The Regional Efficiency of Mixed Crop and Livestock Type of Farming and Its Determinants

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Anotace

Smíšená rostlinná a živočišná výroba představuje významnou část zemědělské produkce České republiky. Jsou tedy na místě otázky týkající se faktorů určujících její produkční efektivnost. Cílem článku je vyhodnotit produkční efektivnost a její determinanty ve smíšené výrobě v regionech EU. Metoda DEA v podmínkách variabilních výnosů z rozsahu (DEAVRS) identifikuje efektivní a neefektivní regiony včetně efektivnosti z rozsahu. V dalším kroku jsou pomocí dvouvýběrového t-testu vyhodnoceny rozdíly ekonomických a strukturálních ukazatelů mezi efektivními a neefektivními regiony. Výzkum odhalil, že substituce práce kapitálem či službami pozitivně ovlivňuje čistou přidanou hodnotu na AWU. Významnými ekonomickými determinanty produkční efektivnosti smíšených farem jsou rostlinná produkce na hektar, živočišná produkce na dobytčí jednotku, produktivita energie a kapitálu. Zemědělské podniky v neefektivních regionech hospodaří extenzivněji a produkují více nekomoditních výstupů (veřejného zboží) než efektivní regiony.

Klíčová slova

Rostlinná a živočišná produkce, technická efektivnost, důchod, regiony EU, substituce vstupů

Abstract

The mixed crop and livestock farming represents significant share in agricultural output in the Czech Republic. So, it raises questions about determinants of its production efficiency. The aim of the article is to evaluate production efficiency and its determinants of mixed crop and livestock farming among the EU regions. The DEA method with variable returns to scale (DEAVRS) reveals efficient and inefficient regions including the scale efficiency. In the next step, the two-sample t-test determines differences of economic and structural indicators between efficient and inefficient regions. The research reveals that substitution of labor by capital/ contract work positively affects income indicator Farm Net Value Added per AWU. The significant economic determinants of production efficiency in mixed type of farming are crop output per hectare, livestock output per livestock unit, productivity of energy and capital. Agricultural enterprises in inefficient regions have more extensive structure and produce more non-commodity output (public goods).

Key words

Crop and livestock production, technical efficiency, income, EU regions, input substitution .

Introduction

The production efficiency is one of the key prerequisites for the competitiveness of enterprises in every business. The assessment of production efficiency in agriculture is limited by weather conditions and by large variability of farms not only within the member states but also among EU regions. Nevertheless, the identification of production efficiency and its main determinants can reveal the weaker regions and show ways how to improve their farming performance in new Common Agricultural Policy after 2013.

The goal of the paper is to evaluate the production efficiency of mixed type of farming among the FADN EU regions and to determine which structural and economic factors significantly affect the farming performance. Production efficiency of other types of farming will be considered in future research. The mixed type farming has been very important part of the Czech agriculture for a long time. The structure of today's Czech agriculture is rooted in its history. Family farms are not as important as in western states of the European Union. The bigger part of the agricultural area (about 70 percent) is used by large holdings of legal persons. There was 6 245 farms with combined crop and livestock production in 2010, out of 22 864 agricultural holdings. The Czech farms with mixed production are large with 454.6 ha of utilized agricultural area on average in 2010 (CZSO, 2011).

The paper is organized as follows. After literature review about production efficiency in agriculture, the material and methods are described. The paper puts emphasis on Central European countries. The results describe and discuss the most important findings about determinants of production efficiency of mixed crop and livestock type of farming amongst EU regions. The conclusions indicate the purpose and the main findings.

Many researchers consider the agricultural production efficiency in the Czech Republic. Juřica et al. (2004), Jelínek (2006), Medonos (2006), Davidova and Latruffe (2007), Boudný et al. (2011) and Čechura (2010, 2012) concern the technical efficiency in Czech conventional farming. Žídková et al. (2011) deals with factors affecting efficiency of the farms in the Czech Republic, the subject of the analysis is the development of the investments in agriculture. Malá (2011) aims at the efficiency of Czech organic farming and its determinants. Čechura (2012) identifies the key factors determining the efficiency of input use and the total factor productivity (TFP) development. He concludes that the developments in the individual branches are characterized by idiosyncratic factors, as well as the systemic effect, especially in the animal production. The most important factors which determine both technical efficiency and TFP are those connected with institutional and economic changes, in particular an increase in the imports of meat (Svatoš, Smutka, 2012) and increasing subsidies. Machek and Špicka (2013) also apply TFP approach in agriculture. They estimate Total Factor Productivity of Agricultural Sector Based on Firm-Level Accounting Data. The results of the analysis suggest that the agricultural TFP growth does not necessarily move in the same direction as the growth of the economy.

