https://doi.org/10.17221/415/2020-AGRICECON

Determinants of farm profitability in the EU regions. Does farm size matter?

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Citation: Kryszak Ł., Guth M., Czyżewski B. (2021): Determinants of farm profitability in the EU regions. Does farm size matter? Agric. Econ. – Czech, 67: 90–100.

Abstract: Farms in the European Union come in a wide variety of sizes and the effect of farm size on profitability (return on assets – ROA) has not been sufficiently investigated. The principal goal of this paper, therefore, is to study the determinants of farm profitability using the panels of the Farm Accountancy Data Network (FADN) on farms of different economic size between 2007 and 2018. We use a profitability function based on ratios that show the production and financial management strategies used by the farms. We also analyse the impact of subsidies under the Common Agricultural Policy (CAP). To deal with endogeneity, we run dynamic panel models using the system generalised method of moments (sys-GMM) estimators. We highlight the important role of the high level of equity turnover. An increase in production relative to the farm's equity plays a crucial role in the growth of profitability for all groups of farms, but it is especially important for smaller entities. In addition, farm managers should control the level of debt since the debt-to-asset ratio is a highly significant negative determinant of farm profitability in most of the groups. The increase in subsidy rate generally translates into higher ROA, but this variable has a negative impact across the largest holdings.

Keywords: dynamic panel models; Farm Accountancy Data Network (FADN); farm finance; large farms; return on assets (ROA); small farms

Agriculture in the EU Member States is characterised by a wide range in the scale of production and the economic performance of farms. Large farms are widespread, e.g. in some regions of Spain, France and Scandinavia. Very large farms are common in the countries of Central and Eastern Europe that experienced collective agriculture. They are dominant in the Czech Republic, Slovakia, and Bulgaria, and they are also found in Hungary and the Baltic states where they coexist with other social forms of production. By contrast, in Poland and Slovenia, where the peasantry resisted collectivisation, this type of farm exists only marginally (Bojnec and Fertő 2013). Small farms in the EU are often located in peripheral regions, such as in northern Scandinavia, Scotland and Ireland, South-Eastern Europe and in all the Mediterranean countries.

The general pattern of development of the agricultural sector of the EU has been towards a greater concentration. The number of farms is steadily declining, and the remaining farming land is often acquired by larger farms. Thus, land use and agricultural production have become more concentrated, which causes severe threats to the natural environment. To reverse these trends, Common Agricultural Policy and Member States national policies support smaller farms through land consolidation schemes, regulations on land sales and prices, or taxation changes to favour small or family-owned farms. The importance of small farms for rural sustainability in Europe has been demonstrated in numerous studies (Shucksmith and Rønningen 2011; McDonagh et al. 2017). These farms support high levels of biodiversity and promote eco-

Supported by the National Science Center (Poland, No. UMO-2016/23/N/HS4/03453).

https://doi.org/10.17221/415/2020-AGRICECON

logical resilience due to their heterogeneity and diversity (Konvicka et al. 2016). Moreover, with the presence of small farms it is easier to achieve trade-offs in the landscape as they play a key role in fire and soil erosion prevention by maintaining meadows and pastures in mountain areas (Tasser et al. 2007).

According to Eurostat data (Eurostat 2020), in 2016, there were 3.9 million farms in the EU-28 that had an annual standard output (SO) less than EUR 2 000, while a further 3.04 million farms had an annual output within the range of EUR 2 000 to EUR 8 000. Together these entities accounted for 66.3% of all the farms in the EU-28. However, their share in standard output accounted for only 4.4%. Small farms (annual output below EUR 8 000) were particularly prevalent in Romania (94.6% of all farms) and Malta (84.3%), and they accounted for more than 70% of the total number of farms in Bulgaria, Hungary, Latvia, Lithuania and Portugal. On the other end of the spectrum, 116 640 farms in the EU-28 had an output of at least EUR 500 000 in 2016, which accounted for 1.1% of the total number of farms but 37.7% of the standard output.

The literature suggests that farm size may have a significant impact on many economic aspects of a farm's operation, including its profitability. Using the example of farms in Kansas, Mugera et al. (2016) find that larger farms tend to exhibit both higher productivity and profitability. They also find that the impact on the profitability of a change in productivity is similar for small and large farms, while the impact of terms of trade is considerably higher for large entities. However, the criterion they use seems to be incompatible with the European context since all farms with total income lower than USD 250 000 are classified as small. Hadrich and Olson (2011) come to a similar conclusion from their study of a sample of North Dakota farms.

In a study of the US dairy sector, Wolf et al. (2016) find that small and large herds' profitability is similar in poor years, but in good years larger herds realised significantly higher profit. Using the example of salmon producers in Norway, Asche et al. (2018) find that the impact of farm size on profitability differs, depending on the adopted farm size proxy.

