The research covered farms in the sub-region of Bydgoszcz, which took advantage of subsidised loans before Poland's accession to the European Union (1996-2003)[1]. Simultaneously, in 2004-2011, these farms kept their accounts as part of the Polish FADN system. There were 175 farms that satisfied these criteria.

[1] The article is a part of a wider research problem: "Changes in the production potential and efficiency of farms making investments in the sub-region of Bydgoszcz after 1995". Subsidised

Eventually, the research covered 156 farms, with 14 farms being omitted as outlier farms, in which the amount of investment expenditures as of before the accession was more than two standard deviations from the mean, and 5 fruit-growing and horticultural farms. The fact of omitting such farms in further research as non-standard ones is justified with their low number.

At the first stage of analysis, DEA was used to estimate technical efficiency of the factors of production at the analysed farms. DEA is defined as a frontier analysis or a data envelope analysis, as it makes it possible to determine the efficiency of transforming multidimensional inputs into multidimensional outputs in regard to the best solutions observed (at model farms). DEA is a useful tool for examining the efficiency of business units [Kagan 2014, p. 10-38; Ziółkowska 2008, p. 7-38]. The major advantage of DEA is the fact it is highly flexible at adjusting to the data acquired. The analyses of interrelations between inputs and outputs are not a priori depicted in the form of a specific function, and, therefore, it is not necessary to verify and prove the usefulness of function types for the problem analysed. The method's disadvantages are, above all, its high sensitivity to erroneous data and a failure to take account of the random factor [Kucharski 2014, p.14].

The total efficiency of the factors of production was determined using DEA in a VRS (Variable Returns to Scale) model. The inputs included:

- the area of owned and leased agricultural land in hectares,
- the value of fixed assets, exclusive of land,
- employment in AWU/farm.

The outputs, on the other hand, included the total value of production[2].

At the next stage of research, regression analysis was applied to determine the impact of individual factors on the farms' technical efficiency. The structural parameters of linear models (linear regression) and non-linear ones (second-degree polynomial, power and logarithmic models) with numerous independent variables were estimated. The criteria for the assessment of the quality and goodness of fit of the models were an adequately high R-squared value (as close to one as possible), a relatively small residual standard error, the F statistic based on the Fisher-Snedecor distribution, the White test for heteroscedasticity of residuals, the Student's t-test do assess the models' parameters and the Jarque-Bera test for normality of distribution of residuals. The parameters of regression equations were estimated using the method of ordinary least squares (OLS).

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loans were granted from 1994, and as no data have been preserved for 1994 and 1995 with regard to farms taking advantage of such loans, it is not possible for the research to cover an earlier period.

[2] The value of production and fixed assets was expressed in the fixed prices as of 2011. In order to estimate the value of production, the price indices of the Central Statistical Office for crop and animal production, and the general price index for other productions were used. The fixed assets were expressed in the prices as of 2011, using the price index of the Central Statistical Office for goods and services purchased for investment purposes.

3. SELECTION OF VARIABLES DETERMINING EFFICIENCY

The farms' technical efficiency is influenced by a number of factors, including, among other things, the production potential of the farms, organisation of production, production intensity and costs of production. Apart from material production resources, the factors influencing the level of efficiency also include the quality of human capital engaged in farming, the degree of production innovation and the features of the factors of production, which are difficult to quantify [Karwat-Woźniak 2007, p. 7]. The determinants of technical efficiency of farms have been addressed in a number of studies and analyses conducted in Poland, as well as in industrialised and developing countries [Czekaj 2008, p. 31-44; Ziółkowska 2009, p. 124-132; Kulawik 2010, p. 208-217; Gospodarowicz, Karwat-Woźniak 2009, p. 59-74; S. Davidova, Latruffe 2007; Davidova, Latruffe, Balcome, Zawalińska 2002].

The basic criteria for the selection of variables were substantive prerequisites resulting from the research objective, as well as the findings of other authors which proved the existence of interrelations between efficiency and specific variables [Czekaj 2008, p. 31-44; Kulawik 2010, p. 208-217; Ziółkowska 2009, p. 124-132]. Moreover, the variables were selected taking account of the formal and statistical criteria [Zeliaś, Pawełek, Wanat 2003, p. 191-194]. The independent variables were marked by high variability, were strongly correlated with the dependent variable and were poorly intercorrelated [Zieliaś 1998, p.183-195][3].