The production efficiency in Central European Countries has been studied by Gorton and Davidova (2004). The results did not prove less efficiency of corporate farms than family farms. The best corporate farms tend to perform as well as the best family farms. The Central European Countries in transition with well-established small family farms are less inefficient compared to larger cohorts as against countries with large corporate farms. Bojnec and Latruffe (2011) consider size-efficiency relationship of family farms during transition period in Slovenia. Using DEA method and FADN data, they suggest that family labor is more crucial than any other production factor in the country‘s farming economy. Moreover, the correlation coefficients between size and efficiency have always the same sign whatever the efficiency measure.

Bakucs et al. (2010) evaluate technical efficiency of Hungarian farms before after EU accession. They conclude that increase of subsidies in post-accession period contributes to lower efficiency of Hungarian farms. Due to an increasing scarcity of labor on farms, authors recommend promoting a farming system that uses labor and it is competitive.

Latruffe et al. (2004) analyze technical efficiency and its determinants for a panel of Poland specialized crop and livestock production before EU accession. Authors compare DEA with Stochastic Frontier Analysis (SFA). They find out that livestock farms are more technically efficient than crop farms. Large farms are more efficient than small farms. The key determinants of efficiency are a degree of downstream market integration and soil quality.

Błażejczyk-Majka, Kala and Maciejewski (2012) use FADN data to find out whether a higher specialization and a bigger economic size class of farms determine a higher technical efficiency at the same scale for the farms from the new and old countries of the EU. Results recorded for mixed farms in relation to the pure technical efficiency indicate a bigger efficiency of the farms from the “old” EU regions (EU-15) in comparison to the farms from the “new” regions, except for the biggest farms.

Hussien (2011) calculates the production efficiency of the mixed crop-livestock farmers in two districts of north eastern Ethiopia. He concludes that the production efficiency of mixed crop-livestock farming is determined by farm size, livestock ownership, labor availability, off/non-farm income participation, total household assets, total household consumption expenditure and improved technology adoption.

Materials and methods

The geographic scope

The FADN RICA provides structural and economic data in standard results. Complete data for 2011 are available in 101 EU regions. The analysis focuses on mixed crop and livestock type of farming (code 80 in TF14 FADN grouping) which comprises farms with prevailing combined field crops-grazing livestock and various crops and livestock type of farming. FADN use special weighting system. The individual weight is equal to the ratio between the numbers of holdings, of the same classification cell (FADN region x type of farming x economic size class), in the population and in the sample.

The FADN regions with available data on mixed crop and livestock farming represent 25 EU member states. Table 1 gives information about state affiliation of the analyzed regions.

The quantitative methods

Analysis of economic efficiency of mixed farming respects the view on efficiency in utilization of production factors (Coelli et al, 1998; Fried, Lovell, Schmidt, 2008). To determine the level of the production efficiency of farms, the Data Envelopment Analysis method (DEA) is applied. Production unit is efficient when there isn't any other unit maintaining the same level of outputs with lower level of inputs, respectively, when there isn't any other unit achieving the higher level of outputs with the same level of inputs. Units with the highest efficiency are located on the efficient frontier. The purpose of the DEA method is to construct a non-parametric envelopment frontier over the data points such that all observed points lie on or below the production frontier. The technical efficiency (TE) estimates vary between 0 (0%) and 1 (100 %). The model assumes variable returns to scale (DEAVRS method). The issue of returns to scale concerns what happens to units' outputs when they change the amount of inputs that they are using to produce their outputs. Under the assumption of variable returns to scale a unit found to be inefficient has its efficiency measured relative to other units in the data-set of a similar scale size only. The results distinguish among increasing, constant (effective) and decreasing returns to scale.