Regarding the EU context, Bojnec and Latruffe (2013) and Bojnec and Fertő (2013) find that technical efficiency is positively related to farm size in Slovenia, but smaller farms are more profitable. Subsidies have a negative impact on efficiency but a positive one on profitability. The implications of farm size on-farm profitability determinants across the EU are still not sufficiently investigated. Therefore, in this paper, we try to fill in that gap. Different elements may stimulate farm profitability, i.e. there may be different paths of growth of profitability depending on whether a farm is large, medium-sized or small.

There is no fixed definition of a "small", "medium" or a "large" farm, but a range of different classifications are available (Davidova and Thomson 2014). For instance, farm size can be assessed by area, the number of animals in the herd, the labour force, market participation (e.g. purchased inputs or crop sales) or economic activity. Guiomar et al. (2018) argue that definitions based on the area of a farm have universal appeal because the area is easy to measure and it allows for simple comparisons across countries and world regions. Nevertheless, the area cannot capture all the complexities of the farming system, so it would be useful to consider additional criteria. Perhaps the most objective criterion for defining farm size is economic output, but with the wide heterogeneity of EU agriculture, the simple dichotomy of large and small farms seems not to be reasonable. For that reason, we study all six size groups according to EU classification. This measure is widely used for statistical and policy purposes within the EU.

To our knowledge, this study is the first to establish determinants of profitability in European agriculture by dividing farms into six groups according to their economic size. We hypothesise that the impact of potential determinants on-farm profitability is related to the size of the farm in economic terms. Furthermore, our study may provide some important policy implications. Bojnec and Fertő (2020) stated that the comparative analysis of farm size is of significant importance for research and farm policy. The growth of farm size is one of the key research issues concerning farming structures and farm restructuring, and it has implications for rural factor markets and farm competitiveness.

Therefore, this paper aims to study the determinants of farm profitability for six panels of the EU farms representative of Farm Accountancy Data Network (FADN) regions. The profitability function is used in different specifications, including standard fixed-effects (FE) modelling and dynamic approach using system GMM estimator (Blundell and Bond 1998).

DATA AND METHODS

Data. This research's main source of data is the public FADN database (European Commission 2020). We derive six panels on the regional level based on the criterion of economic size: very small farms (ES1) have

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a standard output between EUR 2 000 and EUR 8 000, small farms (ES2) from EUR 8 000 to EUR 25 000, medium-small (ES3) EUR 25 000 to EUR 50 000, medium-large (ES4) EUR 50 000 to EUR 100 000, large (ES5) EUR 100 000 to EUR 500 000, and very large (ES6) standard output above EUR 500 000. Because of the differences in agrarian structure in European agriculture, in some Member States the FADN threshold is EUR 8 000 or even EUR 25 000, meaning that there are no data for the smallest farms in those countries (and regions). Data for the largest entities may not be available in other regions since there are not enough large units there. In some countries and regions, these thresholds changed during the study period. Therefore not all FADN regions have representative farms in all six groups in each year of the analysis. So, we used data only from the regions for which data are available for the entire period under consideration (2007–2018). This means that we have data for 26 representative farms in group 1, 72 farms in group 2, 93 farms in group 3, 115 farms in group 4, 120 farms in group 5 and 51 farms in group 6.

We use data for regions of all EU countries belonging to the EU starting from 2007, except for Croatia. We also excluded French overseas territories. Data in the FADN database are available only in nominal prices in euros, but all our measures are expressed as ratios, so the problem of fluctuating exchange rates and prices is mitigated.

Variables. Determinants of farm profitability may be studied using different methods. The first approach is based on DuPont's analysis and its extensions (Nehring et al. 2015). Grifell-Tatjé and Lovell (1999) propose decomposing profit into the price effect (terms of trade) and quantity effect. The latter may be further decomposed into the activity effect (scale effect, resource-mix effect and product-mix effect) and productivity effect (operating efficiency effect and technical change effect). Based on this formulation, Islam et al. (2014) study changes in profitability of broadacre farms in Australia. Similar decomposition is also used by Mugera et al. (2016). They decompose profitability using the Lowe index into components of the terms of trade and total factor productivity. In the second step, they use the system generalised method of moments technique to assess whether these two elements influence farm-level profitability. They also introduce some financial ratios in the model (debt-to-assets, debt-to-equity and cash-to-current assets) as additional covariates. Kroupova (2016) uses the approach of Sipiläinen et al. (2014) to decompose the development of profitability of Czech dairy farms. Under this approach, profitability is decomposed into eight components: output growth, output price change, decoupled subsidies change, input price change, technical change, scale component, mark-up component, and technical efficiency change.

