Volume XVI Number 4, 2024

Effect of Farm Size on the Structure of Crop Production

Anna Žovincová

Department of Statistics, Faculty of Economics and Management, Czech University of Life Sciences Prague, Czech Republic

Abstract

The study deals with the statistical analysis of crop production structure concerning farm size. Given the large-scale nature of Czech agriculture and the deepening structural imbalance, this is a topical issue. Firstly, the trends in the area of sown crops between 1993–2023 and their expected development between 2024–2025 were assessed. Subsequently, the weighted data of conventional farms focused on field crop production operating in the Czech Republic were analysed using the Kruskal–Wallis test. With the exception of peas, the share of crops grown depends on the size of the farm. There are statistically significant differences, mainly between small and very large farms and between small and large farms. At the same time, it is clear that in the long term, there has been a significant decline in the area sown to potatoes, rye, barley, and forage, which are crops that account for a higher proportion of the harvested area structure on small holdings.

Keywords

Agricultural policy, Czech Republic, field crops, nonparametric methods, time series.

Žovincová, A. (2024) "Effect of Farm Size on the Structure of Crop Production", *AGRIS on-line Papers in Economics and Informatics*, Vol. 16, No. 4, pp. 129-140. ISSN 1804-1930. DOI 10.7160/aol.2024.160410.

Introduction

Czech agriculture has a centuries-old tradition that has guaranteed both the self-sufficiency of the nation in basic agricultural commodities and the export of many of these commodities (Czech Statistical Office (CSO), 2011). Especially since the integration of the Czech Republic into the common market and the implementation of the Common Agricultural Policy (CAP), structural imbalances have been deepening. Species diversity has declined and changed, as have crop shares in the area sown. The cultivation of rye, barley and potatoes is declining, while the area of rape and industrial crops is expanding (Procházková et al., 2016). The authors Řezbová and Škubna (2012) mention in their paper the undeniable dependence of the world agricultural commodity market on biotech crops, with predictions confirming a further increase in the importance of this sector. Considering the level of self-sufficiency in basic crop commodities, we can state that we have an active balance in cereals. On the contrary, self-sufficiency is low in potatoes, temperate fruits and vegetables. Low food self-sufficiency can not only negatively affect price stability and food security, but limiting agricultural production also has negative impacts from an ecological and environmental point of view and on rural development in general (Svatošová et al., 2018). In response to the situation, the Ministry of Agriculture (MoA) defines sustainable food security and adequate food self-sufficiency as one of the main priorities within the Development Strategy with a view to 2030. The aim is to increase the area under perennial forage crops, potato production, vegetable cultivation and the area under orchards at the expense of the area under rapeseed. Analysis by Kolodziejczak (2018) shows that the EU as a whole is largely food self-sufficient. The only exception to this is fruit. At the same time, it is clear that self-sufficiency varies across EU countries. It is therefore necessary to ensure effective mechanisms for redistributing surpluses to regions suffering from shortages by promoting the exchange of goods within the EU, while maintaining the economic, social and natural sustainability of agricultural production. Within the neighbouring countries, the level of self-sufficiency in basic commodities is lowest in Slovakia. In contrast, Poland and Germany have higher levels of self-sufficiency in meat and potato production compared to the Czech Republic. Moreover, Polish agriculture shows a high level of self-sufficiency in all the basic commodities monitored.

Czech agriculture is also characterised by its large-scale production, with legal entities having an 11% share of the total number of agricultural entities farming over 69.5% of the land (MoA, 2021). There are significant differences in farm size between EU countries. In terms of farm size, the Czech Republic, together with Slovakia, is at the top of the ranking (Urbánová et al., 2018; Kryszak et al., 2021). Popescu et al. (2016) conducted an empirical analysis of the farm structure and land concentration in Romania and the EU-28. The results show that farms within the EU are characterized by a large number, diversity and show a wide range of sizes. In 2013, the average farm size in the EU was 16.2 ha and 65.9% of the agricultural area was farmed by farms with an area of more than 50 ha. The largest farms were recorded in the Czech Republic (133 ha) and Slovakia (80.7 ha), where the share of area farmed by farms over 50 ha was 93.3% and 92.7% respectively. On the other hand, the smallest farm sizes are found in Malta, Cyprus and Romania, which also have the lowest economic efficiency. Also in neighbouring Austria and Poland, farms tend to be smaller on average (19.4 ha and 10.1 ha respectively) and farms over 50 ha account for 37.9% and 30.8% of the utilised agricultural area.

