THESISES OF THE DOCTORAL (PhD) DISSERTATION

EXPLORING THE FACTORS CAUSING THE INCREASE AND DECLINE OF RAPESEED PRODUCTION IN HUNGARY THROUGH THE EXAMINATION OF NATURAL AND ECONOMIC EFFICIENCY

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1. INTRODUCTION OF THE TOPICS AND OBJECTIVE

In Hungary, rapeseed is ranked among the most important arable crops along with wheat, corn, and sunflower. The significance of this is demonstrated by the fact that the harvested area of rapeseed almost doubled (HCSO, 2023a), while its yield increased by two and a half times between 2012 and 2018 (HCSO, 2023b). Thus, this period can be called the rising phase of rapeseed production. From more than 330,000 hectares, a record volume was harvested in 2018, but after that, a declining trend was observed. The harvested area of rapeseed decreased to 258 thousand hectares in 2021 and to 205 thousand hectares in 2022. The former was 22 percent lower and the latter 38 percent lower than in 2018 (HCSO, 2023a).

The period 2019-2021 is the declining period of rapeseed production in Hungary, with several reasons behind it. On the one hand, the ban on the use of seeds treated with neonicotinoids and the resulting increase in the plant protection risk, and on the other hand, climate change, increasingly frequent drought and lack of precipitation also play a role in the decrease of rapeseed production.

In Hungary, the average yield of rapeseed fell to 2.85 tons (-6%) per hectare in 2021 and 2.47 tons (-19%) in 2022 compared to 2018 (HCSO, 2023c). In 2021, the appearance of pests, spring frosts and lack of precipitation caused the decrease in specific yields (ECSEDINÉ WANEK et al., 2022), while in 2022, the lack of precipitation primarily explained the poor harvest, not only in Hungary but also in other countries of the Eastern Central European region (ECSEDINÉ WANEK et al., 2023).

When examining the foreign trade of rapeseed, the volume of imported rapeseed decreased by 31 thousand tons to 82 thousand tons, based on the average of the periods between 2012-2016 and 2017-2021. Looking the period 2012-2016, Slovakia, Romania and Ukraine were the major exporters of rapeseed to Hungary (86 thousand tons per year on average), while in the period 2017-2021 Romania, Croatia and Serbia became the major importers (64 thousand tons per year on average). In 2022, Ukraine (with 80 thousand tons) was the most significant rapeseed supplier of Hungary. The export volume of rapeseed increased by approximately 33 percent to 722 thousand tons, compared to the averages of 2012-2016 and 2017-2021. While Germany, Austria, and Slovakia (483 thousand tons per year on average) were among the most important target markets in the period 2012-2016, Germany, Austria, and Poland (640 thousand tons per year on average) became the major export markets in the period 2017-2021. In 2022, Austria (46 percent) was the most significant partner country in terms of export volume, with 7 percent more shipments from Hungary than to Germany in the same year (HCSO, 2024d).

In Hungary, the annual average producer price of rapeseed was 28 percent higher in 2021 than in 2012. In 2022, the price of rapeseed increased by 50 percent over the course of a year (AKI MPIS, 2023). This is due to the rise in world and EU crop prices, which can be attributed to several factors: in 2019 and 2020, the production volume of oilseeds and vegetable oils was lower than the market demand, which created a strong demand for available stocks. Due to the human health (curfew) restrictions imposed because of the coronavirus epidemic and the related logistical disruptions, the care and harvesting of oil palm plantations, which are crucial for biodiesel production, has become temporarily impossible (NURKHOIRY– OKTARINA, 2020). Another consequence of the coronavirus outbreak was the significant increase in the consumption of food oil by the population. In addition, China has drastically reduced the production of animal fats, which have thus become a shortage in the world market (AGROINFORM, 2021). Subsequently, in the midst of the global energy crisis unfolding due to the strong demand for energy products, the price of natural gas rose dramatically, leading to a rapid increase in fertilizer prices. The situation was further exacerbated by Russia's war against Ukraine. The temporary lack of navigability in the Black Sea caused a European and global shortage of sunflower oil (before the war, Ukraine was the world's leading exporter of sunflower oil), so in 2022 rapeseed oil became a substitute for sunflower oil (HASSEN– BILAI, 2022).

Research goals:

The aim of the research is to reveal the factors causing the rise and then decline of rapeseed production in Hungary through the analysis of natural and economic efficiency for the period 2012-2022.

