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The impact of the subsidies on efficiency of different sized farms. Case study of the Common Agricultural Policy of the European Union

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Abstract: The aim of the study is to determine the impact of the EU Common Agricultural Policy (CAP) subsidies on farm efficiency, depending on farm economic size. Although the impact of subsidies on efficiency is already relatively well recognised, earlier studies were focused on identifying this issue rather than explaining the variation in its intensity. Typically, the analysis of variation by type of production and country was conducted with microeconomic data. Our survey is based on data from the Farm Accountancy Data Network (FADN) aggregated at the regional level, for farms representative for particular economic size classes. In the survey, we apply stochastic frontier analysis and "true" fixed-effects model. The results of the research confirm the hypothesis that the impact of subsidies on efficiency depends on the size of farms. Statistically significant, stimulating effect of subsidies was identified only in the group of the largest farms. Such results put into question the effectiveness of the CAP in stimulating the development of the European Model of Agriculture, and at the same time indicate that in its current form, the policy may interfere with market mechanisms and lead to the phenomenon of "rent seeking".

Keywords: efficiency; Farm Accountancy Data Network (FADN); panel data; stochastic frontier analysis (SFA); subsidies; true fixed effects

The European Union presently has an extensive system of direct payments, consisting of obligatory support: *i*) direct payment (income support), *ii*) green payment; *iii*) payment for young farmers; and voluntary support: *i*) payment to areas facing natural and other specific constraints (ANC), *ii*) voluntary coupled support (VCS), *iii*) small farmers scheme (SFS), *iv*) redistributive payment. In our research, we focus on direct payments. The direct payments (as income support) under the Common Agricultural Policy generally aim to (European Commission 2020):

- Be a safety net and make farming more profitable;
- Guarantee, broadly understood, food security in Europe;
- Reward farmers for providing public goods that the market fails to deliver.

However, the specific objectives of the subsidies are diverse – some are intended to stimulate the development of small farms and improve their integration with the market (the support system for small farms), increasing their chances of being effective entities. Others, e.g. green payments are more oriented towards achieving environmental objectives and protecting the environment. It is also worth noting that the Common Agricultural Policy is evolving noticeably – from supporting the improvement of agricultural productivity and ensuring a stable supply of affordable food to help tackle climate change and support sustainable

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management of natural resources (European Commission 2020). A significant difference emerges when the support system is examined considering farm size. Small farms may receive additional support to compensate for their inability to achieve economies of scale (European Commission 2020). On the other hand, very large farms face degressivity and capping of subsidies, which leads to a decrease in their competitiveness. In the years 2013–2020, at least 5% reduction is applied to amount from EUR 150 thousand of basic payment. In the years 2021–2027, this reduction will be even more significant, as any support exceeding EUR 60 thousand will be reduced and the maximum amount of support is EUR 100 thousand. This means that large farms may lose the incentive to increase the scale of production (no payment for area over 240 ha, assuming that the average payment in the European Union is about EUR 250 per ha) (European Commission 2018). On the other hand, such a measure seems to support the so-called European model of agriculture, according to which agriculture is supposed to perform both traditional functions (food production) and new ones – related to rural development. In this model, a farm should be of medium size, based on family labour, have a diversified, multi-directional production structure, and among non-economic features – it should maintain cultural and social ties in rural areas (Kowalczyk and Sobiecki 2011).

The role of subsidies of the European Union's Common Agricultural Policy and support for the agricultural sector in general is the subject of many discussions and disputes concerning the legitimacy and effects of this form of support (Swinnen 2015). Identifying the impact of these subsidies on economic efficiency is another issue of interest to many researchers. Some of them argue that subsidies can contribute to a decrease in technical efficiency, because a farm has an income even without carrying out its activities (redistribution to farmers as part of fiscal policy), so the incentive to engage in more efficient production activities may be lower (Minviel and Latruffe 2017). The negative impact of the subsidies on technical efficiency is also indicated by Marzec and Pisulewski (2017) using the translog production function estimated by employing Bayesian Stochastic Frontier Analysis; Minviel and De Witte (2016) using nonparametric efficiency analysis; Serra et al. (2008) using SFA (Stochastic Frontier Analysis). This, of course, raises questions about the effectiveness of subsidies, as well as other alternative tools for supporting farms. However, subsidies can also have a positive impact on farm efficiency when they help to overcome financial barriers and provide an impulse to modernise and implement innovative solutions (Minviel and Latruffe 2017). This thesis is supported by the results of other studies (Latruffe and Desjeux 2016; Latruffe et al. 2017). Also, Cechura (2012) indicates the positive impact of the subsidies on technical efficiency and TFP. It is also possible that subsidies do not have any specific and defined impact on technical efficiency (Pechrova 2015; Latruffe et al. 2017; Minviel and Latruffe 2017). Finally, Bojnec and Latruffe (2013) found that in Slovenia subsidies are negatively related to farms' technical efficiency and economic efficiency scores, however positively related to their allocative efficiency and profitability.

