# INFLUENCE OF THE SIZE OF THE AGRICULTURAL HOLDING ON TECHNICAL AND SCALE EFFICIENCY

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**Annotation:** It is assumed that larger size of the firm can bring competitive advantages resulting from economies of scale, higher innovation potential due to capital strength etc. The paper focuses on the efficiency of production of agricultural holdings and calculates technical, pure technical and scale efficiency. The aim is to find out whether the size of the agricultural holding measured in terms of the acreage of agricultural land influence the technical and scale efficiency of the farm. A non-parametric Data Envelopment Analysis is used. Particularly was chosen input oriented BCC model which assumes variable returns to scale. Differences in technical, pure technical and scale efficiency were tested by non-parametric Kruskall-Wallis test. Accounting data were obtained from Albertina database and data about acreage from Land Parcel Information System. The most technically efficient were according to the expectation large farms (from 74.35%), then medium (69.79%) and small (57.56%). Similarly, the highest pure efficiency of production was noted in large farms (82.88%). Pure efficiency in middle farms (73.97%) and in small farms (73.14%) was almost similar. Regarding the scale efficiency, middle farms were the best with 94.68%. Surprisingly large farms were efficient only from 90.11%. Small farms had again the lowest scale efficiency (79.14%). All differences were statistically significant. There were also the most 100% technically efficient firms in category of "large" farms (8 farms 100% technically efficient, 26 farms 100% pure technically efficient and 8 farms 100% scale efficient). Theoretical assumption about higher technical and pure technical efficiency of larger companies and agricultural holdings was confirmed by our study. However, scale efficiency was higher in middle-sized firms than in large companies. It might be due to the fact that there were the most farms exhibiting decreasing returns to scale in "large" category, so the scale of their operation is above optimum.

**Key words:** agricultural holding, data envelopment analysis, scale efficiency, technical efficiency

**JEL classification:** C01, C12, C21

## 1. Introduction

It is assumed that larger size of the firm can bring competitive advantages resulting from economies of scale, higher innovation potential due to capital strength etc. Larger farms have higher bargaining position as well as have a better ability to access input and output markets. (Michalek, Ciaian and Pokrivcak, 2018). Also, large agricultural holdings in terms of acreage can profit from more efficient usage of resources – e.g. usage of technical equipment on larger fields. The article focuses on the efficiency of production of agricultural holdings and calculates technical, pure technical and scale efficiency. In general, "efficiency refers to the relationship between all outputs and inputs in a production process" (Speelman et al., 2008). While technical efficiency measures the efficiency of transformation of inputs to outputs under the assumption of constant returns to scale, pure technical efficiency supposes variable returns to scale. The scale efficiency score indicates whether a firm operates at the most productive scale size. A unit is scale efficient when its size of operations is optimal so that any modifications on its size will render the unit less efficient.

Technical efficiency of agricultural companies in relation to the size was examined by many studies and context. Literature reviews brings the results of research performed by Data

Envelopment Analysis (DEA) in the member states of the European Union. Stavros et al. (2019) examined the technical efficiency of milk companies in Greece using DEA with output oriented constant and variable returns to scale models. Their results showed that 87.2% of the farms in the sample were inefficient, so the farms, at the level of inputs used, shall increase their output (milk yield) for improving their competitiveness. Regarding the amount of output, Adenuga et al. (2018) found out that farmers that take records of their milk output and with larger farm areas tend to be more efficient.

Baležentis and De Witte (2015) showed on their sample of Lithuanian family farms that the output efficiency positively correlates with time trend and negatively with the share of the subsidies in the total output. Latruffe et al. (2012) assessed the differences in technical efficiency and productivity change, and the technology gaps between French and Hungarian farms in the dairy and cereal, oilseed and protein crops sectors during the period 2001–2007 and found out based on metafrontier DEA that Hungarian technology was the more productive in both sectors.