The potential list of quantitative factors shall be presented in Table 1. The factors shall be divided into five problem groups. The years analysed (1996-2011) were marked by a very high increase in fixed assets. Therefore, it is justified to analyse to what degree the changes in potential influenced the farms' efficiency [Wilkin 1986][4]. An increase in fixed assets results in greater development opportunities, but also generates costs, which can have an adverse effect on efficiency. The degree and scope of the changes in potential resulted from the implemented financial investments with the participation of subsidised loans and EU funds, and, therefore, the amount of investment expenditures was taken into consideration together with the variables characterising the farms' production potential.

The second group of factors is made up of variables characterising the organisation of production and its intensity. Having at their disposal defined resources of production factors, and taking into account the operating conditions of their farms, farmers make decisions regarding the directions of production and the degree of specialisation. The analysis of the degree of production simplification

[3] In order to eliminate collinearity for the following variables: area of the farm, economic size of the farm, total assets, fixed assets and equity, the changes in their values in 2004-2011 were applied instead of average values for individual years. Explanatory variables in a given model should be strongly correlated with the response variable, but intercorrelated to a small extent. Collinearity of features causes deterioration of the model's parameters.

[4] The amount of production resources and the ability to make use of them determine the efficiency of farming.

proved that the analysed group of farms is divided fifty-fifty into specialist and multidirectional farms. Production organisation was characterised with the degree of production simplification, with specialist farms irrespectively of the direction of specialisation and farms with diversified structure of production being distinguished. Moreover, production organisation and intensity are determined by animal stocks per 100 hectares of agricultural land. An important factor determining mainly the production results is production intensity, which has a decisive impact on land productivity. In order to define production intensity, direct costs per hectare of agricultural land were used [Manteuffel 1979, p. 165].

Farmers are among those entrepreneurs who are quite reluctant to take advantage of external sources of financing business activities [Kata 2010, p. 145-156; Mądra 2009, p. 199-216]. Because of this, Polish farms demonstrate a relatively low debt ratio [Kata 2010, p. 145-156]. However, this approach is altering due to quite significant generation changes in the Polish countryside. Young farmers are more willing to take advantage of loans than their fathers. Furthermore, after Poland's accession to the European Union there has been a considerable increase in the opportunities to take advantage of subsidies under the Rural Development Programme (RDP). In the case of financing investments, own contribution is required, and, because of this, farmers more and more often take advantage of loans [Kata 2011, p. 87-99]. In addition, the high demand for land and the related increase in prices result in increased debt of farms, in particular, the larger ones. Therefore, including variables characterising debt into the analysis of efficiency is fully justified, whereby not only current debt is of importance, but, above all, the independence and stability of financing fixed assets, which is indicated by equity [Nowak 2005, p. 98-99].

Business activities are connected with costs, and this is the area of management that farmers can control, contrary to revenues, which are shaped on the market by prices and demand. Farmers are classic price takers, and as such they generally cannot negotiate the price and, consequently, change it into a negotiation instrument with regard to a given product [Niezgoda 2009, p.158; Bezat-Jarzębowska, Rembisz 2015, p. 49]. Therefore, it is necessary to reduce costs, whereby the key issue in cost management is the division into fixed (indirect) and variable (direct) costs. The reduction of variable (direct) costs may cause a decline in production, which is undesired. Taking into account variables that characterise costs in econometric models is of significant importance for determining the strength of relationship and the direction of impact of total costs, as well as variable and fixed costs on total efficiency of farms.

The last group of variables is made up of operating and investment activity subsidies. The available literature provides for quite an unambiguous opinion that, after Poland's accession to the European Union and including Poland into the Common Agricultural Policy, these subsidies have had a significant influence on farming income [Goraj 2010, p. 303-315]. Simultaneously, there are plenty of opinions according to which income support in the form of the Common Agricultural Policy mechanisms reduces the efficiency coercion as a source of income [Bezat-Jarzębowska, Rembisz 2015, p. 101], and subsidies and grants to some extent make

farm managers "lazy" [Kulawik 2008, p. 55]. One of the crucial research questions an answer to which is looked for is to what degree the analysis findings regarding the amount of subsidies are to confirm their adverse impact on efficiency.