One of the objectives of the reformed CAP applicable from 2023 is to provide more targeted support to smaller farms (Consilium.europa.eu, 2023). This objective is supported by the so-called European agricultural model, according to which the farm should be medium-sized, based on family labour, have a diversified, multi-directional production structure and, among non-economic functions, maintain cultural and social links in the countryside (Kowalczyk and Sobiecki, 2014). According to the authors of the CAP Strategic Plan for the Czech Republic, the current system of direct payments has long been unfair for small farms with lower incomes, and a redistributive payment should encourage a fairer distribution of payments that respects the benefits of large-scale production (Lososová and Zdeněk, 2023). Thus, 23% of the total amount of direct payments should go to redistributive payments favouring small farms, compared to 10-12% in neighbouring countries. It is clear that the preference for small enterprises over large ones is more distinctive in the Czech Republic than in other countries (Svobodová et al., 2022). Representatives of the Agrarian Chamber of the Czech Republic and the Agricultural Association of the Czech Republic have warned that the current set-up will lead to further food price increases and reduced production. On the other hand, the Association of Private Farming of the Czech Republic (APF CR) considers the changes to be a step in the right direction. Financial support favouring small farms in the Czech Republic is driven by the need to diversify agricultural activities in the countryside (Svobodová et al., 2022). APF CR has long pointed to the inappropriate structure of farms and agriculture in the Czech Republic, with cereals and rapeseed decisively shaping crop production and its structure. Western European family-type agriculture operates in a more or less balanced commodity structure and it can therefore be concluded that farm size also influences the structural composition. Several studies are also inclined to support smaller farms, especially with regard to ensuring higher biodiversity (Ricciardi et al., 2021). Increasing field size is an important but long-overlooked cause of biodiversity loss in European farmland (Clough et al., 2020). In large agricultural regions, the trend towards more specialised and larger farms growing fewer and fewer crops continues (Bennett et al., 2012). Although small farms contribute to biodiversity conservation and food security at the local level, they often face challenges related to productivity, market access and long-term sustainability (Marsden and Sonnino, 2008). Diversified crop production, while bringing environmental benefits, reduces crop yields and prevents the realisation of economies of scale (Fleisher and Liu, 1992). According to Žáková Kroupová et al. (2023), subsidies have a negligible positive impact on agricultural biodiversity and thus support farmers' incomes rather than agricultural biodiversity. Being a small or medium farmer means that the impact of subsidies on Simpson's index of diversity is rather less than being a very large farmer. The finding may be related to the current legislation that requires that a farm with more than 30 ha of arable land must grow at least three crops, the main crop does not take more than 75% of the arable land, and at the same time the two main crops do not take more than 95% of the arable land (MoA, 2022). Farm size is also discussed in relation to farm productivity and efficiency. Small farms lag behind large farms in both productivity and technical efficiency. Targeting support to small farms leads to relatively small increases in overall productivity compared to targeting larger farms (Čechura et al., 2022). Svobodová et al. (2022) state that the group of farms with significant economic size achieves substantially higher productivity than small and medium-sized farms. This is also true for different production-oriented groups, with farms focused on field crop production achieving higher total factor productivity. Field crop production is an important agricultural production specialisation and significantly influences the whole Czech agriculture (Rudinskaya and Náglová, 2020). Farms specialising in field crops have the highest average economic performance scores, which include productivity, cost and profitability indicators, but also have the worst average environmental sustainability scores, which include the use of organic fertilisers, greening, proportion of grassland and others. Due to the automation of production, these enterprises use relatively little labour, are highly profit-oriented and grow mainly cash crops. In terms of economic size, the highest environmental dimension scores are reported for small enterprises, which in turn have the worst economic dimension scores (Špička et al., 2020). Staniszewski and Borychowski (2020) report that the impact of subsidies on efficiency depends on the size of farms. A statistically significant, stimulating effect of subsidies was identified only in the group of the largest farms. The heterogeneity of small farms also leads to the question of whether acreage is an appropriate size criterion for subsidy degression and whether a more appropriate criterion would be economic size of the farm or its combination with acreage (Lososová and Zdeněk, 2023). A number of factors influence farm size. In our context, these factors include land consolidation, unemployment rates and soil fertility. At the European scale, a significant association between farm size and wheat production has been found (Janovská at al., 2017).

The aim of the paper is to verify whether the structure of crop production in the Czech Republic depends on the size of the farm. The first question concerns the identification of differences in the structure of crop production according to farm size. The second question deals with the shares of the harvested area of individual crops concerning farm size and the comparison of inter-group differences. The paper contributes to the current state of knowledge by applying statistical methods to compare four farm size groups in the field production specialisation. This study fills a gap in research on the structure of crop production in the Czech Republic, as most previous studies have examined farm size mainly in relation to efficiency, productivity, subsidies, or diversity.

Materials and methods

The data were drawn from the CSO and FADN and were processed using MS-Excel, Statistica 14 and IBM SPSS 29 statistical software. Within the sample of the FADN survey conducted in 2021, enterprises specialised in field production were the most represented group, 365 enterprises in total (32.5%). These enterprises represented 5 396 agricultural entities of the given specialization, farmed 36.2% of the total cultivated land in the Czech Republic and contributed 28.8% to the total production of the Czech agricultural sector and 44.3% to crop production. The following main crops were chosen to assess the percentage structure of cropland harvested: wheat, rye, barley, oats, maise, peas, sugar beet, potatoes, rapeseed, mustard, poppy and other feed crops. The sample covers one CAP period 2014–2021 and consists of conventional agricultural enterprises focused on field crop production operating in the Czech Republic. According to the total SO of the enterprise, the categories used were small enterprises (SO 8-25 thousand EUR), medium enterprises (SO 25-100 thousand EUR), large enterprises (SO 100-500 thousand EUR) and very large enterprises (SO over 500 thousand EUR). The number of enterprises sampled each year and size group is shown in the Table A1.

Statistical analysis

Using chain base and fixed base indices and regression analysis of time series, the development of the sown area in the Czech Republic in the period 1993–2023, according to the data of the CSO, was first assessed. The trend of the analysed time series was described using linear, quadratic, and logarithmic trend functions. The correlation index was used to decide on the appropriate type of trend function (Hindls, 2007). Based on the selected trend function, predictions of the sown area of individual crops for the period 2024–2025 were determined.