Undifferentiated member states (FADN regions)	Austria, Czech Republic, Denmark, Estonia, Ireland, Lithuania, Luxembourg, Latvia, The Netherlands, Slovakia, Slovenia
FADN regions within member states	
Belgium	Vlaanderen, Wallonie
Bulgaria	Severozapaden, Severen tsentralen, Severoiztochen, Yugozapaden, Yuzhen tsentralen, Yugoiztochen
Finland	Etela-Suomi
France	Champagne-Ardenne, Picardie, Haute-Normandie, Centre, Basse-Normandie, Bourgogne, Nord-Pas-de-Calais, Lorraine, Alsace, Franche-Comté, Pays de la Loire, Bretagne, Poitou-Charentes, Aquitaine, Midi-Pyrénées, Rhônes-Alpes, Auvergne
Germany	Schleswig-Holstein, Niedersachsen, Nordrhein-Westfalen, Hessen, Rheinland-Pfalz, Baden-Württemberg, Bayern, Saarland, Brandenburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt, Thueringen
Greece	Makedonia-Thraki, Ipiros-Peloponissos-Nissi Ioniou, Thessalia, Sterea Ellas-Nissi Egaeou-Kriti
Hungary	Közép-Magyarország, Közép-Dunántúl, Nyugat-Dunántúl, Dél-Dunántúl, Észak-Magyarország, Észak-Alföld, Dél-Alföld
Italy	Piemonte, Lombardia, Veneto, Friuli-Venezia, Emilia-Romagna, Toscana, Marche, Umbria, Lazio, Abruzzo, Molise, Campania, Basilicata
Poland	Pomorze and Mazury, Wielkopolska and Slask, Mazowsze and Podlasie, Malopolska and Pogórze
Portugal	Norte e Centro, Ribatejo e Oeste, Alentejo e do Algarve
Romania	Nord-Est, Sud-Est, Sud-Muntenia, Sud-Vest-Oltenia, Vest, Nord-Vest, Centru, Bucuresti-Ilfov
Spain	Aragón, Cataluna, Baleares, Castilla-León, Castilla-La Mancha, Extremadura, Andalucia
Sweden	Slattbygdslan
United Kingdom	England-North, England-East, England-West, Scotland

Source: author based on FADN database

Table 1. Regions represented by mixed crop and livestock farming.

Six inputs and two outputs per weighted average farm are used for efficiency calculation. Indicators are linked with FADN standard results codes.

- Outputs in EUR: Crop output (SE135), Livestock output (SE206).
- Land input (SE025 - utilized agricultural area in ha).
- Labour input (SE011 - actual working time in hours per year).
- Material costs (SE281 - seeds and plants, fertilisers, crop protection, other crop specific costs. feed for grazing livestock, feed for pigs & poultry, other livestock specific costs in EUR).
- Energy costs (SE345 - motor fuels and lubricants, electricity, heating fuels in EUR).
- Capital costs (SE360 depreciation, SE375 rent paid, SE380 interest paid, SE340 machinery & building current costs, SE390 taxes and other charges on land and buildings in EUR)
- Contract work (SE350 - costs linked to work carried out by contractors and to the hire of machinery in EUR).

Efficiency scores were calculated separately for each region. The technical efficiency (TE) score divides the sample into two groups - efficient with TE = 1.0 and inefficient with TE < 1.0. The statistical procedure tests the differences of structural and economic indicators between the two groups. The Farm Net Value Added (FNVA) per AWU (Annual Work Unit) represents the main income indicator in agriculture. According to the FADN definition, the FNVA is the remuneration to the fixed factors of production (work, land and capital), whether they be external or family factors. As a result, holdings can be compared irrespective of their family/non-family nature of the factors of production employed. Since it covers costs on external factors, it is convenient for comparison of the different farm structures within the EU-27. The economic indicators also include modified FNVA per AWU which is defined as the remuneration to paid and unpaid work only.