## 2. Materials and Methods

The aim of the paper is to find out whether the size of the agricultural holding measured in terms of the acreage of agricultural land influence the technical and scale efficiency of the farm. Non-parametric Data Envelopment Analysis (DEA) method was chosen to calculate the technical, pure technical and scale efficiency of the farm. DEA assigns to each decision-making unit (DMU) which are the agricultural holdings in our case the total deviation from the production frontier to inefficiency. DMUs lying on the frontier are 100% efficient. The level of the technical inefficiency shows the deviation of the observed productive activity of a unit from the activity of the best unit or units in the sample. This deviation is attributed exclusively to differences in management ability between production units (Stavros et al., 2019).The advantage of the method is that it is deterministic and non-parametric and hence does not require any assumption about the production function. It also enables to take into consideration more inputs (*i*) and outputs (*j*).

Farrell (1957) defined the technical efficiency as the ability of a farm to produce the maximum feasible output from a given set of inputs or (from other point of view) to use minimum feasible inputs to produce a given level of output. On the basis of chosen definition, the approach of the DEA models can be input or output oriented. In our case we choose input oriented which maintains the production while minimizing the use of resources. Efficiency score than tells how efficiently can each DMU use the production factor (capital, labour, land) to produce certain amount of production. BCC model named after Banker, Charnes and Cooper (Banker et al., 1984) that assumed variable returns to scale was estimated in a form (1)

$$\begin{aligned}
&\min h_0 \\
&\text{subject to} \\
&\sum_j x_{ij}\lambda_j \le h_o x_{io}, \forall i \\
&\sum_j x_{rj}\lambda_j \le y_{ro}, \forall r \\
&\sum_j \lambda_j = 1 \qquad \lambda_j \ge 0, \forall j \qquad h_o \in \Re
\end{aligned} \tag{1}$$

where $x_{ij}$ is the input $i$ of DMU $j$, and $y_{rj}$ is the output $r$ of DMU $j$. The model seeks to minimize $h_o$, which is the proportional decrease of the inputs and represents the efficiency of DMU$_o$. First constraint ensures that the decrease of the inputs is limited by the efficiency frontier, where $\lambda_j$ is the contribution intensity of benchmark $j$ for the target of DMU$_o$. Second constraint states that the outputs of DMU$_o$ is limited by the efficiency frontier. Sum of $\lambda_j$ is equal to 1 that secures that the DMUs are compared with similar DMUs in scale and size and guarantees variable returns to scale. Other constraints characterize the nature of the decision variables (Rebolledo-Leiva et al., 2019). The calculation is done for every DMU $j$–agricultural holding.

As a result of this DEA calculation, the efficiency scores for all DMUs are obtained ($h_j$ for all DMU $j$). It enables to identify as well as the identification of benchmarks (best-practices) and the targets for the operational inputs used in the assessment. The model enables to calculate technical efficiency (TE – under constant returns to scale), pure technical efficiency (PTE – under variable to returns to scale) and scale efficiency (SE) as the division of those two (2).

$$SE = \frac{TE}{PTE} \tag{2}$$

Accounting data were obtained from Albertina database and data about acreage from Land Parcel Information System (LPIS). Outputs of production function were sales ($y_1$) and total revenues ($y_2$) in thousand CZK. Inputs were consumption of material and energy ($x_1$), external resources ($x_2$) in thousand CZK, number of employees ($x_3$), and agricultural land ($x_4$) in ha. There were three groups of agricultural holdings according to their size: "small" (up to 500 ha), "medium" (501–1,000 ha) and "large" (over 1,001 ha). There were 562 observations – agricultural holdings – for year 2014. To ensure homogeneity of the DMUs (because DEA is sensitive to outliers), only farms with sales between 50 to 100 million CZK were included in a sample. The description of the output and input variable is displayed in Table 1.