Subsequently, statistical hypotheses were tested. There are often situations where the conditions for using a standard parametric test are violated, or we want to avoid these assumptions in order to increase the generality of the findings (Pereira et al., 2015). To overcome these difficulties, nonparametric tests based on very general assumptions have been developed (Grofík et al., 1987). Thus, nonparametric tests have broader applicability than parametric tests. However, they have the disadvantage of lower test power (Hindls et al., 2007). The Shapiro-Wilk test was used to verify the assumption of normality and the assumption of homogeneity of variances was verified using the Levene's test (see the Table A2). Since the assumptions were not met, the nonparametric Kruskal–Wallis test, which is an alternative nonparametric procedure to the parametric one-factor analysis of variance, was used. The test is based on the following criterion:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{T_i^2}{ni} - 3\,(N+1) \qquad (1)$$

Where n_1, n_2, ..., n_k = the ranges of each file; $N = n_1 + n_2 + ... + n_k$; k = the number of independent random samples; T_1, T_2, ..., T_k = the sums of the rank numbers of each observation for each sample separately after merging the samples into a single file and assigning a rank (Grofík et al., 1987). The test statistic for $n_i > 5$ has approximately χ^2 distribution with k - 1 degrees of freedom. We test the null hypothesis H_0 that all samples come from the same distribution (Jarošová, 2021). If the Kruskal–Wallis test rejects the tested hypothesis, we further assess which groups are statistically significantly different from each other using a post-hoc test. If we are working with unbalanced samples, according to Anděl (2011), we can complement the Kruskal–Wallis test with the so-called general multiple comparison method. Let us denote by $t_i = T_i/n_i$ the average ranking in the i-th sample. Let $h_{KW}(\alpha)$ be the critical value of the Kruskal-Wallis test at the α significance level contained in the special tables, which can be approximated at larger ranges by the quantile of the χ^2 distribution with k - 1 degrees of freedom for a given α. If the inequality holds

$$|t_i - t_k| \geq \sqrt{\frac{N(N+1)}{12}\left(\frac{1}{n_i} + \frac{1}{n_k}\right) h_{KW}(\alpha)}, \qquad (2)$$

then, at the α significance level, we reject the null hypothesis that the distributions of the i-th and k-th samples are identical.

Results and discussion

Development of sown areas

It is clear from Table 1 above that there are significant changes in the area sown to individual crops in the long term. In terms of the share of the total sown area, wheat, grain maise, and rapeseed have increased in importance. At the same time, these are the only crops which, despite the decline in total sown area, have not fallen below the value recorded in 1993 and which have experienced an average annual increase of 0.14%, 3.08% and 2.77% respectively over the period under review. On the other hand, in terms of the share of the total sown area, barley, potatoes, and forage crops on arable land showed a significant decrease. Compared to 1993, the areas of potato (19.96%), flax (20.33%), rye (36.81%) and barley (50.31%) were at their lowest levels in 2023.

Table 2 shows the expected development of the area of each crop based on the calculated trend functions. Only functions whose correlation index is higher than 0.6 and whose result is statistically significant are analysed. These conditions were not met only in the case of wheat. The other results are statistically significant, and according to the values of the correlation index, it is clear that there is a strong dependence between the variables and that the chosen trend functions explain the variability of the time series very well. According to the calculated predictions, it can be expected that in the following years 2024–2025 there will be a slight increase in the sown areas of rye, oats, legumes, industrial sugar beet, flax, forage crops and potatoes, which can be considered as a positive indicator in response to the set

	Average (ha)	Average absolute increment (ha)	Average growth coefficient	Fixed base index 2023/1993	Fixed base index 2004/1993	Fixed base index 2013/1993	Share of total sown area 1993 (%)	Share of total sown area 2023 (%)
Wheat	830487	1152.13	1.0014	1.0441	1.1021	1.0590	24.63	33.85
Rye	41231	-1410.77	0.9672	0.3681	0.8840	0.5599	2.11	1.02
Barley	452576	-10570.97	0.9774	0.5031	0.7348	0.5468	20.08	13.29
Oats	53638	-832.53	0.9848	0.6326	0.8617	0.6408	2.14	1.78
Grain maise	73261	1468.23	1.0308	2.4853	2.9613	3.7743	0.93	3.05
Leguminous crops	40116	-1407.83	0.9804	0.5514	0.3017	0.1896	2.96	2.15
Potatoes	41551	-2799.47	0.9477	0.1996	0.3428	0.2211	3.3	0.87
Technical sugar beet	68770	-1614.67	0.9802	0.5483	0.6629	0.5819	3.37	2.43
Rapeseed	326374	7084.03	1.0277	2.2694	1.5497	2.5015	5.27	15.73
Flax	4889	-208.70	0.9483	0.2033	0.9567	0.1925	0.25	0.07
Arable forage crops	562311	-16886.57	0.9754	0.4733	0.5204	0.4537	30.25	18.84

Source: CSO and author's procession (2023)

Table 1: Basic characteristics of the area sown to each crop between 1993 and 2023.

	Trend function	Correlation index	F p-value	2024 prediction (ha)	-95% +95% prediction	2025 prediction (ha)	-95% +95% prediction
Rye	y´= 83°234.25 – 4°311.97t_i + 80.32t_i^2	0.9078	65.606 0	27 501	17 988 37 014	28 410	17 636 39 184
Barley	y´= 638°131.9 – 11°597.3 t_i	0.9502	269.48 0	267 019	240 534 293 505	255 422	227 667 283 178
Oats	y´= 77°650.8 – 21°948.6 log t_i	0.745	36.172 0	44 614	40 513 48 715	44 321	40 145 48 497
Grain maise	y´= - 1°036.6 + 9°382.53t_i – 225.66 t_i^2	0.9185	75.505 0	68 126	54 680 81 572	62 840	47 613 78 068
Leguminous crops	y´= 85°467.47 – 6°509.41t_i + 175.0 t_i^2	0.9318	92.236 0	56 365	49 156 63 573	61 230	53 066 69 394
Potatoes	y´= 103°296.3 – 6°812.2t_i + 140.6 t_i^2	0.9707	228.62 0	29 306	22 248 36 364	31 634	23 641 39 627
Technical sugar beet	y´= 106°792.1 – 4°559.5t_i + 104.0 t_i^2	0.8779	47.07 0	67 341	58 347 76 336	69 539	59 353 79 725
Rapeseed	y´= 174°907.1 + 16°197.5t_i – 320.5 t_i^2	0.8685	42.993 0	365 019	324 060 405 979	360 383	313 996 406 770
Flax	y´= 12°185.54 – 6°669.22 log t_i	0.6483	21.026 0.0001	2 147	512 3 781	2 058	393 3 722
Arable forage crops	y´= 1°028 202 – 57°413t_i + 1 347 t_i^2	0.9701	223.57 0	570 691	521 005 620 377	600 856	544 586 657 127

Source: CSO and author's procession (2023)

Table 2: Analysis of crop area trend functions and their expected evolution between 2024-2025.