Table 1. Independent variables taken into consideration in econometric models

Specification	Symbol of variable
Investments and production potential	
Investment expenditures before the accession in 1996-2003 in PLN per farm	Inwe_1996-2003
Investment expenditures in 2004-2011 in PLN per farm	Inwe_2004-2011
Increase in farm area before the accession in 1996-2003 (ha)	ΔUR_1996-2003
Increase in farm area in 2004-2011 (ha)	ΔUR_2004-2011
Increase in economic size of farm before the accession in 1996-2003 (EUR)	ΔSO_1996-2003
Increase in economic size of farm in 2004-2011 (EUR)	ΔSO_2004-2011
Increase in total assets before the accession in 1996-2003 in PLN per farm	ΔAkOg_1996-2003
Increase in total assets in 2004-2011 in PLN per farm	ΔAkOg_2004-2011
Increase in fixed assets before the accession in 1996-2003 in PLN per farm	ΔAktTr_1996-2003
Increase in fixes assets in 2004-2011 in PLN per farm	ΔMaTr_2004-2011
Number of annual work units (AWU) per 100 ha of agricultural land in 2004-2011	AWU_100
Organisation and intensity of production	
Degree of production simplification 1-specialist farms 0-multidirectional farms	Spec. Prod.
Cattle stocks in LU/100 ha of agricultural land in 2004-2011	Byd_100
Swine stocks in LU/100 ha of agricultural land in 2004-2011	Trz_100
Direct costs per 1 ha of agricultural land in 2004-2011	KB_UR
Financing of operating and investment activities	
Increase in equity before the accession in 1996-2003 in PLN per farm	ΔKpwł_1996-2003
Increase in equity in 2004-2011 in PLN per farm	ΔKpwł_2004-2011
Debt ratio in 2004-2011 (%)	WZ_Akt
Debt to equity ratio in 2004-2011 (%)	WZ_KW
Costs of production	
Total costs per PLN 100 of production in 2004-2011	KO_PO
Costs of depreciation, and maintenance of machinery and buildings per PLN 100 of production in 2004-2011	KAUMB_PO
Costs of external factors per PLN 100 of production in 2004-2011	KoCzZe_PO
Operating and investment activity subsidies	
Operating activity subsidies in 2004-2011 in PLN per farm	Dpl_Op
Investment activity subsidies in 2004-2011 in PLN per farm	Dpl_Inwe
Share of subsidies in farming income in 2004-2011 (%)	Dpl_Dgr

Source: own work.

4. DETERMINANTS OF EFFICIENCY

The basic purpose of business activity is to obtain the most beneficial economic effect possible. In the case of individual farms this effect is pursuing the highest income possible. This is the basic economic purpose, and in traditional individual farms it is even of existential nature [Zegar 2003, p. 68]. These objectives can be achieved by the best possible use of tangible and human factors of production at the farmers' disposal. The resources of the factors of production, which are the product of their amounts and quality, constitute a specific production potential [Czubak 2013, p. 213]. These factors of production have their alternative applications, and the final effect is determined not only by the amount of applied inputs of the factors of production, but also their interrelations. The grounds for the best possible use of production potential is appropriate allocation of the factors of production so that their amounts and proportions are arranged in an optimal way. One of the measures of the performance of the post-production process is efficiency presented as a ratio of the results achieved to the expenditures incurred [Ziętara, Zieliński 2012, p. 45-50]. Reasonable use of the factors of production is one of the basic conditions for achieving the most beneficial economic effect possible. The said prerequisites have determined a synthetic analysis of the efficiency of the basic factors of production to be conducted following DEA (Table 2).

Table 2. Technical efficiency of the factors of production in 2004-2011

Years	DEA-VRS			Coefficient of variation (%)	Standard deviation
	minimum	maximum	average		
2004	0.358	1.000	**0.703**	22.49	0.158
2005	0.357	1.000	**0.732**	22.74	0.167
2006	0.331	1.000	**0.730**	22.17	0.162
2007	0.318	1.000	**0.702**	23.98	0.168
2008	0.373	1.000	**0.708**	23.06	0.163
2009	0.379	1.000	**0.718**	23.39	0.168
2010	0.356	1.000	**0.719**	23.82	0.171
2011	0.385	1.000	**0.749**	21.77	0.163
Average	0.357	1.000	**0.720**	22.93	0.165

Source: own work.