Research questions

- **Q1**: How did the cost-income situation and profitability of rapeseed producing plants at sectoral level develop during the years 2012-2022? What is the income-generating capacity and profitability of the rapeseed sector compared to the sunflower, wheat, and maize sectors? How did the sectoral technical efficiency of rapeseed producing plants develop on an annual average (in nominal terms) and at different sectoral scales between 2012 and 2022?
- **Q2**: How did the cost-income situation and profitability of rapeseed producing plants develop over the 2012-2021 period (based on deflated data)? What factors have affected the income generating capacity of rapeseed producing plants at the sectoral level?
- **Q3**: How does the level of fertilizer use, and land quality (goldcrown value) affect the gross income per hectare and direct cost-proportional profitability of rapeseed producing plants at sectoral level? How does the sectoral cost of pesticides affect gross income per hectare and direct cost-proportional profitability?
- **Q4**: How did the average technical efficiency of the rapeseed sector develop in the 2012-2021 period, especially during its rising (2012-2018) and declining (2019-2021) phases? Which factors determined the technical efficiency of the rapeseed sector in the rising and declining stages?
- **Q5:** Is there a difference in the technical efficiency of the rapeseed sector for each large region in Hungary?
- **Q6**: How did the plant- and rapeseed sectoral concentration of rapeseed farms develop during the examined period?

In the Q1 and subsequent research questions, I indicated a different time horizon. This was based on the following professional and methodological considerations. In the period 2012-2022, I analyze the sectoral cost-income situation, profitability and technical efficiency of rapeseed producing plants on an annual basis (using nominal data), considering the economic and environmental factors of the given year. Then, narrowing this wider period to 2012-2021, I examine the cost-income situation and profitability and technical efficiency of domestic rapeseed production in a relatively more even, homogeneous ten-year period (analyzing deflated data). From this point of view, the year 2022 – due to extreme economic and environmental conditions – would have greatly distorted the results. Based on the data of the deflated 2012-2021 period, I will compare the factors affecting the rising (2012-2018 period) and declining (2019-2021 period) stages of rapeseed production in Hungary through the examination of natural and economic efficiency.

Hypotheses

H1: The sectoral technical efficiency of rapeseed producing plants was the most favorable in large scale farms between 2012 and 2022.

In order to determine my hypothesis related to research question 1 (Q1), I started from the following relationships:

BARANYAI – TAKÁCS (2006, 139.p) formulated the relationships between efficiency and plant size as follows: *"It is clear that the efficiency of farming improves with the increase in plant size."*. According to SZŰCS (2021), farms with larger production areas can carry out agriculture more efficiently with more modern power and machinery with higher performance, because of which the costs per hectare of production area will also be lower. Technical efficiency was highest between 2001 and 2013 for agricultural holdings with large farm sizes (expressed in Standard Production Value) (TÓTH, 2015).

I believe that the above may also apply to a particular sector (in this case, the rapeseed sector) of agriculture holdings, including arable crop producing plants. The scale efficiency of rapeseed producers with larger rapeseed areas can also be confirmed by their sectoral technical efficiency.

H2: Compared to all other factors, the sectoral income generating capacity of rapeseed producing plants was most affected by the yield development in the period 2012-2021.

To determine my hypothesis related to research question 2 (Q2), I started from the following relationships:

The specific yield of rapeseed was fluctuating between 2012 and 2021 (HCSO, 2023c), which may be mainly due to fluctuating weather conditions (frost, drought). According to KISS (2012), based on the pessimistic (1.5 t/ha) and optimistic (3.5 t/ha) sensitivity analysis of yield averages, the income-generating capacity of rapeseed production (based on the unsubsidized contribution margin) can be excessively extreme at real prices (-16.4 thousand HUF/ha – 232.4 thousand HUF/ha). In terms of crop safety, according to a questionnaire survey conducted among farmers in Hajdú-Bihar County, rapeseed ranked fourth among the main field crops (CSATÁRI, 2009).

In my opinion, the statements above support that the yield of rapeseed can have a significant impact on the income-generating capacity of rapeseed production.

H3: In rapeseed producing plants, the direct cost-proportional profitability was most favorable in case of local conditions with high goldcrown value and medium fertilizer use.

In order to determine my hypothesis related to research question 3 (Q3), I started from the following relationships:

During crop production, special attention should be paid to the proper use of each input. One of these factors is the quality of the land, which is still tied to the goldcrown value today (NAÁRNÉ TÓTH et al., 2016; POSTA et al., 2023).

In addition to pesticides, fertilizers are also a determining input in yield safety. The latter is applied in an appropriate amount – after soil test is carried out – considering soil conditions (e.g. soil type, humus content, PH value) (EŐRI, 2001). In addition, the principle of decreasing yield (Gossen's 1st law) draws attention to the determination of the appropriate additional expenditures, because after the inflection point of the production function (marginal yield maximum), although the yield increases with the increase in expenditure, but at a lower rate than before. When the marginal yield is zero, the yield is at its maximum. Thus, after that, the additional expenditure results in a negative marginal yield, which is associated with a decrease in yield. A decline in the level of yield can lead to lower sales, which can lead to a deterioration in income productivity (STEINHAUSER, 1984).