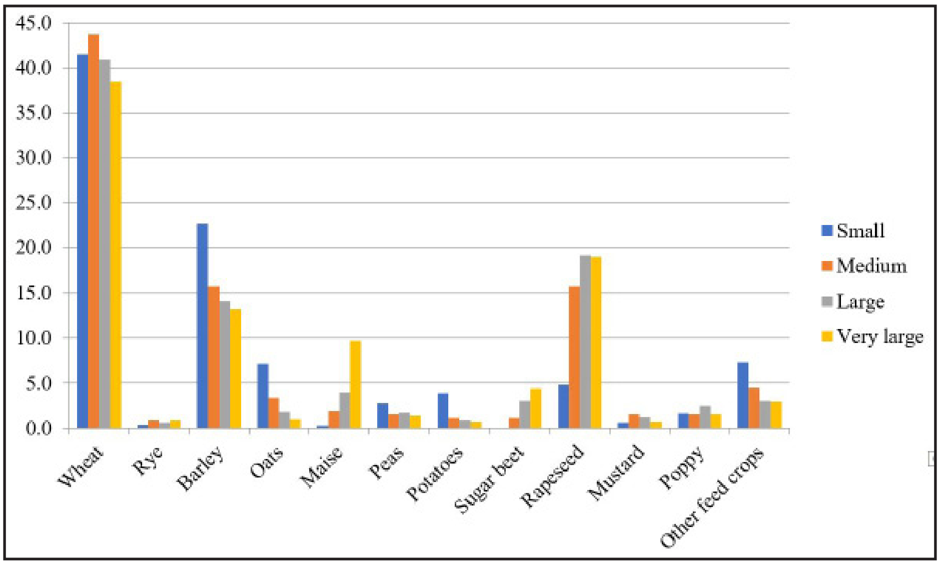
measures. On the other hand, a decrease in the area sown to rapeseed and grain maise can be expected.

The identification of trends can help to identify commodities that require special attention from agricultural policy. Alternatively, the effectiveness of the agrarian policy measures can be assessed, which should lead to an increase in the sown area of sensitive commodities.

Farm size and structure of crop production

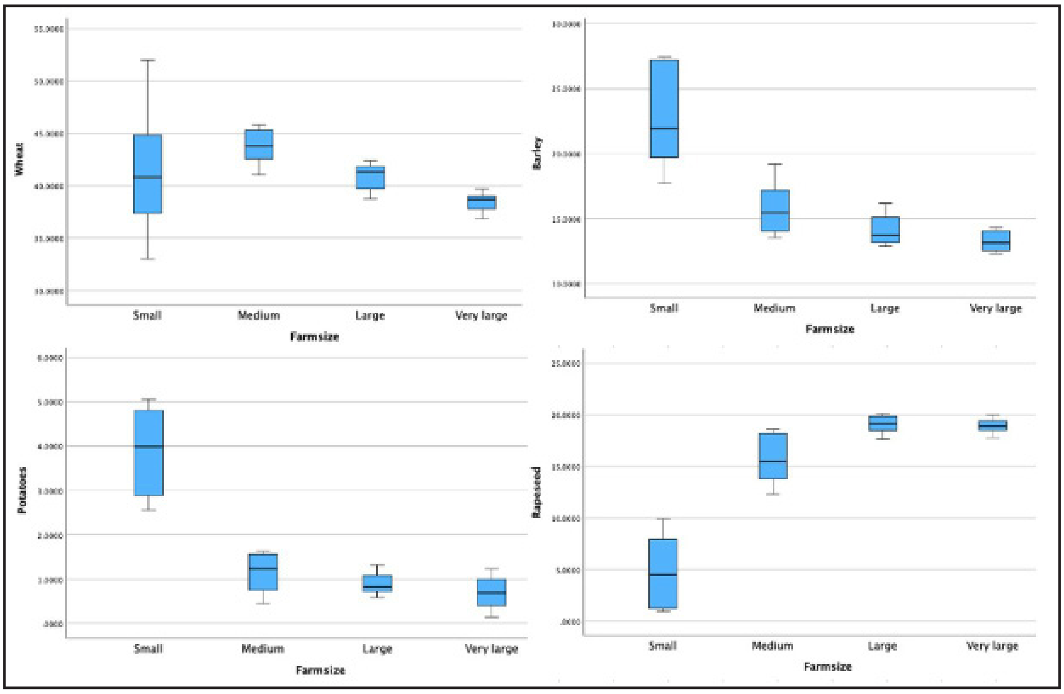
The size of farms is influenced by several factors (Janovská et al., 2017). One of them is demonstrably the structure of crop production. The following Figure 1 shows the average structure of harvested area per arable land for different farm size groups, between which there is a significant difference. The largest differences are observed for barley, maise, potatoes, oilseed rape and other fodder crops. On the other hand, the average percentages of wheat, rye, peas, mustard, and poppy are similar. In the overall crop production structure, there was a slight increase in the share of wheat, poppy, peas, and other feed crops in 2019 compared to 2014. The share of barley, potatoes and maise decreased. These findings are in line with the claims of the APF CR, which has long pointed out that cereals and oilseed rape decisively shape the structure of crop production. According to Malinovský (2021), the production of barley, oats, and rye will decline in the following years in favour of wheat and maise. From the analyses carried out, it is clear that the crops whose importance in terms of sown area in the Czech Republic has been declining for a long time have a higher share in the structure of harvested arable land in small farms.