In this paper, we adopt an approach introduced by Gloy et al. (2002). We assume that profitability may be affected by production management, financial management and human resource management. The use of production factors is subject to many constraints, including resource endowments. The ability to combine farm sources, therefore, seems to be crucial. In the EU, subsidies within Common Agricultural Policy (CAP) should also impact farm profitability.

The profitability (our dependent variable) can be measured in several ways. It may be understood as return on assets (ROA) (Gloy et al. 2002) but also return on equity (ROE), return on sales (ROS) or the ratio of the total cost to total revenue (Bojnec and Latruffe 2013). Since we focus here on a managerial perspective, we used *ROA* as a dependent variable. However, different FADN categories may stand for returns. The FADN database provides several income (profit) measures, such as gross income, farm net value added, farm net income or farm family income. From the manager's perspective, the final income (net income) is the primary interest. One may claim that profit should be calculated by extracting one's own estimated labour cost from the value of net income. In EU, however, family farming predominates. It means that the main farm operator rarely calculates the alternative costs of his or her work. Therefore, we assume that net income may serve as a profit, and we calculate *ROA* as the ratio of farm net income to total assets in the farm.

As independent variables, we use a set of 10 determinants in the following four categories:

i) Production management decisions. The typical measure of production management is productivity. In this study, we introduce equity turnover. This measure shows how much production the farm achieves relative to its equity. This area also covers other aspects with a particular focus on the level of specialisation and investments. Many papers have addressed the problem of the economic viability of specialisation strategies against the background of diversification (Barry et al. 2001). However, those studies do not provide unambiguous results. Nehring et al. (2015) show that excessive concentration on one type of production may lead to a decrease in farm profitability. Large, more diversified farms achieved

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better economic results. Similar conclusions are reached by Kopta (2013), who notes that focusing on only one activity does not always lead to improved profitability. Palash and Bauer (2017) claim that a farm's profitability may be affected by land allocation to specific types of production. In this study, we measure specialisation using the Herfindahl index (0–1). The higher the index, the more specialised is the farm. Investments, in turn, create opportunities for long-term income growth. They are an important determinant of the income if their level exceeds the consumption of fixed materials (Grzelak 2017). Therefore, we use an indicator of gross investments relative to depreciation.

ii) Following Gloy et al. (2002) and Gloy and LaDue (2003), we assume that financial management decisions may further influence farm profitability. This applies in particular to the level of debt relative to assets. The use of external capital is associated with the need to pay interest, but at the same time, it allows for the use of leverage, so it may have a positive impact on efficiency (Kay et al. 2012). Similarly, the share of the cost of external factors (labour, land and capital) in total cost may further affect profitability. For example, rented land may be used more efficiently because it must generate enough profit to cover the additional costs of rent (Bojnec and Latruffe 2009). In turn, when the share of current assets in a farm is relatively high, then the holding is not excessively burdened with fixed costs which improves its flexibility. Kryszak and Staniszewski (2017) show that the economic results of a farm may be affected not only by the level of costs but also by the relationship between different types of costs. We assumed here that farms have higher profitability when the share of general costs in relation to specific costs (linked to a given type of production) is smaller.

iii) Some important information on human resources management at farms (e.g. the operator's age and level of education) is not available in aggregated FADN data (European Commission 2020). However, this aspect of management may be proxied by the share of hired labour in total labour input on the farm. The decision to hire external labour can be made to improve farm efficiency, which in turn should translate into profitability.

iv) The analysis of profitability and its determinants in the EU requires the inclusion of subsidies in agricultural policy, as they may constitute a large share of farm revenue. On the one hand, payment rates are discussed at the international level so they may be treated as an exogenous factor. Therefore, in profitability analysis, one should use the subsidy rate, i.e. the relation of subsidies to total output (Bojnec and Latruffe 2013). On the other hand, farmers may decide whether they want to apply for additional payments, e.g. payments related to special environmental practices. These subsidies constitute another part of income, but their use may entail additional requirements and thus additional costs. The impact of the share of rural development (*RD*) payments on-farm profitability is therefore ambiguous.

We also tried to include different variables from these four categories (e.g. share of crop or livestock production, the share of paid labour costs, the ratio of equity to assets), but they were highly correlated with variables that we present above, and this resulted in multicollinearity. One may suggest that not only the level of debt is important but also its structure (i.e. long-term liabilities *vs.* short-term loans). However, many smaller farms do not record any debt, especially long-term. Therefore, we refrain from introducing this indicator.