The ambiguous results of the previously conducted research motivated us to address this issue. The hypothesis we are testing concerns the differences in the impact of subsidies on the technical efficiency of agricultural production depending on the economic size of farms. Such a formulation of the hypothesis follows the rationale that small farms (with the lowest economic power) are not able to use subsidies to improve farming efficiency and achieve economies of scale, and often these subsidies are of social nature for them, supplementing the income of the household functioning in parallel with the agricultural holding. On the other hand, farms with the greatest economic power may not have such a strong imperative to improve technical efficiency, as they gain an advantage over others due to economies of scale. Therefore, it may be assumed that the most positive impact of the subsidy will be observed in the group of medium-sized farms. Such farms are large enough to be able to invest in development and small enough to be motivated to do so.

Our approach is also innovative from a technical point of view because separate models were estimated for different farm size groups, which will answer the question of whether the direction and strength of the relationship between the size of subsidies and technical efficiency vary with farm size. This approach is different from the traditional one, where farm size appears only as one of the control variables explaining technical efficiency (Hadley 2006; Zhu and Lansink 2010; Zhu et al. 2012). The approach proposed in this article captures the relationship between the size of the farm and the way support operates and also takes into account the problem of differentiation of production function parameters in farms of different production scale.

MATERIAL AND METHODS

The study used panel data for the FADN regions of the European Union. The modelled dependent

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variable is technical efficiency, and the main explanatory variable the value of direct payments per holding. For modelling, we used the parametric method of stochastic frontier analysis (SFA). Based on literature analysis by Minviel and Latruffe (2017), it can be concluded that the above research strategy is well-grounded. 80% of the studies analysed by the authors concentrated on direct payments, 76% relied on parametric estimation methods and used 87% panel data.

The data for our research come from public FADN database. Our observation consists of farms representative for all types of the agricultural production, of the FADN region, from the economic size groups of: 2–8, 8–25, 25–50, 50–100, 100–500 and more than EUR 500 thousand of standard output (SO), in the period 2007–2017. After excluding atypical regions and those with no data for the whole period (Hamburg, Bucharest, Guadeloupe, Martinique, Réunion, Croatia) from the sample, the final number of observations was 129. In addition, in some countries, only farms with economic size of more than EUR 25 thousand of SO are included in the FADN observation field (Belgium, Germany, France, United Kingdom), there are also occasional data gaps; hence the final number of observations in each model varies. Detailed information on the data used is presented in Table 1.

To estimate the level of effectiveness and its correlation with the amount of subsidies, a "true" fixed-effects Greene (2005) model was used. This method, originating from the SFA parametric efficiency research strand (Parmeter and Kumbhakar 2014), extends it with the ability to reliably estimate efficiency using panel data. In its basic form, the "true" fixed-effects model is:

$$y_{it} = \alpha_i + x'_{it}\beta + \varepsilon_{it} \quad (1)$$

$$\varepsilon_{it} = v_{it} - u_{it} \quad (2)$$

$$v_{it} \sim \mathbb{N}\left(0, \sigma_v^2\right) \quad (3)$$

$$u_{it} \sim \mathbb{N}^+\left(0, \sigma_{uit}^2\right) \quad (4)$$

where: y_{it} – the effects of the production of the i^{th} entity in period t; α_i – the intercept, representing a non-measurable, specific and constant over time heterogeneity; x'_{it} – input vector of the i^{th} entity in period t; β – a parameter representing the elasticity of production relative to input x; ε_{it} – error term; v_{it} – idiosyncratic error component, with normal distribution, representing measurement error and noise; u_{it} – an inefficiency component, having e.g. a half-normal distribution, specific to the i^{th} entity, in period t.