The different structures between the different farm sizes are also evident in Figure 2 below, which includes box plots of the percentages of wheat, barley, potatoes, and rapeseed in the structure of each farm size group. The highest variability over time is observed for small enterprises, while the lowest variability is observed for the largest enterprises. In the case of barley, potatoes and rapeseed, small enterprises are the outliers in terms of their shares, and they are also the most variable over time. The share of these crops in the structure of large and very large enterprises is similar and relatively stable compared to small enterprises. While the share of rapeseed is the lowest for small enterprises, averaging 4.84%, this average share rises to 19.09% and 18.94% for large and very large enterprises respectively. On the other hand, barley and potatoes reach the highest share for small enterprises, at 22.65% and 3.88% respectively. In comparison, for very large enterprises, the average share of barley and potatoes is 14.20% and 0.87% respectively. This fact is related to the findings of Procházková et al. (2016), according to which the cultivation of rye, barley and potatoes, which are predominant in the structure of small enterprises, is receding.



Source: FADN and author's procession (2023)

Figure 1: Average structure of harvested area per arable land (%).



Source: FADN and author's procession (2023)

Figure 2: Categorised box plot of percentage of wheat, barley, potatoes and rapeseed.

On the contrary, in the long run, the areas of rapeseed and industrial crops are expanding, whose harvested areas reach higher shares in very large and large enterprises. This fact is also linked to the low level of self-sufficiency in potatoes (Svatošová et al., 2018). Potatoes, together with sugar beet, selected fruit and vegetables, hops, and protein crops, are among the sensitive sectors supported by EU resources through voluntary coupled support (MoA, 2021). The introduction of aid in the potato sector has slowed down the rate of decline in potato areas (Žovincová, 2019).

According to the results of the Kruskal–Wallis test in Table 3, it is clear that for almost all crops H_0 cannot be accepted, and therefore, the share of the crop grown depends on the size of the farm. The only crop for which no dependence between share of cultivation and farm size was found is peas. Thus, farm size influences the proportion

Crop	K-W test	P-value	Hypothesis	Post-hoc test	P-value
Wheat	13.6532	0.0034**	H1	M x VL	0.0013**
Rye	9.0303	0.0289*	H1	S x VL	0.0769
Barley	18.9193	0.0003***	H1	S x L S x VL	0.0085** 0.0002***
Oats	25.2796	0.0000***	H1	S x L S x VL M x VL	0.0128* 0.0000*** 0.0030**
Maise	26.3801	0.0000***	H1	S x L S x VL M x VL	0.0137* 0.0001*** 0.0026**
Peas	0.6806	0.8777	H0	x	x
Potatoes	16.2871	0.0010**	H1	S x L S x VL	0.0096** 0.0007***
Sugar beet	26.4024	0.0000***	H1	S x L S x VL M x VL	0.0061** 0.0000*** 0.0029**
Rapeseed	21.0419	0.0001***	H1	S x L S x VL	0.0004*** 0.0010**
Mustard	14.5848	0.0022**	H1	M x S M x VL	0.0194* 0.0180*
Poppy	9.1038	0.0279*	H1	L x VL	0.0496*
Other feed crops	13.8141	0.0032**	H1	S x L S x VL	0.0128* 0.0089**

Note: If p-value < 0.05, then H0 cannot be accepted at the chosen significance level, and the proportion of cultivation of a given crop depends on the size of the farm. Furthermore, if the p-value < 0.05, then there is a statistically significant difference just between the indicated size groups of enterprises, where S = small, M = medium, L = large, VL = very large. The level of significance is indicated as P < 0.05 *, P < 0.01 **, P < 0.001***. The post-hoc test includes only groups of enterprises between which there is a statistically significant difference.

Source: FADN and author's procession (2023)

Table 3:Results of Kruskal–Wallis test (K-W test) and post-hoc multiple comparison test.

of crops grown, respectively, the structure of crop production and agricultural policy should take this into account in measures relating to farm size and self-sufficiency. The new redistributive payments favouring small farms in the Czech Republic are to go to 23%, which critics argue could impact medium-sized farms (Lososová and Zdeněk, 2023). An administrative division of large farms into smaller ones can be expected. This will result in a higher number of enterprises and a decrease in their size rather than a change in the structure of crop production. At the same time, this raises the question of whether SO would be a better indicator for subsidy payments than the agricultural area used (Urbánová et al. 2018). The level of production, hence self-sufficiency, especially for commodities not regulated by agricultural policy measures, can be largely linked to the level of their aggregate profitability achieved and to the competitiveness of downstream processing industries (Procházková et al., 2018). At the same time, the smallest producers lag behind the largest ones due to scale effects (Čechura et al., 2022).

The multiple comparison method found a statistically significant difference mainly between small-sized enterprises and large and very large enterprises. In a similar direction, the findings of Janovská et al. (2017) suggest that there is a significant association between wheat production and farm size on a European scale. The most significant differences are observed between the smallest and the largest farms, especially for barley, oats, maise, potatoes, sugar beet and rapeseed. There is also a significant difference between medium-sized and very large enterprises for wheat, oats, maise, sugar beet and mustard. With respect to farm size, the main issues examined so far have been biodiversity (Ricciardi et al., 2021), wheat production (Janovská et al., 2017; Skalicky et al., 2021), the impact of subsidies on agricultural diversity (Žáková Kroupová et al., 2023), the impact of subsidies on farm efficiency (Staniszewski and Borychowski, 2020), and efficiency and productivity (Čechura et al., 2022; Svobodová et al., 2022), which are significantly higher for enterprises with high economic size than for small and medium-sized enterprises, and in terms of overall productivity growth, policy support for small enterprises is a trade-off. It is clear from the various studies that there is no uniform view on the issue of farm size. Significant differences in the structure of crop production according to farm size are another indicator that should be addressed and also targeted by CAP measures. Compared to other EU Member States, the Czech Republic and Slovakia have the largest farm size (Urbánová et al., 2018) and it is therefore clear that large farms significantly influence the structure of crop production.