Total efficiency of the factors of production determined with the use of DEA was characterised by high stability over the years analysed (Table 2). It was the lowest in 2007, with VRS-0.702, and the highest in 2011, with VRS-0.749. Despite the high stability of average efficiency, there were significant differences among individual farms. Some of the farms reached the highest degree of efficiency in all the years analysed, and these were fully effective farms with VRS-1, but there were also farms with low efficiency of VRS<0.5. Because of the high diversity

of farms' efficiency, it was justified to conduct an analysis aimed at indicating the determinants of efficiency.

The impact of the factors of production on total efficiency was determined by way of gradually distinguishing a group of independent variables, which explained the changes in efficiency to the highest degree. This was achieved with the use of non-full (segmented) regression models, with the independent variables in the form of the division of the factors adopted in Table 1. This approach made it possible to determine which of the homogeneous groups of factors had the greatest impact on total efficiency. Table 3 shall present the final results of the estimation of structural parameters using the model taking account of all the quantitative variables (the full model).

Table 3. Determinants of technical efficiency of the factors of production estimated for the linear model (dependent variable as the average value of DEA-VRS) in 2004-2011

Independent variables	Regression coefficient	Standard error	Student's t	p-value	
Stała	0.845859	0.0784871	10.7770	<0.0001	***
Inwe_1996-2003	−3.32106e-07	9.2603e-08	−3.5863	0.0005	***
Inwe_2004-2011	8.2331e-08	3.90009e-08	2.1110	0.0367	**
ΔUR_1996-2003	0.00210874	0.000587684	3.5882	0.0005	***
ΔUR_2004-2011	−0.00029321	0.000674474	−0.4347	0.6645	
ΔSO_1996-2003	−7.5407e-07	5.33388e-07	−1.4137	0.1598	
ΔSO_2004-2011	−2.46411e-07	4.93944e-07	−0.4989	0.6187	
AkOg_1996-2003	−2.3925e-010	1.16869e-07	−0.0020	0.9984	
ΔAkOg_2004-2011	−9.63001e-08	1.13083e-07	−0.8516	0.3960	
ΔAktTr_1996-2003	−1.12394e-07	8.78426e-08	−1.2795	0.2030	
ΔMaTr_2004-2011	−5.22757e-08	1.12188e-07	−0.4660	0.6420	
AWU_100	−0.0090944	0.00362829	−2.5065	0.0134	**
Spec_Prod.	0.030165	0.0340989	0.8846	0.3780	
Byd_100	−0.00036581	0.000341476	−1.0713	0.2860	
Trz_100	−0.00066689	0.000339752	−1.9629	0.0518	*
KB_UR	0.00010338	1.3171e-05	7.8491	<0.0001	***
ΔKpwł_996-2003	3.23572e-08	9.53337e-08	0.3394	0.7349	
ΔKpwł_2004-2011	9.64611e-08	4.81018e-08	2.0054	0.0470	**
WZ_Akt	0.00229039	0.000982601	2.3309	0.0213	**
WZ_KW	−0.00135956	0.000624394	−2.1774	0.0313	**
KO_PO	−0.00502326	0.00124128	−4.0468	<0.0001	***
KAUMB_PO	−0.00155608	0.00186467	−0.8345	0.0455	**
KoCzZe_PO	0.0142456	0.00381874	3.7305	0.0003	***
Dpl_Inwe	−2.1922e-07	9.22074e-08	−2.3775	0.0189	**
Dpl_Dgr	−0.00053152	0.000290606	−1.8290	0.0697	*

Statistical significance *** – 1%, ** – 5%, * – 10%
Source: own work.

Arithmetic mean of dependent variable	0.720824	Standard deviation of dependent variable	0.172822
Residual sum of squares	1.177691	Residual standard error	0.095548
Coefficient of determination R-squared	0.743957	Adjusted R-squared	0.704337
F(25, 129)	14.99289	p-value for F-test	3.28e-27
Log likelihood	158.2544	Akaike information criterion	−264.5088
Schwarz-Bayesian criteria	−185.3797	Hannan-Quinn information criterion	−232.3683