Table 1. Descriptive characteristics of the sample (thousands of CZK)

| | **Whole sample** | | | **Small** | | | **Medium** | | | **Large** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Obs. (nr.)** | 562 | | | 122 | | | 249 | | | 191 | | |
| **Char.** | **mean** | **min** | **max** | **mean** | **min** | **max** | **mean** | **min** | **max** | **mean** | **min** | **max** |
| $y_1$ | 26,907 | 10,007 | 49,971 | 19,921 | 10,030 | 49971 | 24,881 | 10229 | 49,767 | 34,010 | 10,007 | 49,969 |
| $y_2$ | 40,126 | 8,894 | 108,928 | 25,849 | 8,894 | 61199 | 35,936 | 10453 | 98,916 | 54,708 | 21,722 | 108,928 |
| $x_1$ | 14,439 | 305 | 39,920 | 7,997 | 305 | 32586 | 13,092 | 1373 | 30,014 | 20,309 | 3,025 | 39,920 |
| $x_2$ | 28,912 | 141 | 336,072 | 16,769 | 141 | 203623 | 28,066 | 439 | 336,072 | 37,770 | 2,733 | 190,363 |
| $x_3$ | 20 | 1 | 72 | 13 | 1 | 52 | 17 | 1 | 60 | 29 | 1 | 72 |
| $x_4$ | 855 | 1 | 4,081 | 231 | 1 | 497 | 750 | 504 | 1,000 | 1,391 | 1,003 | 4,083 |

*Source: Albertina database, 2014; LPIS, 2014; own calculations, 2019*

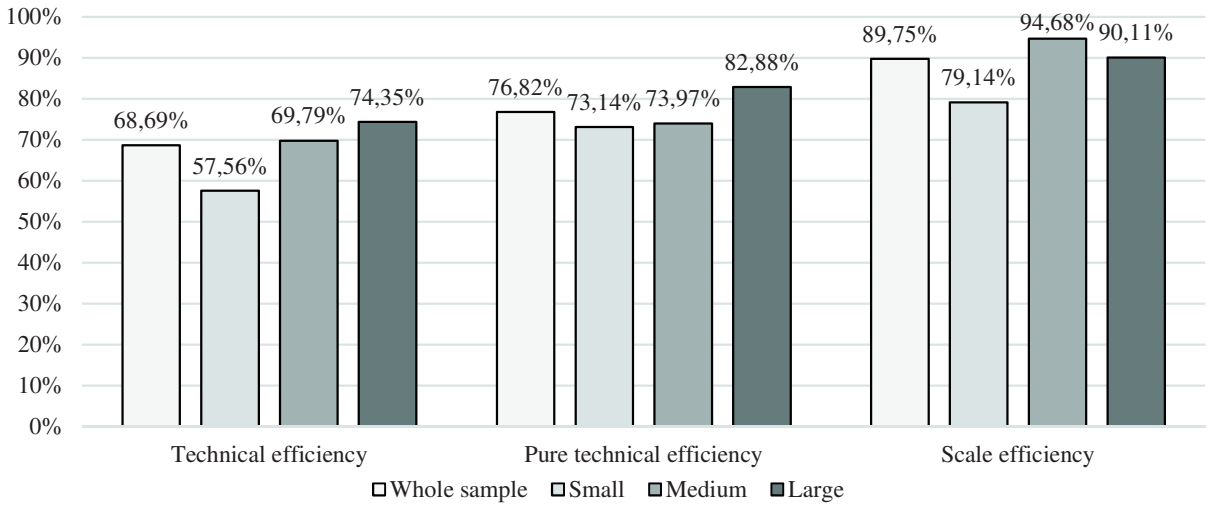
It can be seen, naturally, that the large group has the highest average sales, revenues, energy consumption, number of employees and acreage – all values are above average of the whole sample. The weight of the large companies is so significant that the values of middle and small farms are below average of the whole sample. As technical, pure technical and scale efficiency are not normally distributed, the differences among different size groups were tested by non-parametric Kruskall-Wallis equality-of-populations rank test. Null hypothesis assumes equality.

## 3. Results and Discussion

The results of calculation for the whole sample and each size group are displayed in Figure 1. Under constant returns to scale, the DMU in a sample were efficient from 68.69%. Pure technical efficiency under variable returns to scale was higher (76.82%) as there were more 100% technically efficient unit. It is a nature of the BCC model as the envelope under variable returns to scale includes more units. It is due to the shape of envelope of the data. While under variable returns to scale it is conical, in BCC model it changes on convex and include more units to the frontier (Pechrová, 2014). While there are 16 100% efficient DMU under constant returns to scale, there are already 46 of them in the second model. 100% scale efficient firms are only those which are both, technical and pure technically 100% efficient. Hence, there are 16 of them.