In addition, exogenous variables (z_{it}) which are expected to affect the efficiency of entities can be introduced into the model. They are included as factors that calibrate the distribution of inefficiencies. The inefficiency variance σ_{uit}^2 is then parameterised according to the formula:

$$\sigma_{uit}^2 = \exp\left(z_{it}\gamma\right) \quad (5)$$

The resulting parameter vector γ informs about the direction and strength of the impact. A negative sign indicates a reduction in inefficiency variance and therefore a positive impact on efficiency. It should be noted here that from the perspective of the described

Table 1. Average values of inputs, effects and direct payments for representative farms in FADN regions from 2007 to 2017, by economic size, in prices and at the euro exchange rate from 2007

	Standard output (thousand EUR)											
	2–8		8–25		25–50		50–100		100–500		> 500	
	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
Output	9.0	5.2	22.1	15.0	45.3	14.5	82.7	22.1	227.2	70.2	1 152.5	633.0
Land	6.9	5.3	16.0	10.4	39.2	28.7	64.3	44.8	142.6	126.2	491.1	544.8
Labour	2.2	0.8	2.6	1.1	3.2	1.4	4.0	2.1	7.2	5.2	30.0	30.3
Capital	6.0	2.8	15.0	12.2	33.8	15.6	59.4	23.0	157.2	66.6	784.0	518.7
Dir_pay	1.6	1.2	3.8	2.4	8.5	4.5	14.1	7.0	30.0	17.6	95.7	99.0
n	492		847		1 202		1 388		1 399		835	

n – number of observations; $\bar{x}$ – average; σ – standard deviation; *output* – total output in thousands of euro (SE131); *land* – total utilised agricultural area in ha (SE025); *labour* – total labour input in thousands h (SE011); *capital* – capital input as the sum of total intermediate consumption and depreciation in thousands of euro (SE275 + SE360); *dir_pay* – total direct payments in thousands of euro (SE606)

Source: Original study based on European Commission (2019)

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methodology, the phenomenon of heteroskedasticity of the inefficiency indicator is desirable, as it reveals the impact of potential explanatory variables. The estimated inefficiency can be simply transformed into an efficiency index, within the range 0–1, according to the method proposed by Battese and Coelli (1988):

$$Eff = e^{-u_{it}} \tag{6}$$

In practice, however, a number of assumptions still need to be made to assess efficiency. The first one concerns the choice between a panel model with fixed effects and a one with random effects. The choice depends on the relationship between x'_{it} and α_i. If this relationship exists, which means a correlation of inputs with immeasurable heterogeneity, the model with fixed effects is adequate. For this study, based on aggregated data, this approach seems justified. It was empirically confirmed by the Hausman test. Another assumption concerns the shape of the production function. Typically, two of its forms are used most often – the Cobb-Douglas function and the translogarithmic function, with the latter considered more flexible. Another argument for this approach comes from the wrong skewness (Almanidis and Sickles 2011) generated by the Cobb-Douglas function for the data analysed in this study. Therefore, the translogarithmic function was adopted for the study. The method described by Pavelescu (2011) was used to estimate the production elasticity rates. Finally, due to the fact that in the "true" fixed-effects method, inefficiencies are estimated using a maximum-likelihood dummy variable (MLDV) estimator, it is necessary to make assumptions about the distribution of inefficiencies. The semi-normal, exponential and truncated normal distributions have been used most frequently in the previous studies. Due to the lack of theoretical and practical reasons to accept any of them, models using all three of them were estimated, treating this procedure as a kind of "robustness test". The use of the MLDV estimator requires addressing the problem of the incidental variable. It may render the estimator inconsistent (it does not bring the estimated value closer to the actual value as the observation number increases), however, as indicated by Belotti and Ilardi's (2012), the problem disappears when the panel covers more than 10 periods.

The calculation was based on the STATA 15 program and the *sfpanel* command, developed by Belotti et al. (2013). The full version of the study included an estimation of 3 versions of models for each of the area groups, differentiated by the distribution of inefficiency. Within each distribution, the following models were estimated: a base model (pure production function), a model with year-dependent production changes control (production function with binary variables for years) and a model with subsidies (production function with binary variables for years and the inefficiency component parameterised by the *dir_pay* variable). For the purposes of the Hausman test, analogous models in the "true" random effects version were estimated (Greene 2005). For comparisons of the results in different model configurations despite the Hausman's test, we used the Wald test and the Likelihood-Ratio test.

RESULTS AND DISCUSSION

At the first stage of the study, it was checked whether there is a problem of wrong skewness in the economic size groups, which would make it impossible to estimate the efficiency. For this purpose, traditional panel models were calculated for the Cobb-Douglas and translogarithmic functions. The results of the estimates are presented in Table 2.