It is important to mention that many other factors play a role in the structure of production and farm size, which have already been the subject of some studies or create space for further research. In relation to the structure of crop production and farm size, other areas of interest are level of production, self-sufficiency, regulatory measures for individual commodities, profitability and the competitiveness of downstream processing industries. The impact of farm size on production structure could be further explored across production orientations or selected countries.

Conclusion

This study investigated the relationship between farm size and crop production structure of conventional arable farms in the Czech Republic. The analysis was based on the application of statistical methods from the field of nonparametric testing and time series. In contrast to previous studies that assessed farm size mainly in relation to production, efficiency, biodiversity, or subsidies, this study assessed the importance of individual crops in the overall cropping structure of small, medium, large, and very large farms.

The results show that there have been significant and often negative changes in the structure of crop production in the Czech Republic during the period under review. It is also clear that farm size influences the structure of crop production. Given the large-scale nature of Czech agriculture, the structure of crop production is largely defined by large enterprises. For all the crops evaluated, with the exception of peas, it is not possible to accept H_0, and therefore, the share of the crop grown depends on the size of the holding. A statistically significant difference was found mainly between small enterprises and large and very large enterprises. Compared to large and very large enterprises, small enterprises have a predominant share of barley, oats, potatoes and other feed crops. In contrast, large and very large enterprises have a higher share of maise, rapeseed and sugar beet.

The results also have important policy implications. Measures should not focus purely on the size of the holding, but the production structure of the holding should also be assessed alongside the size. If one of the objectives of the reformed CAP applicable from 2023 is to provide more targeted support to smaller farms, the proposals should also include approaches to increase their efficiency and productivity. At the same time, one of the main priorities of the Ministry of Agriculture is sustainable food security and adequate food self-sufficiency, with the aim of increasing the area under permanent fodder crops, potatoes, orchards and vegetables at the expense of the area under rapeseed. Appropriate measures should thus be set up to support both the productivity of small farms and changes in the structure of crop production on large farms, which decisively shape Czech agriculture. Here, the established legislation requiring a farm larger than 30 ha of arable land to grow at least three crops seems sensible. Voluntary coupled support for sensitive commodities also plays an important role. In order to increase the productivity of small farms, increasing support should also be linked to the purchase of agricultural equipment. Increased investment in research and development leading to higher yields also seems to be a possible solution in terms of ensuring an adequate level of self-sufficiency.

Acknowledgements

This article is a part of the dissertation in the doctoral study program Quantitative Methods in Economics at the Faculty of Economics and Management, Czech University of Life Sciences Prague. The dissertation is entitled "Changes in the production dimension and structure of Czech agriculture".

Corresponding author:
Ing. Anna Žovincová
Department of Statistics, Faculty of Economics and Management, Czech University of Life Sciences Prague
Kamýcká 129, 165 00 Praha – Suchdol, Czech Republic
Phone: +420774214413, E-mail: zovincova@pef.czu.cz

References

[1] Anděl, J. (2011) "Základy matematické statistiky", 3rd ed. Prague: Matfyzpress. ISBN 978-80-7378-162-0. (In Czech).

[2] Bennett, A. J., Bending, G. D., Chandler, D., Hilton, S. and Mills, P. (2012) "Meeting the demand for crop production: the challenge of yield decline in crops grown in short rotations", *Biological Reviews*, Vol. 87, pp. 52-71. ISSN 1469-185X. DOI 10.1111/j.1469-185X.2011.00184.x.

[3] Collective of office and external authors of APF CR (2021) "*On the problem of self-sufficiency of Czech agriculture*", Oct. 2021. [Online]. Available: https://www.asz.cz [Accessed: Sept. 21, 2023].

[4] Clough, Y., Kirchweger, S. and Kantelhardt, J. (2020) "Field sizes and the future of farmland biodiversity in European landscapes", *Conservation Letters*, Vol. 13, p. e12752. ISSN 1755-263X. DOI.org/10.1111/conl.12752.

[5] Czech Statistical Office (2011) "*České zemědělství očima statistiky*", Czech Statistical Office, Prague, 83 p. ISBN 978-80-250-2110-1. (In Czech).

[6] Czech Statistical Office (2024) "*Agriculture – time series*", Czech statistical Office. [Online]. Available: https://www.czso.cz/csu/czso/zem_ts [Accessed: March 20, 2024].

[7] Čechura, L., Žáková Kroupová, Z. and Lekešová, M. (2022) "Productivity and efficiency in Czech agriculture: Does farm size matter?", *Agricultural Economics*, Vol. 68, pp. 1-10. ISSN 0139-570X. DOI 10.17221/384/2021-AGRICECON.

[8] European Commission (2022) "*Proposed CAP strategic plans - summary overview*". [Online]. Available: https://agriculture.ec.europa.eu/cap-my-country/cap-strategic-plans_en [Accessed: Oct. 27, 2022].

[9] European Commission-FADN (2020) "*Definitions of Variables Used in FADN Standard Results", RI/CC 1750*. [Online]. Available: https://circabc.europa.eu/ui/group/880bbb5b-abc9-4c4c-9259-5c58867c27f5/library/162fb4de-22c9-489a-a0f6-8cd9f75de730 [Accessed: May 8, 2022].