Econometric strategy. For this study, we use the profitability function as described by Gloy et al. (2002). We assume that profitability is influenced by the management decisions taken by farmers (regarding production, finance and human resources) and the subsidy rate.

The profitability function for the full model takes the following form:

$$\begin{aligned} \dot{PROF}_{it} = {} & \beta_0 + \beta_1 ET_{it} + \beta_2 HI_{it} + \\ & + \beta_3 INV/D_{it} + \beta_4 DA_{it} + \beta_5 CA_{it} + \\ & + \beta_6 EC_{it} + \beta_7 OVS_{it} + \beta_8 PL_{it} + \\ & + \beta_9 SR_{it} + \beta_{10} RD_{it} + u_i + \varepsilon_{it} \end{aligned} \tag{1}$$

where: *PROF* – profitability; *ET* – equity turnover; *HI* – Herfindahl specialisation index; *INV/D* – reproduction ratio (gross investments-to-depreciation); *DA* – debt-to-asset ratio; *CA* – share of current assets in total assets; *EC* – share of external costs (interest rates, paid labour and rents); *OVS* – share of farming overheads (general costs) in total costs; *PL* – share of paid labour (in hours) in total labour input; *SR* – ratio of total operational subsidies to total output; *RD* – share of rural development payments in total subsidies.

We estimate Equation (1) separately for six groups of representative farms with different economic size, according to FADN rules.

We used the fixed-effects model (FE) as the assumptions of random distribution of error term, and no correlation between individual effects and vector of co-

https://doi.org/10.17221/415/2020-AGRICECON

variates in secondary data is unlikely to hold. However, we also ran the Hausman test, and it further proved that we should use FE models in all six groups. As autocorrelation and heteroscedasticity may influence our results, we calculate robust standard errors proposed by Arellano (2003).

Profitability function estimates may also suffer from endogeneity. Fixed effects models are useful to deal with one of its sources, i.e. omitted variable bias, as the impact of the remaining factors not included in the model is captured by the fixed-effects. However, we need to assume another source of endogeneity, as some managerial decisions are not fully independent and profitability may determine some of the explanatory variables. In our study, this may be particularly true for debt and investment level. We tackle this problem by estimating a two-step dynamic panel model using the system generalised method of moment (GMM) estimator proposed by Blundell and Bond (1998) with finite-sample corrected standard errors (Windmeijer 2005). The system GMM estimator is usually more efficient than the first difference GMM estimator, as it allows us to use more instruments (Roodman 2009). The inclusion of too many weak instruments may, however, distort the results. Therefore, the validity of the instruments must be tested. Standard errors in the more efficient two-step estimator are biased downwards, so the robust model should be used. However, when using robust model, the popular test of instrument validity (Sargan test) is not useful because in this case its asymptotic distribution is not known, so we provide *P*-values for the Hansen test, which is weakened when there are too many instruments. Therefore, we use a maximum of three lags of the dependent variable (*ROA*) as instruments for first difference equations and the differenced lags of *ROA* as instruments for the levels equation.

Furthermore, we argue that some of our right-hand side variables may be predetermined, i.e. their levels may depend on previous values of *ROA*. We treat the investment-to-depreciation ratio, the share of external costs, the share of paid labour, debt-to-asset ratio and current-to-total-assets ratio as predetermined variables. Technically, this means that they are not correlated with the contemporaneous error term. However, they become endogenous in the first differences. We, therefore, use these variables as "internal" instruments but only for levels equation. We do not use this set of instruments for the ES5 and ES6 groups because the Hansen test results show that these instrument subsets should not be used.

RESULTS AND DISCUSSION

Descriptive statistics. Table 1 presents complete descriptive statistics of explanatory variables and the dependent variable used for econometric modelling. We present mean values and standard deviation for all six economic groups under consideration.

The smallest farms exhibit the highest levels of return on assets. On average, the *ROA* was 0.097, meaning that from each euro of assets, a farm achieved EUR 0.097 of net income. The lowest levels of profitability were recorded, on average, among the largest farms, where the *ROA* was 0.079. However, we cannot say that there is an obvious pattern at the EU level when it comes to farm size and farm performance. The profitability of the fifth group (large farms) was, on average, only slightly lower than that of the smallest entities. Linking the fact that small farms, even if profitable, do not generate enough "mass" of income and the largest farms are less profitable, one may claim that medium-large and large farms provide optimal conditions for farm operators.