The results presented in Table 2 confirm the problem indicated before. It turns out that the estimation of efficiency is possible only for economic size groups EUR 25–50, 50–100 and 100–500 thousand of standard output. Probably not without significance here is the fact that these are the most numerous groups, because FADN gathers data for typical farms of this size in all countries. As shown in Simar and Wilson's (2010) study, the probability of the wrong skewness decreases with the increase of the sample size. Anyway, with the obtained data, it was possible to make the estimation for three models. Therefore, EUR 25–50 thousand of SO farms will be called smaller farms, EUR 50–100 thousand of SO – medium-sized farms, and EUR 100–500 thousand of SO – large farms, although the authors are aware that all of the analysed groups are far above the EU average farm size (67.6% of farms in 2016 was below EUR 8 000 of SO; Eurostat 2018). The parameters of the estimated production functions and the efficiency identified within them are presented in Table 3. The presented models contain binary variables controlling year-dependent production changes. The validity of such an approach is proved by the likelihood ratio tests conducted earlier.

In Table 3 we present all models that were estimated. For the others, the log-likelihood estimator did not reach a convergence within the assumed iteration limit. Although only 4 out of 9 assumed models were estimated, the results allow for some generalisations.

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Table 2. Wrong skewness problem in production function models for farms of different economic size groups in FADN regions

Production function	Model type	Skewness in models for different economic size (SO; thousand EUR)*					
		2–8	8–25	25–50	50–100	100–500	> 500
Translog	fixed effects	0.640 (0.584)	0.432 (0.465)	**–0.130 (–0.091)**	**–0.028 (–0.020)**	**–0.060 (–0.152)**	0.435 (0.404)
	random effects	0.640 (0.630)	0.452 (0.477)	–0.005 (0.018)	0.054 (0.066)	0.109 (0.076)	0.419 (0.402)
Cobb-Douglas	fixed effects	0.588 (0.564)	0.404 (0.489)	0.878 (0.141)	0.183 (0.173)	0.629 (0.626)	0.581 (0.502)
	random effects	0.547 (0.550)	0.211 (0.327)	0.147 (0.187)	0.183 (0.177)	0.490 (0.447)	0.494 (0.428)

*Model without year-dependent production changes control (model with control); models without wrong skewness problem in bold; SO – standard output

Source: Original study based on European Commission (2019)

Firstly, it proved justified to estimate the production function separately for different economic size groups. They differ essentially in terms of parameters, in particular those relating to land use. For the smaller and the medium group (EUR 25–50 thousand SO and EUR 50–100 thousand SO), this factor was much

Table 3. Models of the impact of direct payments on efficiency in farms representative of FADN regions, broken down by economic size groups

Model	Economic size (SO; thousand EUR)				
	25–50_*hn*	50–100_*hn*	50–100_*exp*	100–500_*hn*	100–500_*hn_re*
Land_elast	–0.04**	–0.0025	–0.001	0.117***	0.018
Labour_elast	0.278***	0.250***	0.238***	0.185***	0.175***
Capital_elast	0.807***	0.749***	0.749***	0.647***	0.642***
Returns_to_scale	1.045	0.997	0.986	0.949	0.835
U_sigma_dir_pay	0.00048	0.00013	–0.000014	–0.00032***	–0.00033***
U_sigma_cons	–16.75**	–12.08**	–6.09***	–2.71***	–2.92***
V_sigma_cons	–4.75***	–4.84***	–5.12***	–4.96***	–4.82***
Wald test	2.06 (0.151)	0.78 (0.377)	0.35 (0.553)	14.64 (0.0001)	14.7 (0.0001)
LR test	3.25 (0.0713)	1.02 (0.600)	0.37 (0.544)	20.89 (0.0000)	–
Hausman test	–	–	–	–5.42	–5.42
Avg_eff_BC (%)	99.69	99.49	95.87	98.71	99.07
Std. dev. (%)	0.69	0.30	2.39	2.84	1.69
Min (%)	86.24	94.21	63.17	64.97	83.26
Max (%)	99.98	99.81	98.91	100.00	100.00

Significance at level ***(0.01), **(0.05), *(0.1); for test we present statistics and *P*-value (in parentheses); SO – standard output; *hn* – half-normal distribution; *exp* – exponential distribution; *re* – random effects model; *_elast* – production elasticity; *returns_to_scale* – returns to scale as a sum of elasticities; *u_sigma* – inefficiency variance; *v_sigma* – idiosyncratic term variance; *dir_pay* – direct payments impact; *cons* – intercept; Wald test – for significane of *dir_pay* variable in the model; LR test – whether a model with the *dir_pay* variable is better fitted than a model without it; *avg_eff_BC* – average efficiency calculated according to Batesse and Coelli; std. dev. – standard deviation