As a result of estimating the model's structural parameters, the majority of variables characterising the production potential proved to be statistically insignificant. The changes in resources of the factors of production and their interrelations were influenced by investments, which resulted not only in replacement of fixed assets, but also in their enlargement and modernisation. This brings about opportunities for the implementation of new technologies, which result in reduction of current assets and labour inputs. The farms which made investments after the accession of Poland to the European Union achieved higher efficiency [Czekaj 2008, p. 31-44]. Contrary to investments implemented after 2004, the increase in investments before the accession caused lower efficiency. Therefore, a legitimate question arises about the cause of this situation. It may have happened that after an investment was implemented, there was deterioration of results instead of growth in production and improvement of efficiency [Sass 2016, p. 417-419; Czekaj 2008, p. 31-44]. In particular, this refers to investments related to livestock buildings and farm enlargement. A considerable increase in the number of cows at a farm may result in a decrease of efficiency per cow. It is similar in the case of an increase in the area of cultivated land, which may be in a wrong culture, and which may record a decrease in crops at the beginning of cultivation. Before the accession (in comparison with the post-accession period), there were significantly more investments related to construction of new livestock buildings and modernisation of the existing ones, and more investments connected with land purchase. This explains why the investments implemented in 1996-2003 could temporarily reduce the efficiency of the farms. A highly significant variable was the increase in cultivated before the accession. The increase in area in 1996-2003 improved the efficiency of the factors of production. The farms which invested in land before the accession increased their potential, establishing good conditions for development. After 2004, these farms were the main beneficiaries of EU funds. However, after the accession, the increase in farms' area was of no importance for improvement of efficiency. Similarly, the increase in total assets and fixed assets had no statistically significant impact on efficiency.

The changes in production potential, both before and after Poland's accession to the European Union, accounted for the variability of efficiency of the factors of production only to a small extent. The production potential has a large

impact, above all, on production and farming income [Zegar, p. 103], which are primary in comparison with efficiency. Efficiency is of relative nature, as it is the achievement of the best effect possible with specific land, labour and capital inputs. The importance of farms' potential in the production process cannot be underestimated, but it has an indirect influence on the efficiency of the factors of production.

Among the variables characterising the production potential, a significant one was the number of annual work units (AWU) per 100 ha of agricultural land. Growth in employment (labour inputs) resulted in lower efficiency of the farms. In order to improve their efficiency, farmers should increase the number of technical devices and not the labour inputs. The fact that farmers understand well the need to substitute labour with technical devices is confirmed with the increase in investment expenditures after 2004 [Czubak 2013]. This process shall intensify because of the lack of people to work in agriculture, which results in higher labour costs.

Analysing the influence of individual factors on efficiency, it is the impact of variables characterising costs that was revealed to the greatest extent in the process of econometric modelling. The increase in direct costs (production intensity) and the costs of external factors enhanced efficiency, and the costs of depreciation and maintenance of machinery and buildings reduced efficiency. The key problem of cost management is the division into fixed (indirect) costs and variable (direct) costs. The reduction of variable (direct) costs may cause a decline in production and reduction of land productivity. In the analysed farms with the highest efficiency (VRS-1), the costs of fertilisation and crop protection products were higher by 44% in comparison with those with the lowest efficiency (VRS<0.5), but, at the same time, their crop production per hectare of agricultural land was higher by 43%. On the other hand, in the case of fully effective farms, the costs of depreciation and maintenance of machinery and buildings, which are among fixed costs, were lower by 58%. This lets us reach quite an unambiguous conclusion that improvement of efficiency to a great extent depends on reduction fixed costs, which is connected, among other things, with the need to be cautious when making investments and to take advantage of services or collective use of machinery to a greater extent. Unfortunately, the desire to own machinery for one's own use only dominates over other forms of use, which are more rational from the viewpoint of cost reduction. This is also favoured by a relatively easy access to EU funds.

When discussing the importance of individual types of costs for improvement of the farms' efficiency, attention should be paid to the costs of external factors. These costs were statistically significant and their increase resulted in improvement of efficiency. This means that the farms which took advantage of loans and leased land [Czekaj 2006] recorded higher efficiency. The significant importance of loans in financing of farming activity is confirmed with the debt ratio. The farms which took advantage of loans recorded higher efficiency. The

effect of financial leverage on the improvement of return on equity was revealed [Nowak 2005, p. 231-237]. However, the negative influence of the debt to equity ratio and the positive influence of the increase in equity after the accession unambiguously indicate the need to exercise caution when taking advantage of external sources of financing. Most importantly, fixed assets should be financed with equity [Nowak 2005, p. 98-101].