Large and very large farms exhibit much higher values of equity turnover. It may mean that smaller entities have too much equity relative to their real production capabilities. Or it may mean that larger entities are more productive since they use better technology. Larger farms are also more specialised. In addition, there are big differences regarding the ratio of investments-to-depreciation. Large farms have a higher proportion of current assets, which shows better liquidity. They are also more engaged in investments, as their average investment level exceeds depreciation. By contrast, in small farms, investment is usually lower than the consumption of fixed materials. As noted before, small and medium farms use external financing only on a small scale. Therefore, their debt-to-asset ratio is rather negligible, while larger entities are more indebted. Larger entities are more eager to use external production factors, as demonstrated by the share of external costs. Smaller farms have a higher proportion of farming overhead in their cost structures, and they use hired labour only marginally. On the largest farms, more than 78% of working hours are provided by employees. Concerning subsidies, we may observe that their proportion of farm revenue is higher among small and medium-sized farms, and then it decreases. Among the largest entities, subsidies account for less than 10% of total output. This may be caused by the so-called "capping" mechanism, i.e. a limit of the amounts of payment a farm may receive. Large and very large

https://doi.org/10.17221/415/2020-AGRICECON

Table 1. Descriptive statistics of variables used in regressions

Variable	ES1		ES2		ES3		ES4		ES5		ES6	
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
ROA (return on assets)	0.097	0.076	0.086	0.067	0.078	0.061	0.082	0.056	0.094	0.065	0.079	0.063
Equity turnover (SE131/SE501)	0.228	0.133	0.196	0.140	0.216	0.144	0.291	0.182	0.458	0.271	0.738	0.440
Specialisation (Herfindahl)	0.161	0.058	0.207	0.108	0.211	0.096	0.222	0.103	0.230	0.113	0.227	0.111
Investment-to-depreciation ratio (SE516/SE360)	0.590	1.905	0.664	1.563	0.862	1.266	0.926	1.812	1.242	0.959	1.377	0.816
Debt-to-asset ratio (SE485/SE436)	0.018	0.042	0.039	0.078	0.078	0.088	0.129	0.123	0.194	0.165	0.285	0.186
Current-to-total-assets ratio (SE465/SE436)	0.184	0.147	0.210	0.132	0.215	0.130	0.242	0.134	0.277	0.136	0.323	0.146
Share of external costs (SE365/SE270)	0.097	0.072	0.123	0.078	0.140	0.073	0.153	0.069	0.185	0.077	0.230	0.069
Share of farming overheads (SE336/SE270)	0.288	0.060	0.300	0.079	0.297	0.075	0.285	0.071	0.245	0.060	0.217	0.055
Share of paid labour (SE021/SE011)	0.083	0.083	0.119	0.124	0.171	0.168	0.219	0.185	0.420	0.244	0.782	0.195
Subsidy rate (SE405/SE131)	0.260	0.166	0.281	0.240	0.288	0.183	0.256	0.148	0.184	0.108	0.097	0.070
Share of rural development payments (SE624/SE605)	0.216	0.188	0.220	0.179	0.234	0.148	0.211	0.139	0.161	0.134	0.108	0.100

ES1 – standard output between EUR 2 000 and EUR 8 000; ES2 – standard output from EUR 8 000 to EUR 25 000; ES3 – standard output from EUR 25 000 to EUR 50 000; ES4 – standard output from EUR 50 000 to EUR 100 000; ES5 – standard output from EUR 100 000 to EUR 500 000; ES6 – standard output from EUR 500 000 and above; Farm Accountancy Data Network (FADN) variable codes are provided in parentheses

Source: Own elaboration based on Farm Accountancy Data Network (FADN) (European Commission 2020)

farms exhibit lower proportions of rural development (*RD*) payments, which is not a surprise since rural development payments are designed for small and medium-sized farms foremost.

Fixed-effect modelling results. The results of our estimations are presented in Tables (2–3). First, we present the results of fixed-effect modelling (Table 2). Our models explain variation in profitability quite well, especially for small and medium farms. The within R-squared ranges from 0.35 for very large entities to 0.73 for the smallest farms.

Equity turnover is a highly significant determinant of profitability in all groups of farms. However, the marginal impact is stronger among small farms that have, on average, lower levels of this indicator. Large entities already have a big scale of production, so producing more from the equity may result in higher costs, so there is not much benefit on the profit side. The specialisation is a positive determinant of profitability, but it is significant only for medium and large farms (but not the largest). Therefore, increasing specialisation translates into *ROA* growth among these groups of farms, which are already more specialised.