[10] Farm Accountancy Data Network (2020) "*Sample survey of economic results of agricultural holdings in the FADN CZ network for 2020*", Prague: Institute of Agricultural Economics and Information. ISBN 978-80-7271-254-0. (In Czech).

[11] Farm Accountancy Data Network (2023) "*Public database*", Institute of Agricultural Economics and Information. [Online]. Available: https://public.fadn.cz/ [Accessed: Oct. 27, 2023].

[12] Fleisher, B. M. and Liu, Y. (1992) "Economies of scale, plot size, human capital, and productivity in Chinese agriculture", *Quarterly Review of Economics and Finance*, Vol. 32, pp. 112-124. ISSN 1062-9769.

[13] Grofík, R., Kubíček, J., Hrubý, J., Dufek, J., Kába, B. and Zeipelt, R. (1987) "*Statistika*", Bratislava: Príroda. 284 p. (In Czech).

[14] Hindls, R. (2007) "*Statistika pro ekonomy*", Professional Publishing, 8th ed. Prague. ISBN 978-80-86946-43-6. (In Czech).

[15] Janovská, V., Simova, P., Vlasak, J. and Sklenicka, P. (2017) "Factors affecting farm size on the European level and the national level of the Czech Republic", *Agricultural Economics*, Vol. 63, pp. 1-12. ISSN 0139-570X. DOI 10.17221/317/2015-AGRICECON.

[16] Jarošová, E. (2021) "*Návrhy a vyhodnocení průmyslových experimentů*", Professional Publishing, Prague. ISBN 978-80-88260-54-7. (In Czech).

[17] Kolodziejczak, M. (2018) "Food self-sufficiency in EU countries: an attempted projection to 2080", International Scientific Conference *AP XXVII. Food safety - Food security.* Czech University of Life Sciences Prague, ISBN 978-80-213-2890-7.

[18] Kowalczyk, S. and Sobiecki, R. (2014) "The European model of agriculture in relation to global challenges", *Problems of Agricultural Economics*, Vol. 329, pp. 35-58. ISSN 0044-1600. DOI: 10.22004/ag.econ.235229.

[19] Kryszak, Ł., Guth, M. and Czyżewski, B. (2021) "Determinants of farm profitability in the EU regions. Does farm size matter?", *Agricultural Economics*, Vol. 67, pp. 90-100. ISSN 0139-570X. DOI 10.17221/415/2020-AGRICECON.

[20] Lososová, J. and Zdeněk, R. (2023) "Simulation of the impacts of the proposed direct payment scheme - The case of the Czech Republic", *Agricultural Economics*, Vol. 69, No. 1, pp. 13-24. ISSN 0139-570X. DOI 10.17221/328/2022-AGRICECON.

[21] Malinovský, V. (2021) "Predicting Trends in Cereal Production in the Czech Republic by Means of Neural Networks", *AGRIS on-line Papers in Economics and Informatics*, Vol. 13, No. 1, pp. 87-103. ISSN 1804-1930. DOI 10.7160/aol.2021.130107.

[22] Marsden, T. and Sonnino, R. (2008) "Rural development and the regional state: Denying multifunctional agriculture in the UK", *Journal of Rural Studies*, Vol. 24, No. 4, pp. 422-431. ISSN 1873-1392. DOI.10.1016/j.jrurstud.2008.04.001.

[23] Ministry of Agriculture of the Czech Republic (2016) "*Strategie resortu Ministerstva zemědělství s výhledem do roku 2030*", Ministry of Agriculture of the Czech Republic, Prague. ISBN 978-80-7434-356-8. (In Czech).

[24] Ministry of Agriculture of the Czech Republic (2014 – 2021) "*Zpráva o stavu zemědělství České Republiky*", Ministry of Agriculture of the Czech Republic. [Online]. Available: https://eagri.cz/public/web/mze/zemedelstvi/publikace-a-dokumenty/zelene-zpravy/?pos=0 [Accessed: Jan. 10, 2023]. (In Czech).

[25] Ministry of Agriculture of the Czech Republic (2021) "*Situační a výhledová zpráva - Půda*", Ministry of Agriculture of the Czech Republic, Prague. ISBN 978-80-7434-598-2. (In Czech).

[26] Ministry of Agriculture of the Czech Republic (2022) "*Metodická příručka k podmínkám poskytování přímých plateb v České republice v roce 2022*", Ministry of Agriculture of the Czech Republic, [Online]. Available: https://eagri.cz/public/portal/mze/dotace/prime-platby/metodicka-prirucka-pro-prime-platby-pro-3 [Accessed: Sept. 18, 2023]. (In Czech).

[27] Pereira, D. G., Alfonso, A. and Medeiros, F. M. (2015) "Overview of Friedman's Test and Post-hoc Analysis", *Communications in Statistics - Simulation and Computation*, Vol. 44, No. 10, pp. 2636-2653, ISSN 1532-4141. DOI 10.1080/03610918.2014.931971.

[28] Popescu, A., Alecu, I. N., Dinu, T. A., Stoian, E., Condei, R. and Ciocan, H. (2016) "Farm structure and land concentration in Romania and the European Union's agriculture", *Agriculture and Agricultural Science Procedia*, Vol. 10, pp. 566-577. ISSN 2210-7843. DOI 10.1016/j.aaspro.2016.09.036.

[29] Procházková, R., Prášilová, M. and Hloušková, Z. (2016) "Efficiency of agriculture as related to foodstuffs Autarky in the Czech Republic", In: *Proceedings from the International Scientific Conference AP XXV.*, Czech University of Life Sciences Prague. ISBN 978-80-213-2670-5.