Statistical procedures for assessment of differences between efficient and inefficient groups are selected depending on the features of the two groups. The skewness, kurtosis and omnibus normality are tested. Since the choice of appropriate statistical tests varies by the normality and variance assumptions of the sample, some researchers recommend against using a preliminary test on variances. If the two sample sizes are approximately equal, the equal-variance t-test can be used. If the ratio of the two sample sizes (larger sample size over the smaller sample size) is equal to or greater than 1.5, it is possible to use the unequal-variance t-test (Ott, 1984). The results of DEA indicate 56 efficient regions and 45 inefficient regions, so the prerequisite for equal-variance t-test is fulfilled.

The two-sample t-test compares the distribution between two groups – inefficient regions (μ_1) and efficient regions (μ_2). The null and alternative hypotheses are: H0: mean μ_1 = mean μ_2, HA: mean μ_1 > mean μ_2 (Diff > 0) or mean μ_1 < mean μ_2 (Diff < 0). So, the one-sided test of hypotheses is applied depending on the subjective assumptions about the efficiency determinants. The statistical analysis is processed automatically by software StataSE 12. Table 2 contains basic descriptive statistics of farms.

The sample contains regions with relatively small size as well as regions with very large farms with more than 1 000 hectares on average. Mixed farms have extensive and intensive stocking intensity. So, the paper also evaluates if the intensity affects production efficiency.

Variable	Mean	Standard Deviation	Min	Max
Crop output (EUR)	85 430.39	146 197.79	773.00	842 498.00
Livestock output (EUR)	76 855.08	115 856.65	2 481.00	648 570.00
Utilized agricultural area (ha)	106.30	177.40	0.93	1 116.69
Labour input (AWU)	2.43	3.69	0.76	29.19
Economics size (ESU*)	139.29	227.80	4.60	1 244.30
Livestock units per 100 ha	72.72	42.87	23.30	274.05
Stocking intensity (LU/ha of forage crops)	1.43	1.13	0.32	10.22

Note: * ESU (Economic Size Unit) = 1 ESU is 1 000 EUR of standard output.
Source: author

Table 2. Basic descriptive statistics of farms (N = 101).

Results and discussion

Results in table 3 confirm the theoretical assumption about returns to scale.

As the business grows, a company initially increases the scale efficiency. After achieving the optimum size the scale efficiency gradually decreases. The Czech Republic, Slovakia, regions in former East Germany (Brandenburg, Sachsen, Sachsen-Anhalt, Thueringen), three regions in France (Champagne-Ardenne, Bourgogne, Pays de la Loire), two regions in Italy (Toscana, Umbria), region Közép-Dunántúl in Hungary and region Yugoiztochen in Bulgaria had decreasing returns to scale in 2011. It means that output increases by less than that proportional change in inputs. Nevertheless, not all of regions with decreasing returns to scale have large average farms, e. g. regions in Italy and Bulgaria. Efficient mixed type of farming with decreasing returns to scale is typical for the Czech Republic, Slovakia, France (Champagne-Ardenne, Pays de la Loire) and Germany (Brandenburg, Sachsen, Thueringen).

All regions with efficient returns to scale are fully technically effective (TE = 1.0). The optimum-sized regions are in "old" EU member states - in France, Germany, Italy, Belgium, the Netherlands, Denmark, Greece, Spain, and Portugal. The optimal average size of farms in "new" member states are in Lithuania, Bulgaria (Severen tsentralen, Severozapaden, Yuzhen tsentralen) and Romania (Bucuresti-Ilfov).

Table 4 contains economic indicators and the results of two-sample t-test. The economic indicators cover input and output variables including current subsidies.

The average size of efficient farms is significantly higher than in inefficient regions. It is consistent with Latruffe et al. (2004) and Hussien (2011). The farms in efficient regions use more labor input which indicates higher farming intensity. Regarding the production, the test proves that the efficient regions have significantly higher crop output per hectare and livestock output per livestock unit. The inefficient regions have higher share of other output. The more efficient input-output ratio of efficient regions has positive impact on the significantly favorable share of intermediate consumption to total output. It means that efficient regions spend less specific costs and overhead costs per one unit of output. Simultaneously, the efficient regions spend more specific crop costs per hectare which, on the other side, generate higher crop output per hectare. Efficient regions produce more intensively than extensive regions.