Considering the rational use of fertilizers in accordance with the soil conditions and the relationship between yield and input, it can be assumed that it is sufficient to apply a medium level of fertilizer on rapeseed areas with high goldcrown value, the effect of which is also confirmed in profitability.

H4: The sectoral technical efficiency of rapeseed producing plants was higher in the booming phase (2012-2018) than in the declining phase (2019-2021).

In order to determine my hypothesis related to research question 4 (Q4), I started from the following relationships:

FELKAI et al. (2013) performed different types of efficiency reserve calculations for the main crop production sectors in Hungary (wheat, maize, rapeseed, sunflower, barley) based on annual data from 2005 and 2010, from which it can be concluded that the technical efficiency of rapeseed producing plants changed from 58 percent to 49 percent from 2005 to 2010, which showed a declining trend.

Since the harvested area of rapeseed decreased from 331 thousand hectares to 258 thousand hectares, and with this, the production volume decreased by 27 percent to 500 thousand tons from 2018 to 2021 in Hungary (HCSO, 2023a; HCSO, 2023b), it is believed that the technical efficiency of the sector may have decreased in the declining phase (2019-2021 period) compared to the rising phase (2012-2018 period).

H5: The sectoral technical efficiency of rapeseed producing plants in the Transdanubia statistical large region is better than that of farms in the Great Plain and North statistical large region.

To determine my hypothesis related to research question 5 (Q5), I started from the following relationships:

Compared to other regions, natural conditions (such as humidity, precipitation, temperature, soil type) are more favorable for the cultivation of rapeseed in the Transdanubia regions (MÁTHÉ, 1996; EŐRI, 2001; ERTSEY et al., 2003; ANTAL et al., 2005). Within this, places of rapeseed production with prominent production features can be found in Győr-Moson-Sopron, Zala and Vas counties (EŐRI, 2001; APÁTI – SZŐLLŐSI, 2018). According to the data of the Hungarian Central Statistical Office, Győr-Moson-Sopron and Zala counties had the highest yield in terms of the average of the 2012-2021 period. However, the specific yield was no longer highest in these counties based on the average of the examined period. The most favorable average yield was observed in Baranya and Tolna counties (HCSO, 2023d).

In my opinion, based on the above, the technical efficiency of the rapeseed sector is probably better due to the more favorable climatic conditions to produce rapeseed in the Transdanubia statistical large region.

H6a: Field crop producing plants engaged in rapeseed production had a medium concentration in the rape sector between 2012 and 2022.

H6b: The concentration of rapeseed producing plants in Hungary has increased regarding the rapeseed sector in the last ten years (2012-2022).

In order to determine my hypotheses related to research question 6 (Q6), I started from the following contexts:

Based on previous studies (ERDŐS – SZŐLLŐSI, 2022; ERDŐS – SZŐLLŐSI, 2023), the concentration of arable crop producing plants in Hungary was moderate in 2015 and 2019 (ERDŐS– SZŐLLŐSI, 2022), according to net sales and balance sheet total. In addition, based on the size of arable land, there was no difference in the concentration of individual and social enterprises engaged in arable crop production in Hungary, it was at a medium level in 2018 and 2020 (ERDŐS – SZŐLLŐSI, 2023).

Since the concentration of arable crop producing holdings in Hungary was medium in 2018 and 2020, based on the size of the arable area, it can be assumed that the concentration level is similar in a given sector (in this case, the rapeseed sector).

There is a decline in rapeseed production in Hungary between 2019 and 2022 in terms of harvested area and yield, so in my opinion, it can be assumed that most of the area sown with rapeseed is oriented towards larger rapeseed producing farms.

2. MATERIAL AND METHODS

During my research work, I used secondary data both for the data presented in the literature review chapter and for the preparation of my own calculations. For my own calculations, I used various deterministic methods (descriptive statistical analysis, correlation analysis, group formation, regression analysis, DEA, Lorenz curve, Gini index).

2.1. Methodological background for the development of the rapeseed industry sample based on the Farm Accountancy Data Network (FADN) database

For my analysis, I used the Farm Accountancy Data Network (FADN) sector level data of the Institute of Agricultural Economics Nonprofit Ltd. (AKI). During the analysis, I have considered the farms that have grown rapeseed at least once in the examined period, however, due to the simplification and smoother wording, I will call these enterprises as rapeseed producers or rapeseed producing plants when interpreting the results.