Investments (relative to depreciation) are a significant determinant of profitability in only two groups,

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Table 2. Regression of profitability (*ROA*) of EU farms regarding economic size – fixed-effects modelling

Variable	ES1	ES2	ES3	ES4	ES5	ES6
Equity turnover	0.658***	0.320***	0.488***	0.426***	0.372***	0.203***
	(0.069)	(0.050)	(0.028)	(0.025)	(0.034)	(0.030)
Specialisation (Herfindahl)	–0.072	0.033	0.053**	0.084***	0.140***	0.009
	(0.058)	(0.024)	(0.025)	(0.021)	(0.030)	(0.069)
Investment-to-depreciation ratio	0.003***	0.000	0.001	0.001	0.003***	–0.002
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)
Debt-to-asset ratio	–0.497***	0.025	–0.319***	–0.391***	–0.560***	–0.386***
	(0.101)	(0.099)	(0.036)	(0.049)	(0.074)	(0.084)
Current-to-total-assets ratio	0.022	–0.025	0.017	0.019	0.009	–0.051*
	(0.052)	(0.021)	(0.015)	(0.014)	(0.016)	(0.026)
Share of external costs	–0.009	0.363***	0.321***	0.180***	0.293***	0.222**
	(0.111)	(0.088)	(0.044)	(0.049)	(0.089)	(0.104)
Share of farming overheads	0.217***	–0.020	–0.108***	–0.094***	–0.079	0.121
	(0.075)	(0.042)	(0.033)	(0.035)	(0.065)	(0.080)
Share of paid labour	–0.237***	–0.462***	–0.247***	–0.142***	–0.166***	–0.044
	(0.083)	(0.071)	(0.029)	(0.030)	(0.044)	(0.039)
Subsidy rate	0.194***	0.038*	0.081***	0.089***	0.069*	–0.236**
	(0.038)	(0.020)	(0.019)	(0.020)	(0.039)	(0.097)
Share of rural development payments	0.037**	0.040**	0.027**	0.031**	0.017	0.067**
	(0.016)	(0.017)	(0.013)	(0.013)	(0.016)	(0.032)
Constant	–0.139***	0.018	–0.018	–0.014	0.014	0.030
	(0.032)	(0.023)	(0.012)	(0.014)	(0.020)	(0.043)
Observations	312	864	1 116	1 380	1 500	612
Number of groups	26	72	93	115	125	51
Within *R*-squared	0.734	0.522	0.667	0.626	0.509	0.348

***, **, *$P < 0.01$, $P < 0.05$, $P < 0.1$, respectively; ES1 – standard output between EUR 2 000 and EUR 8 000; ES2 – standard output from EUR 8 000 to EUR 25 000; ES3 – standard output from EUR 25 000 to EUR 50 000; ES4 – standard output from EUR 50 000 to EUR 100 000; ES5 – standard output from EUR 100 000 to EUR 500 000; ES6 – standard output from EUR 500 000 and above; *ROA* – return on assets; robust standard errors in brackets

Source: Own elaboration based on Farm Accountancy Data Network (FADN) (European Commission 2020)

but the marginal effect of this variable's increase is close to zero. This may be caused by the fact that at least some European farms deal with overinvestment problems (Guan et al. 2009). However, it is also possible that the positive effects of investments may be disclosed in subsequent periods.

A high debt-to-asset ratio is a negative determinant of profitability in almost all groups of farms (except for ES2). This is in line with Hadrich and Olson (2011) findings who also find that higher debt relative to equity hinders farm performance in North Dakota. It also comports with Ferjani and Koehler (2007), who notice that high levels of debt may be a negative determinant of income. Surprisingly, a high share of liquid assets is not a determinant of *ROA*. Only for the largest farms (which have the highest proportion of current assets), is it significant, but the marginal impact is rather weak. These results suggest that relationships between different types of assets are not very important in shaping farm profitability across the EU. A greater share of paid labour hinders profitability, but this effect is especially strong for smaller farms (ES1 and ES2) that produce small income. It is, therefore, better for small farms to rely on the farmer's own work if possible. The growing share of external costs, in turn, is a positive determinant, especially for medium-sized farms. This may

https://doi.org/10.17221/415/2020-AGRICECON

Table 3. Regression of profitability (*ROA*) of EU farms regarding economic size – dynamic panel models