The hypotheses about partial factor productivity verify if the efficient regions have higher productivity of all production factors than inefficient units. The table 4 shows that efficient regions have significantly higher total output per energy costs, capital costs (at $\alpha = 0.01$), labor and contracting work (at $\alpha = 0.1$) than inefficient regions. On the contrary, material productivity is not significantly higher in the efficient regions. The input productivity raises a question about substitution among inputs. Table 5 provides possible answer.

The correlation matrix in table 5 indicates lower correlation between contract work and labor and between capital costs and labor. There could be capital-labor substitution or contract work-labor substitution among regions. The substitution between capital/contract work can be quantified as follows:

$$LC_{sub} = \frac{TO/LI}{TO/(CC+CW)}, \text{ where}$$

LC_{sub} is substitution between capital/contract work, TO is total output, LI denotes labor input (actual working time in hours per year), CC denotes capital costs (depreciation, rent paid, interest paid, machinery & building current costs, taxes and other charges on land and buildings) and CW means contract work (costs linked to work carried out by contractors and to the hire of machinery).

Indicator	Inefficient regions	Efficient regions	Total	Average UAA (ha)	Average ESU
Number of regions with decreasing returns to scale	6	7	13	364.1	452.3
Number of regions with efficient returns to scale	0	37	37	85.5	139.2
Number of regions with increasing returns to scale	39	12	51	55.7	59.6
Total	45	56	101	106.3	139.3

Source: author

Table 3. Distribution of the returns to scale.

Indicator	Unit	Inefficient regions (μ_1), N = 45	Efficient regions (μ_2), N = 56	H_0 ($\mu_1 - \mu_2$)	T-Statistic	P-value	Sig.
Utilized agricultural area	ha/farm	77.73	129.26	Diff < 0	-1.459	0.0739	*
	SD	107.88	216.11				
Economic size	ESU/farm	89.17	179.56	Diff < 0	-2.012	0.0235	**
	SD	149.52	269.74				
Labour input (hours per year)	hours/farm	3,713.35	6,104.19	Diff < 0	-1.610	0.0553	*
	SD	3,127.42	9,550.14				
Crop output	EUR/ha	760.33	986.04	Diff < 0	-2.572	0.0058	***
	SD	285.30	529.74				
Livestock output	EUR/LU	975.51	1,094.84	Diff < 0	-1.869	0.0323	**
	SD	254.12	362.59				
Other production in Total input	%	6.460	3.876	Diff > 0	2.839	0.0027	***
	SD	5.151	3.999				
Total output per Total input	EUR/EUR	1.060	1.212	Diff < 0	-3.401	0.0005	***
	SD	0.151	0.267				
Total output per Total intermediate consumption	EUR/EUR	1.558	1.729	Diff < 0	-2.506	0.0069	***
	SD	0.297	0.372				
Total output per Working hour	EUR/hour	27.77	36.29	Diff < 0	-1.522	0.0656	*
	SD	23.56	31.04				
Total output per Material costs	EUR/EUR	2.660	2.953	Diff < 0	-1.269	0.1037	-
	SD	0.612	1.445				
Total output per Energy costs	EUR/EUR	10.86	14.95	Diff < 0	-4.925	0.0000	***
	SD	3.16	4.79				
Total output per Capital costs	EUR/EUR	3.348	4.588	Diff < 0	-3.876	0.0001	***
	SD	0.829	2.011				
Total output per Contracting work	EUR/EUR	27.61	35.95	Diff < 0	-1.433	0.0776	*
	SD	11.97	37.51				
Specific crop costs per hectare	EUR/ha	229.04	284.96	Diff < 0	-1.997	0.0243	**
	SD	94.44	167.61				
Specific livestock costs per LU	EUR/LU	563.38	560.11	Diff < 0	0.078	0.5311	-
	SD	212.34	206.59				

Source: author

Table 4. Differences in economic indicators.