Among the variables characterising organisation of production, the degree of the farms' specialisation was statistically insignificant. More than half of the analysed farms were multidirectional farms, and around 30% of them specialised in pork production. The lowest percentage, i.e. 11% of the farms, specialised in crop production. These findings imply that both multidirectional and specialist farms can be effective. On the other hand, the increase in swine stocks reduced the farms' efficiency. This may have resulted from the deteriorating profitability of pork production after the accession of Poland to the European Union [Czyżewski, Smędzik-Ambroży 2013, p. 159-170]. After 2004, a more rapid growth was recorded in the case of cereals, rape, milk and beef cattle prices than in the case of pork prices.

The analysis conducted has confirmed the opinions of other authors that grants and subsidies reduce the efficiency coercion [Czekaj 2008, p. 36]. Both the participation of subsidies in farming income and investment subsidies reduced efficiency.

One of the objectives of econometric modelling is looking for a regression model to best describe the nature of the relationship between the response (dependent) variable and the explanatory (independent) variables. The results of econometric modelling have been presented using multiple linear regression. The findings regarding both the designation of determinants of efficiency and their substantive interpretation indicate that the said objective has been achieved. Moreover, taking into account the satisfaction of the model quality criteria, the estimated model of multiple linear regression is of high cognitive value. It explains in around 75% the variability of total efficiency, however, around 25% of this variability is still not accounted for. The reason for the failure to explain the variability to a greater extent may be the omission of important factors, such as qualitative variables characterising human capital[5], and soil quality, as well as selection of a wrong regression model. Therefore, apart from the linear regression model, curvilinear regression models have been applied, i.e. second-degree polynomial (quadratic function), as well as power and logarithmic functions. The results of the estimation of the models' structural parameters (direction of impact and statistical significance of the variables) shall be presented in Table 4.

[5] Because of limited opportunities to present the findings, only quantitative variables have been taken into account. The impact of qualitative factors on efficiency was significantly lower and it amounted to around 27%.

Table 4. Determinants of technical efficiency of the factors of production (DEA-VRS) estimated with the use of linear, power, logarithmic and quadratic regression

Independent variables	Multiple regression models			
	linear	power	logarithmic	quadratic
Inwe_1996-2003	(-) ***	(-)*	(-)**	(-)**
Inwe_2004-2011	(+)**			
ΔUR_1996-2003	(+)***			(+)**
AWU_100	(-)**	(-)***	(-)***	(-)***
Trz_100	(-)*			
KB_UR	(+)***	(+)***	(+)***	(+)***
ΔKpwl_2004-2011	(+)**	(+)***	(+)***	
WZ_Akt	(+)**			(+)**
WZ_KW	(-)**			(-)*
KO_PO	(-)***	(-)***	(-)***	(-)***
KAUMB_PO	(-)**			(-)*
KoCzZe_PO	(+)***	(+)*	(+)*	(+)***
Dpl_Inwe	(-)**			
Dpl_Dgr	(-)*			(-)*
Coefficient of determination R-squared	0.7439	0.7206	0.7506	0.6214
Adjusted R-squared	0.7043	0.6275	0.6611	0.5835

Source: own work.

Similar model results were achieved for linear regression and second-degree polynomial. On the other hand, identical results were achieved for power and logarithmic regression, and in the case of these models the number of explanatory variables for efficiency was the lowest. In all the regression models, significant factors included production intensity, total costs and costs of external factors, as well as the number of annual work units per 100 ha of agricultural land and investment expenditures before the accession of Poland to the European Union. Moreover, full harmony was recorded as regards the direction of impact of these variables irrespectively of the econometric model. This means that these variables were important determinants of the farms' technical efficiency. It is worth highlighting the great significance of the increase in equity in 2004-2011, which was significant for three regression models. This confirms the great importance of equity for independence and stability of financing farm assets. On the other hand, investment expenditures after Poland's accession to the European Union were of significance in the linear regression model only. By contrast, investments before the accession appeared in all the regression models, and the increase in farm area in the linear and quadratic regression models. These variables characterise the production potential in the pre-accession period and indicate its great significance for the development of farms after the accession to the European Union.

The discussions taking place in various groups and organisations, as well as scientific publications and reports of the Agency for Restructuring and Modernisation of Agriculture (ARMA) pay attention to the significance of EU funds for the development of farms after 2004. However, it should be pointed out that the modernisation of agriculture, as well as agricultural and food processing was dynamised much earlier. The establishment of ARMA in 1993 and interest subsidies for loans granted by banks for farm modernisation contributed to the emergence of developing farms. After joining the European Union, these farms have made effective use of the EU funds.