Variable	ES1	ES2	ES3	ES4	ES5	ES6
ROA_{t-1}	0.007	0.054	0.155*	0.063	0.027	0.080
	(0.066)	(0.095)	(0.085)	(0.067)	(0.106)	(0.106)
Equity turnover	0.887***	0.501***	0.493***	0.558***	0.299***	0.134*
	(0.090)	(0.097)	(0.072)	(0.080)	(0.093)	(0.078)
Specialisation (Herfindahl)	–0.068	–0.394**	–0.029	0.250	0.444	0.190
	(0.302)	(0.153)	(0.091)	(0.186)	(0.344)	(0.251)
Investment-to-depreciation ratio	0.002*	–0.003	–0.002	0.004	–0.010	–0.021
	(0.001)	(0.004)	(0.003)	(0.003)	(0.037)	(0.022)
Debt-to-asset ratio	–0.684***	0.041	–0.420***	–0.750***	–0.740***	–0.177
	(0.165)	(0.103)	(0.118)	(0.117)	(0.214)	(0.183)
Current-to-total-assets ratio	–0.181***	0.025	0.007	–0.067	0.559	–0.076
	(0.057)	(0.045)	(0.023)	(0.057)	(0.366)	(0.131)
Share of external costs	0.239**	0.367***	0.292***	0.256**	0.485	0.348
	(0.121)	(0.141)	(0.074)	(0.129)	(1.084)	(0.350)
Share of farming overhead	0.144	–0.083	0.001	0.299*	0.271	0.752**
	(0.142)	(0.150)	(0.103)	(0.156)	(0.394)	(0.352)
Share of paid labour	–0.374***	–0.284***	–0.158***	–0.079	–0.291	0.082
	(0.107)	(0.109)	(0.060)	(0.057)	(0.413)	(0.160)
Subsidy rate	0.109**	–0.012	0.136***	0.273***	0.554*	–0.641***
	(0.055)	(0.051)	(0.046)	(0.083)	(0.291)	(0.202)
Share of rural development payments	0.031	0.188**	0.009	–0.099*	–0.245	0.003
	(0.032)	(0.081)	(0.068)	(0.057)	(0.424)	(0.086)
Constant	–0.118*	0.035	–0.055	–0.186**	–0.242*	–0.215*
	(0.070)	(0.048)	(0.055)	(0.076)	(0.139)	(0.123)
AR(2) test (*P*-value)	0.11	0.48	0.99	0.53	0.46	0.05
Hansen test (*P*-value)	0.62	0.57	0.11	0.12	0.5	0.97
Instruments	26	26	43	26	21	21
Observations	286	792	1 023	1 265	1 375	561
Number of groups	26	72	93	115	125	51

***, **, *P < 0.01, P < 0.05, P < 0.1, respectively; AR(2) test – Arellano-Bond test for second-order [AR(2)] serial correlation; ES1 – standard output between EUR 2 000 and EUR 8 000; ES2 – standard output from EUR 8 000 to EUR 25 000; ES3 – standard output from EUR 25 000 to EUR 50 000; ES4 – standard output from EUR 50 000 to EUR 100 000; ES5 – standard output from EUR 100 000 to EUR 500 000; ES6 – standard output from EUR 500 000 and above; *ROA* – return on assets; robust standard errors in brackets

Source: Own elaboration based on Farm Accountancy Data Network (FADN) (European Commission 2020)

mean that in medium or big farms, it may be more reasonable to increase the share of rented land. This would be in line with Bojnec and Latruffe (2009) who claim that rented land might be used more efficiently as the rental charge must be covered.

The impact of the growing share of farming overhead is ambiguous. It is positive among the smallest farms but negative among medium farms. This suggests that medium-sized farms should increase the share of costs that are linked to specific farming practices. In small farms that are not very specialised, "general" costs do not hinder profitability. It is interesting to note that a higher share of subsidies relative to production increases profitability, as they are a direct source of income. In the case of very large farms, we do not observe such an effect. This could be caused by a de-

https://doi.org/10.17221/415/2020-AGRICECON

gressive mechanism introduced in CAP, which requires Member States to reduce payments for farms receiving more than EUR 150 000. Higher subsidy rates would then mean that the total output of the farm is relatively low and it negatively influences the profitability. In the small farm panel, the potential effect of operational payments is stronger, as demonstrated by marginal coefficients. A larger share of *RD* payments affected profitability in almost all groups of farms positively. This may be linked to the fact that this type of subsidy is linked to specific activities rather than payments for possession of land.

Dynamic panel models results. As stated in the data and methods section, the profit function estimations may suffer from endogeneity, because explanatory variables might not be exogenous, i.e. they may be predetermined by the level of profitability. Therefore, we estimate dynamic panel models using system GMM estimator as a robustness check of our results (Table 3). The Hansen test shows that the instruments used are valid (*P*-values are higher than 0.05). Based on the Arellano-Bond test for second order [AR(2)] values, we cannot reject the null hypothesis of no serial correlation in the first-differenced errors at the second order. Therefore, we can say that the models are properly estimated.

Main findings based on dynamic panel models are similar to FE modelling results, but there are also some differences. Dynamic estimates further prove that equity turnover is a significant determinant of farm profitability, especially for small and medium-sized farms. However, a standard fixed-effects model may slightly underestimate its impact on smaller entities and overestimate it for larger ones. Dynamic models show that there is a bigger difference in the strength of equity turnover impact on farm profitability.