Source: Original study based on European Commission (2019)

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less important, if at all. Although it should be noticed that the lack of significance of the relatively constant land input may result from estimating models using a fixed effects estimator. Although this thesis is contradicted by the results for the largest farms (EUR 100–500 thousand SO), where this factor was strongly significant despite the use of the same estimator, and after replacing it with a theoretically more conducive quasi-constant variable estimator of random effects, the elasticity of production in relation to land input decreased and lost its significance. To generalise, it can be concluded that with the increase in the economic size of farms, the importance of capital and labour inputs decreases and the importance of the land factor increases. This phenomenon can be explained by the over-representation of farms specialised in field crops, where the land input is crucial, in the group of the largest farms. This also justifies addressing, at the next stage of research, the issue of diversification of the impact of subsidies with regard to the production type. Moreover, such an outcome provides an economic explanation of the process of land factor polarisation, whereby the largest farms become even larger and the medium and smaller ones reduce their area. The estimates of scale effects are also consistent with the theory of economics. In the case of smaller farms, they are positive, so increasing the inputs brings more than proportionate effects. In the case of medium-sized farms they are close to unity, and in the case of the largest farms they are decreasing.

Secondly, we can conclude on the impact of subsidies on efficiency. In the group of smaller and medium-sized farms such dependencies were not identified. This is indicated by the lack of significance of the parameter, and Wald and LR tests proving the extension of the model unjustified. The situation is different in the case of the largest farms, where the impact is significantly positive (negative impact on inefficiency, positive on efficiency). Such a result is stable regardless of the estimator used (the Hausman's test did not give a clear answer which of the estimators is more adequate, so we present both). Considering the fact that subsidies are granted per ha, this may mean that only larger amounts of support have a significant impact on efficiency.

Thirdly, the efficiency indicators obtained in our analysis should be interpreted. It can be noted that on average, efficiency is high, up to 99%. Such a result is different from the results of other studies comparing agricultural efficiency in EU countries or regions (Sielska and Kuszewski 2016; Martinho 2017). This difference is due to at least three reasons. First of all, only FADN farms, which by definition must have at least "economic viability", were included in the analysis. In addition, only relatively large economic size groups were included in the final comparisons, which additionally contributes to their efficiency. Moreover, the farms were compared within, not between groups or average values for a given region, which eliminated the burden of the results with the differentiation of production functions depending on the farm size. Finally, the applied translogarithmic form of the production function adjusts to the data, so that the error of the estimated models is relatively smaller than in the case of the Cobb-Douglas function, and thus the scale of inefficiency must also be smaller. It should also be borne in mind that the technical efficiency estimated within the framework of these study is not economic efficiency, so entities relatively efficient in transforming inputs into outputs may be economically inefficient due to bad allocation decisions concerning production type and price conditions, as well as alternative costs incurred.

CONCLUSION

In conclusion, the conducted surveys show that it is reasonable to make estimations of agricultural efficiency using the SFA method, taking into account the different production functions for farms of different economic sizes. With this approach, subsidies prove to have a significant effect on efficiency only in the case of the largest farms, where efficiency is generally high. Moreover, our results raise at least two doubts in the context of the strategic objectives of the Common Agricultural Policy. Firstly, the extent to which the current support model contributes to strengthening the European Model of Agriculture should be considered. Why, although in this model, the desired structure is that based on medium-sized family farms, does the basic support instrument (direct payments) improve the efficiency of the largest entities? Secondly, a question arises whether the current system, in theory decoupled from market mechanisms, does not actually disrupt them. Since the largest entities already operate in the area of decreasing scale effects, market mechanisms force them to limit or even reduce the size of production, while the system of subsidies related to the size of a holding incentivise them to increase the scale of production and "rent seeking" (Czyżewski and Matuszczak 2018).

Moreover, as Kostlivy and Fuksova (2019) point out, different types of subsidies can have a different impact

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on the technical efficiency of farms of different sizes (e.g. the negative impact of less favoured area or agri-environmental support subsidies and the positive impact of subsidies on modernisation investments). These conclusions, combined with the above findings from our research, may provide a new stimulus to reorient agricultural policy and improve its effectiveness. It, therefore, appears that agricultural policy instruments should be better adapted to the realities of the functioning of the agricultural sector, based on the different production models and agricultural production functions in the EU Member States.

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