	Land	Labour	Material	Energy	Capital	Contract
Land	1.000	0.937	0.964	0.975	0.931	0.921
Labour	0.937	1.000	0.904	0.949	**0.838**	**0.839**
Material	0.964	0.904	1.000	0.985	0.978	0.941
Energy	0.975	0.949	0.985	1.000	0.948	0.907
Capital	0.931	**0.838**	0.978	0.948	1.000	0.955
Contract	0.921	**0.839**	0.941	0.907	0.955	1.000

Note: All correlation coefficients are statistically significant at $\alpha = 0.01$
Source: author

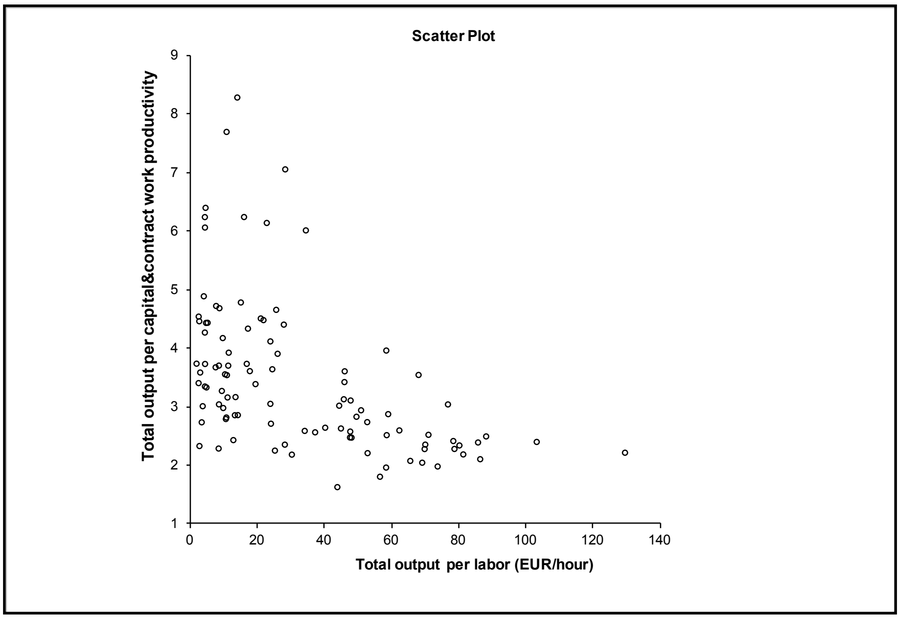
Table 5. Pearson correlation among input variables.

The analysis reveals that the substitution between capital/contract work and labor significantly affects the key income indicator FNVA per AWU. Figure 1 shows correlation between capital/contract work productivity and labor productivity. The Spearman's rank correlation coefficient between labor productivity (numerator) and capital/contract work productivity (denominator) is -0.5915 (p-value = 0.0000). Pearson correlation coefficient is -0.5000 (p-value = 0.0000).

The higher is the LC_{sub} indicator, the more labor is substituted either by capital or by contract work. Regions in Western and Northern Europe have highest LC_{sub} indicator, so they use more capital or contract work. In 1st/top/ quartile of LC_{sub} (> 19.12) there are regions in Denmark, France, Sweden, Finland, Benelux, Germany and United Kingdom. On the contrary, regions in Central, Southern and Eastern Europe have lowest LC_{sub} indicator (< 2.45). Thus, they use more labor forces on farm. In 4^{th}/bottom quartile of LC_{sub} there are regions in Poland, Lithuania, Spain, Bulgaria, Greece, Romania and Portugal.

Table 6 contains results of linear regression analysis between FNVA/AWU (in thousands EUR) as dependent variable y and indicator LCsub as independent variable x. The LC_{sub} indicator can be used as valuable determinant of farm income level for mixed type of farming because it explains a variability of FNVA per AWU by 73.7 %. Figure 2 visually presents the regression. Table 7 presents the differences in FNVA/AWU and subsidies.