In contrast to fixed-effect modelling, the results of dynamic panel models show that higher specialisation may hinder the profitability of smaller farms (ES2) which are probably more vulnerable to risk. This would be in line with the findings of Kopta (2013) and Nehring et al. (2015), who claimed that increasing specialisation might even hamper profitability. However, the estimated coefficient of the specialisation variable is positive and relatively high for larger entities. Its insignificance may be related to a greater variation in this variable‘s level for the large farm sample. The role of specialisation for EU farms should be further studied, perhaps using another specialisation measure.

The dynamic model further proved that the investment-to-depreciation ratio has no significant effect on profitability, except for the smallest entities. A higher level of debt negatively affects profitability, and dynamic panel models suggest that this effect may be even underestimated when FE models are employed, especially for small and medium-sized entities.

Estimation results based on dynamic models further prove that the growing share of external costs may be a stimulus of profitability (especially for small and medium farms) while the liquidity of assets is not an important factor. Results based on these models also suggest that there is no significant negative impact of the growing share of farming overhead in medium-sized farms, and in larger entities, it may even be positive. Similar to FE models, the higher share of paid labour is detrimental for profitability, especially for small and medium farms. Such an effect, however, becomes weaker and insignificant when larger farms are considered. This may be linked to the fact that without external labour, the largest farms could not operate effectively and could not produce a profit.

The increase in subsidy rate generally translates into higher *ROA*, but similar to FE models. This variable has a negative impact on the largest holdings. We can refer here to the degressivity mechanism once again. Results of dynamic models also suggest that a higher share of *RD* payments in the total of subsidies has a significant positive impact on *ROA* only for small (ES2) entities. For medium-large (ES4) farms, it can even have a negative effect. This is more in line with the evidence provided by Bojnec and Fertő (2019), who find that public goods payments play a more important role for small farms.

CONCLUSION

In this paper, we aimed at estimating panel models of determinants of farm profitability in EU FADN regions. More specifically, we tried to determine whether a farm's size changes the impact of a given factor on the farm's profitability, defined as return on assets. Since the econometric estimations of profit function based on standard approaches may be biased, we also calculated dynamic panel models. Generally, this produces similar results, but some differences were found. It turned out that the role of profitability stimuli for small, medium-sized and large farms differs, especially when it comes to the impact of equity turnover (in term of its strength), the share of paid labour and subsidies. However, we need to stress that our calculations concern EU FADN farms only. As we stated, very small farms are those with SO below EUR 8 000 but more than EUR 2 000. Analyses using data represen-

https://doi.org/10.17221/415/2020-AGRICECON

tative of the smallest holdings within the EU (beyond FADN scope) seems to be a promising line for further research. The research framework proposed in this paper could also be used for datasets specific to a given country or region. In this case, it will be possible to add additional variables to the model, especially those related to human capital.

Summarising the results of our calculations, we may highlight the important role of the high level of equity turnover. An increase in production relative to a farm's equity plays a crucial role in the growth of profitability for all groups of farms, but it is especially important for small and medium entities. Small farms may search for strategies that enable them to increase the equity turnover by increasing output or decreasing the equity they hold. The latter strategy may be justified since the impact of investments relative to depreciation was rather weak. This shows that EU farms are saturated with respect to capital. Farm managers should also pay careful attention to control the level of debt since the debt-to-asset ratio was a highly significant and negative determinant of farm profitability in most farms. With all this in mind, farm operators should consider whether the capital-intensive path of farm development is appropriate. Instead of excessive investments, the managers of medium-sized farms could reorganise their operational schemes and rely more on external factors, such as land or capital. However, it is better when farmers can rely mostly on their own work, taking into account the negative impact of the cost of paid labour. Based on dynamic models, we may conclude that medium-large farms (ES4 and ES5) benefit more from the higher subsidy rate. Smaller farms (ES2) improve their profitability when they apply for rural development payments, which is in line with Common Agricultural Policy's general directions.

Our analysis has shown that managerial decisions of the farmer's operator are important for farm profitability. Therefore, our recommendation is to develop agricultural advisory centres and education further to help farmers make adequate decisions. We also provide arguments for great flexibility of Common Agricultural Policy since farms of different sizes have different needs. Investment support needs to be rethought, as increasing investment in fixed assets no longer translates into improved profitability.

While considering the fragmented agrarian structure and environmental challenges, particular care will be needed to ensure small farms' adequate profitability. However, given the challenges that agriculture will face in the coming years, particularly climate change and the growing demand for food, support mechanisms for the largest farms should be rethought. Their long-term viability may be crucial for the global competitiveness of European agriculture.

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Received: October 14, 2020
Accepted: February 9, 2021