The most technically efficient were according to expectations large farms (from 74.35%), then medium (69.79%) and small (57.56%). Similarly, the highest pure efficiency of production was noted in large farms (82.88%). Pure efficiency in middle farms (73.97%) and in small farms (73.14%) was almost similar. Regarding the scale efficiency, middle farms were the best with 94.68%. Surprisingly large farms were efficient only from 90.11%. Small farms had again the lowest scale efficiency (79.14%).

Figure 1. Comparison of technical, pure technical and scale efficiency of the whole sample, small, middle and large agricultural holdings




*Source: Own calculations, 2019*

Testing by Kruskall-Wallis test revealed that differences were statistically significant. There were also the most 100% technically efficient firms in category of "large" farms (8 farms 100% technically efficient, 26 100% pure technically efficient and 8 100% scale efficient).

Theoretical assumption about higher technical and pure technical efficiency of larger companies and agricultural holdings was confirmed by our study. In all cases the probability that the populations are equal was close to zero (p-value = 0.0001). However, scale efficiency was higher in middle-sized firms than in large companies. It might be due to the fact that there were the most farms exhibiting decreasing returns to scale in "large" category, so the scale of their operation is above optimum.

Our findings are in line with Adhikari and Bjorndal (2012) who examined technical inefficiency in Nepalese agriculture. They also observed decreasing returns to scale in a category of large

holdings. “Among the three farm sizes in the data set, medium size farmers achieve a higher technical efficiency than large and small farm sizes, suggesting that productive efficiency can be increased with the encouragement of creating medium size holdings” (Adhikari and Bjorndal, 2012). They suggested that productivity gains could be achieved by breaking up of large farms into small family farms. That solution would not be possible in Czech agriculture due to different size and ownership structure. The core of agricultural production is concentrated within the group of large agricultural holdings, which farm almost two thirds of the agricultural land of the Czech Republic and account for 76% of the total number of livestock (in livestock units) (Czech Statistical Office, 2018).

For the Czech case would be more relevant the research of Ren et al. (2019) who analysed the characteristics that would improve the performance of Chinese agricultural holdings. They found out that increasing farm size has a positive impact on farmer's net profit, as well as economic, technical and labour efficiency. It might be due to the fact that at larger farms it is easier to adopt new technologies and more time and money can be spent on the pursuit of agricultural knowledge. According to Hu et al. (2019), farmers with larger farms can pay more attention to productive technology rather than processing technology. From their regional analysis they found out that “it seems the regions with larger farms have a much higher technology progress rate overall, and while the effect varies depending on scale, there are remarkably positive impacts in large-farm regions, slightly negative impacts in medium-sized farm regions, and notable negative impact in small-farm regions” (Hu et al., 2019). Similarly, research of Kirner and Bartel-Kratochvil (2007) shows that bigger holdings obtained a higher income from agriculture and forestry than smaller holdings. Hence, the size of the holding seems that clearly have positive effect on its economy. However, the attention must be paid to the optimal size and scale.

## 4. Conclusion

The aim was to find out whether the size of the agricultural holding measured in terms of the acreage of agricultural land influence the technical and scale efficiency of the farm. A non-parametric Data Envelopment Analysis was used to calculate the efficiency and Kruskal-Wallis test to assess the differences among different size groups. The most technically efficient were according to expectations large farms (from 74.35%), then medium (69.79%) and small (57.56%). Similarly, the highest pure efficiency of production was noted in large farms (82.88%). Pure efficiency in middle farms (73.97%) and in small farms (73.14%) was almost similar. Regarding the scale efficiency, middle farms were the best with 94.68%. Surprisingly large farms were efficient only from 90.11%. Small farms had again the lowest scale efficiency (79.14%). All differences were statistically significant. There were also the most 100% technically efficient firms in category of “large” farms (8 farms 100% technically efficient, 26 100% pure technically efficient and 8 100% scale efficient).

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The challenge for future research is to examine in detail the determinants of technical efficiency, especially subsidies, which are important for agricultural holdings and ensures higher income or viability of the farms.

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