The differences in FNVA per AWU differ between efficient and inefficient regions. Effective regions are characterized by a higher income per AWU and per hectare. On the contrary, inefficient regions receive significantly higher current subsidies per total output because they produce less total output per average farm. Total current subsidies per hectare do not significantly differ. An important finding is that inefficient regions receive more rural development subsidies than efficient regions. Production function includes only commodity outputs and production of the non-commodity outputs (public goods) actually leads



Source: author

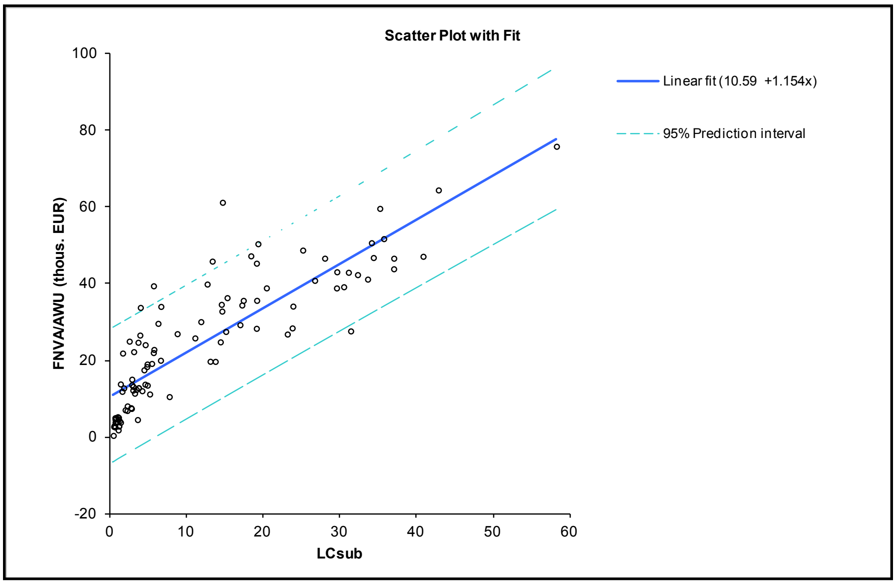
Figure 1. Relations between labor productivity and capital/contract work productivity.

Regression	Adj. R^2	p-value	Standard error	Breusch-Pagan χ2 (p-value)
y = 10.59072 + 1.15361x	0.73740	0.0000	8.74687	0.02 (0.8928)

Note: There isn't any heteroskedasticity in linear regression model.

Source: author

Table 6. Regression between income indicators FNVA/AWU (thous. EUR) and LC_{sub}



Source: author

Figure 2. Regression line.

Indicator	Unit	Inefficient regions (μ_1), N = 45	Efficient regions (μ_2), N = 56	H_0 (μ_1 - μ_2)	T-Statistic	P-value	Sig.
Total current subsidies per Total output	EUR/EUR	0.266	0.188	Diff > 0	3.958	0.0001	***
	SD	0.109	0.090				
Total current subsidies per hectare	EUR/ha	361.13	346.74	Diff > 0	0.476	0.3177	-
	SD	146.47	154.66				
Rural development subsidies* per Total output	EUR/EUR	0.057	0.025	Diff > 0	3.458	0.0004	***
	SD	0.063	0.023				
Rural development subsidies* per hectare	EUR/ha	79.39	45.00	Diff > 0	2.510	0.0069	***
	SD	88.27	46.95				
Farm net value added (FNVA) per AWU	EUR/AWU	20 839.18	27 755.79	Diff < 0	-2.057	0.0212	**
	SD	14 250.73	18 589.26				
Farm net value added (FNVA) per hectare	EUR/ha	594.66	986.32	Diff < 0	-3.713	0.0002	***
	SD	235.39	674.83				
LCsub	x	11.26	12.97	Diff < 0	-0.670	0.2523	-
	SD	11.35	13.79				

Note: *Rural development subsidies = environmental subsidies + LFA payments + other RD subsidies
Source: author

Table 7. Differences in income indicator FNVA/AWU and subsidies.

to a decrease in technical efficiency, since agricultural enterprises spend higher costs and/or achieve lower production (Boudný et al., 2011). Differences in rural development subsidies indicate that inefficient regions farm more extensively and produce more public goods.