[30] Ricciardi, V., Mehrabi, Z. and Wittman, H. (2021) "Higher yields and more biodiversity on smaller farms", *Nature Sustainability*, Vol. 4, pp. 651-657. ISSN 0028-0836. DOI 10.1038/s41893-021-00699-2.

[31] Rudinskaya, T. and Náglová, Z. (2020) "Position of the Czech republic in EU field crop production", In: *Proceedings from the International Scientific Conference AP XXIX. Trends and challenges of agrarian sector*. Czech University of Life Sciences Prague. ISBN 978-80-213-3041-2.

[32] Řezbová, H. and Škubna, O. (2012) "The role of transgenic crops in the future of global food and feed", *AGRIS on-line Papers in Economics and Informatics*, Vol. 4, No. 2. ISSN 1804-1930.

[33] Staniszewski, J. and Borychowski, M. (2020) "The impact of the subsidies on efficiency of different sized farms. Case study of the Common Agricultural Policy of the European Union", *Agricultural Economics*, Vol. 66, pp. 373-380. ISSN 0139-570X. DOI 10.17221/151/2020-AGRICECON.

[34] Svatošová, L., Köppelová, J. and Brož, D. (2018) "Trends in consumption of selected types of foodstuffs as related to nutrition recommendations and self-sufficiency", In: *Proceedings from the International Scientific Conference AP XXVII. Food safety - Food security*. Czech University of Life Sciences Prague, ISBN 978-80-213-2890-7.

[35] Svobodová, E., Redlichová, R., Chmelíková, G. and Blažková, I. (2022) "Are the Agricultural Subsidies Based on the Farm Size Justified? Empirical Evidence from the Czech Republic", *Agriculture*, Vol. 12, No. 10, p. 1574. ISSN 2077-0472. DOI 10.3390/ agriculture12101574.

[36] Špička, J., Vintr, T., Aulová, R. and Macháčková, J. (2020) "Trade-off between the economic and environmental sustainability in Czech dual farm structure", *Agricultural Economics*, Vol. 66, No. 6, pp. 243-250. ISSN 0139-570X. DOI 10.17221/390/2019-AGRICECON.

[37] Urbánová, M., Dobošová, Ľ., Kozáková, J., Ďurišová, E. and Čeryová, D. (2018) "Physical and economic size of farms in the EU - focus on Slovakia", In: *Proceedings from the International Scientific Conference AP XXVII. Food safety - Food security*. Czech University of Life Sciences Prague. ISBN 978-80-213-2890-7.

[38] Žáková Kroupová, Z., Čechura, L., Opatrný, M., Hloušková, Z. and Mlezivová, I. (2023) "Assessment of the impact of agricultural support on crop diversity", *Agricultural Economics*, Vol. 69, No. 3, pp. 89-100. ISSN 0139-570X. DOI 10.17221/387/2022-AGRICECON.

[39] Žovincová, A. (2019) "Importance of the potato market in the Czech Republic in comparison with selected EU countries" In: *Think together, Scientific Doctoral Conference*, Czech University of Life Sciences Prague. ISBN 978-80-213-2169-4.

Appendix

Year	Small		Medium		Large		Very large	
	n	ha	n	ha	n	ha	n	ha
2014	22	50 773	135	140 229	173	336 686	131	695 047
2015	21	55 461	135	142 150	168	347 717	128	635 095
2016	22	41 470	133	130 463	169	342 569	130	668 507
2017	13	47 146	106	124 143	175	351 414	162	750 293
2018	19	43 954	121	123 217	160	338 246	159	773 752
2019	20	38 029	106	132 414	167	337 851	148	800 541
2020	N/A	N/A	98	130 405	139	314 640	116	751 805
2021	N/A	N/A	111	139 989	144	348 810	104	801 727

Source: FADN (2023)

Table A1: Number of farms in the research sample and their acreage of agricultural land area.

In the FADN CZ survey, the economic size threshold for the survey area, i.e. for the inclusion of enterprises in the FADN CZ sample, has been increased from EUR 8 000 to EUR 15 000 of standard production, as defined in the amendment to Commission Implementing Regulation (EU) No 2015/220, since the accounting year 2020. Based on this change, small enterprises with an economic size of IV are no longer included in the survey since the financial year 2020. This has had an impact on the results for the 2020 accounting year, especially for natural person enterprises (FADN, 2020).

	Shapiro-Wilk test		Levene's test	
Wheat	SW-W = 0.8924	p = 0.2463	F = 10.203	p = 0.00013
Rye	SW-W = 0.7536	p = 0.0216	F = 3.2238	p = 0.03888
Barley	SW-W = 0.8739	p = 0.1644	F = 8.0416	p = 0.00059
Oats	SW-W = 0.7154	p = 0.0034	F = 10.053	p = 0.00014
Maise	SW-W = 0.7076	p = 0.0027	F = 2.4758	p = 0.08377
Peas	SW-W = 0.8056	p = 0.0659	F = 22.026	p = 0.00000
Potatoes	SW-W = 0.8848	p = 0.2090	F = 8.6679	p = 0.00037
Sugar beet	SW-W = 0.8849	p = 0.2095	F = 6.4282	p = 0.00211
Rapeseed	SW-W = 0.8305	p = 0.1085	F = 23.049	p = 0.00000
Mustard	SW-W = 0.6979	p = 0.0059	F = 4.8485	p = 0.00824
Poppy	SW-W = 0.8045	p = 0.0320	F = 13.168	p = 0.00002
Other feed crops	SW-W = 0.8803	p = 0.1898	F = 4.7385	p = 0.00911

Source: FADN (2023)

Table A2: Verification of the assumptions of normality and homogeneity of variances using the Shapiro-Wilk test and the Levene's test. If $P < 0.05$, then the normality/homogeneity of variances assumption was not met. The results of the Shapiro - Wilk's test report only the groups with the lowest p-value..