The share of subsidies in farming income was significant in the linear and quadratic regression models, and investment subsidies appeared in the linear regression model only. Both the share of subsidies in farming income and investment subsidies reduced the efficiency of the factors of production.

5. SUMMARY

The analysis findings let us draw the following conclusions.

The total efficiency of the factors of production determined with the use of DEA was characterised by high stability. It was the lowest in 2007, with VRS-0.702, and the highest in 2011, with VRS-0.749. Despite the high stability of average efficiency, there were significant differences among individual farms. Some of the farms reached the highest degree of efficiency in all the years analysed, and these were fully effective farms with VRS-1, but there were also farms with low efficiency of VRS<0.5. Because of the high diversity of farms' efficiency, it was justified to look for factors affecting technical efficiency.

Using interdependence analysis, quantitative variables having a significant impact on efficiency were defined. The variables which enhanced efficiency included investment expenditures before and after the accession, the increase in the area of cultivated land before the accession, production intensity (direct costs per hectare), the increase in equity after the accession, debt ratio and the costs of external factors. On the other hand, the variables which reduced efficiency included total labour inputs, swine stocks, debt to equity ratio, total costs per PLN 100 of production, the costs of depreciation and maintenance of machinery and buildings, as well as investment subsidies and the share of subsidies in farming income.

Technical efficiency was highly influenced by costs. The increase in direct costs (production intensity) and the costs of external factors enhanced efficiency, and the costs of depreciation and maintenance of machinery and buildings reduced efficiency. Farmers should look for improvement of efficiency in the reduction of fixed (indirect) costs, which is connected, among other things, with the need to be cautious when making investments and to take advantage of services or collective use of machinery to a greater extent. However, after Poland's accession to the EU, the farmers' desire to own their private machinery dominates over other

forms of use, which are more rational from the viewpoint of cost reduction. This is also favoured by a relatively easy access to EU funds.

The great significance of quantitative factors for technical efficiency is also confirmed by the formal and statistical features of econometric models, such as normality of distribution of residuals (no grounds for rejecting the null hypothesis), the high degree of the models' fit to empirical data (the models explained the variability of efficiency in around 70-75%), a high value of the F-test and a small residual standard error.

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DETERMINANTY EFEKTYWNOŚCI TECHNICZNEJ CZYNNIKÓW WYTWÓRCZYCH W RODZINNYCH GOSPODARSTWACH ROLNYCH

Streszczenie: Podstawowym celem badań było określenie wpływu wybranych czynników endogenicznych, a także wielkości dopłat z funduszy unijnych na efektywność techniczną czynników wytwórczych w rodzinnych gospodarstwach rolnych. Badaniami objęto gospodarstwa z podregionu bydgoskiego, które przed akcesją Polski do Unii Europejskiej (1996-2003)

korzystały z kredytów preferencyjnych. Jednocześnie prowadziły w latach 2004-2011 nieprzerwanie rachunkowość w systemie Polski FADN. Wykorzystując rachunek regresji określono wpływ poszczególnych czynników na efektywność techniczną gospodarstw. Estymowano parametry strukturalne modeli liniowych i nieliniowych z wieloma zmiennymi niezależnymi. W wyniku przeprowadzonych analiz ustalono, że poprawiały efektywność: nakłady inwestycyjne przed i po akcesji, przyrost powierzchni użytkowanej ziemi przed akcesją, intensywność produkcji, przyrost kapitału własnego po akcesji, zadłużenie aktywów i koszty czynników zewnętrznych. Natomiast pogarszały efektywność: nakłady pracy, obsada trzody chlewnej, zadłużenie kapitału własnego, koszty stale, a także dopłaty do działalności inwestycyjnej i udział dopłat w dochodzie.

Słowa kluczowe: efektywność techniczna czynników wytwórczych, metoda DEA, rachunek regresji, determinanty efektywności.

Dr Roman Sass
Wydział Prawa, Administracji i Ekonomii
Kujawsko-Pomorska Szkoła Wyższa w Bydgoszczy
ul. Toruńska 55-57
85-023 Bydgoszcz
e-mail: r.sass@kpsw.edu.pl
orcid: 0000-0002-4604-8531