The efficiency of mixed type of farms does not significantly depend on crop structure. There are significant differences in livestock structure. Efficient regions have higher share of dairy cows per total livestock units. The stocking density per hectare of feed crops and the number of livestock units per 100 hectares are significantly higher in efficient regions. Efficient regions also

Indicator	Unit	Inefficient regions (μ_1), N = 45	Efficient regions (μ_2), N = 56	H_0 (μ_1 - μ_2)	T-Statistic	P-value	Sig.
Cereals in UAA	%	45.24	44.86	Diff < 0	0.138	0.5547	-
	SD	12.92	14.44				
Other field crops in UAA	%	11.13	11.18	Diff < 0	-0.033	0.4869	-
	SD	5.32	8.35				
Forage crops in UAA	%	36.44	35.24	Diff > 0	0.466	0.3213	-
	SD	12.56	13.17				
Setaside land per Total agricultural area	%	1.133	0.947	Diff > 0	0.552	0.2910	-
	SD	1.548	1.784				
Dairy cows per Total LU	%	14.02	20.05	Diff < 0	-2.168	0.0163	**
	SD	11.32	15.63				
Other cattle per Total LU	%	55.77	55.04	Diff > 0	0.144	0.4429	-
	SD	25.99	24.87				
Pigs per Total LU	%	25.35	17.24	Diff > 0	1.923	0.0287	**
	SD	22.89	19.48				
Poultry per Total LU	%	3.497	6.947	Diff < 0	-1.934	0.0280	**
	SD	6.190	10.595				
Number of LU per 100 hectares	LU/100 ha	59.99	82.95	Diff < 0	-2.762	0.0034	***
	SD	24.08	51.37				
Stocking intensity	LU/ha f.c.	1.127	1.672	Diff < 0	-2.458	0.0079	***
	SD	0.459	1.427				
Yield of wheat	t/ha	4.801	5.239	Diff < 0	-1.142	0.1282	-
	SD	1.754	2.018				
Milk yield	kg/cow	5,996.53	6,128.90	Diff < 0	-0.312	0.3781	-
	SD	1,734.24	2,193.62				
Debt ratio	%	14.83	16.28	Diff < 0	-0.449	0.3272	-
	SD	14.75	17.21				
Share of hired labour	%	17.88	26.08	Diff < 0	-1.783	0.0388	**
	SD	18.56	25.97				
Share of rented UAA	%	57.70	59.23	Diff < 0	-0.295	0.3844	-
	SD	24.01	27.62				

Source: author

Table 8. Structural determinants of production efficiency in EU regions.

have significantly lower share of pigs and higher share of poultry than inefficient regions. The wheat yield and milk yield are higher in efficient regions but the differences are not statistically significant. It indicates the assumption about production inefficiency of extensive farming. The conclusion is consistent with Boudný et al. (2011).

The share of hired external factors does not significantly differ between efficient and inefficient regions except of hired labor. Higher share of hired labor in efficient regions is related to larger average farms in efficient group of regions. The use of external capital and rented utilized agricultural area is slightly higher in efficient regions but not significantly.

Conclusions

The aim of the paper is to assess the production efficiency of mixed type of farming among the FADN EU regions in 2011 and to determine structural and economic determinants of production efficiency. The analysis of 101 EU regions with available data on mixed crop and livestock farming is processed by DEA method and t-test of statistical hypotheses. The research reveals some significant determinants of regional production efficiency and income level:

- The analysis of technical efficiency of mixed crop and livestock farms reveals 56 efficient regions and 45 inefficient regions in 2011. There are generally larger farms in efficient regions on average. In the Central Europe, mixed type of farming in the Czech Republic, Slovakia and three regions in Hungary is technically efficient. All four regions in Poland are inefficient with increasing returns to scale.
- The theoretical assumptions about scale efficiency are verified. All regions with optimal returns to scale are efficient. Decreasing returns to scale are typical for regions with largest farms on average, such as the Czech Republic, Slovakia and regions in former East Germany.
- Crop output per hectare and livestock output per livestock unit are key output determinants of production efficiency. On the input side, the efficient regions have higher land productivity, labor productivity, energy productivity, capital productivity and productivity of contract work than inefficient regions. Efficient regions have significantly higher FNVA per AWU and hectare.
- The results prove substitution between labor and capital/contract work. The proposed indicator LCsub, as the share of labor productivity to capital/contract work productivity, significantly determines the FNVA per AWU in mixed type of farming.
- Subsidies on rural development are significantly higher per total output as well as per hectare in inefficient regions. The inefficient regions provide more public goods for rural development which are generally produced with higher costs and/or lower production. Moreover, the structural indicators show that the higher farming intensity significantly increases the production efficiency.

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