The research begins with an analysis of the period 2012-2022 on an annual basis, taking into account the extreme economic and environmental conditions in 2022 (volatile prices at the global level, the Russian-Ukrainian war and extremely unfavorable weather conditions). Subsequently, I examined each relationship based on the aggregated data of the given period. However, for this, it is essential that the data can be combined, so I deflated them in accordance with the 2012 price level. The data for 2022 would have distorted the aggregation due to extreme drought and economic conditions, so I excluded it from the analysis and narrowed the database to the period of 2012-2021.

The steps to design a sample related to the nominal and deflated database were as follows:

- In the case of wage costs, I applied standardization. Since I did not have the average wage cost per working hour in the years 2012-2017, I made an additional calculation in this regard. From the ratio of the wage costs of regular employees to the number of working hours, I formed an average wage cost per working hour (in the period 2012-2017) for the reference population. Subsequently, in the period 2018-2022, I calculated the average wage (HUF/hour) without sectoral contribution already available in the database, and then multiplied it by the total number of working hours of the sampled plants. This avoids the impact of significant wage cost differences between family farms and company farms. Thus, all the plants examined had the same wage level.

- Plants using 100% foreign machine services (those that do not have their own fleet of machines) were excluded from the sample. I assumed that it should have at least a minimum machinery costs for the given plant and focus on commodity production. The cost of machinery includes the cost of diesel, lubricants, maintenance, and repair.
- Plants with a 0 HUF fertilizer and/or pesticide costs were also excluded. Rapeseed is a nutrient-intensive arable crop with high sensitivity to plant protection, inevitably grown with some fertilizer and pesticide inputs.
- Outliers for each variable (seed, fertilizer and pesticide costs, personnel costs, costs of foreign machine services + machinery costs, goldcrown value, yield value, yield, gross income) were filtered out based on the boxplot. The boxplot illustrates the outliers graphically (SAJTOS– MITEV, 2007; FIELD, 2009).

After considering the above described, the number of sample items varied between 127-212 in each year. I defined the sector size categories based on the quartile function. Accordingly, the limit for the third quarter became 70 hectares. The two sectoral size categories thus established are as follows: holdings under 70 hectares and holdings with a minimum of 70 hectares. Based on the above classification, three-quarters of the sample belongs to those below 70 hectares, while the top quarter belongs to those above 70 hectares. The classification into statistical large region was carried out according to the headquarters of the plants specified in the Farm Accountancy Data Network database (Great Plain and North, Transdanubia and Central Hungary). Since the Central Hungarian statistical large region had a low number of elements on an annual basis, I ignored this in my analysis and focused on comparing the two major regions (Great Plain and North, and Transdanubia).

2.2. Analysis background of the income generating capacity and profitability of the rapeseed sector

For the annual analysis of the rapeseed sector, I used the data with nominal values between 2012-2022, because this allowed me to compare the different years independently of each other, taking into account the economic and environmental conditions of the given year. At the same time, to be able to homogenize, process and evaluate the data of a longer time series (a ten-year period) similar to the work of – FELKAI et al. (2013) KOVÁCS (2016) and ZUBOR-NEMES (2021), I used deflated data and narrowed the examined period to the years of 2012-2021. Based on the deflated and aggregated database, I prepared a descriptive statistical analysis (minimum, median, weighted average, weighted standard deviation, relative standard deviation, maximum) to analyze the cost-income situation of the entire sample containing 2,446 rapeseed producing plants in the ten-year period examined. Similar to the work of SZABÓ (2024), I determined the averages by unit of area (rapeseed sowing area) and by the total amount produced as well. I used the gross income per hectare for the assessment of income-generating capacity, while I applied the direct-cost-proportional-profitability and the revenue-proportional-profitability indicators for the assessment of profitability. The gross income I calculated is a broader category of results, in which I did not consider overhead costs and calculated with revenue instead of production value. Therefore, the gross income per hectare I calculated is to be interpreted without subsidies. In my analysis, by gross income I mean the difference between sales revenue and direct production cost (*Table 1*). From the point of view of the efficiency analysis, it would be considered distorting factors if the land rent and depreciation were included in the direct costs, so I mean the direct production cost without these cost items. The land rental fee is considered a distorting factor because while individual farmers can be landowners, corporate businesses can only rent the land. Since the examined companies may use different methods to determine their depreciation, it would affect the development of their economic efficiency. This is supported by the statement of SZŰCS – SZŐLLŐSI (2007:53): *"The economic content of depreciation is a category independent of efficiency, the size of which is determined by the properties of fixed assets and various official provisions."*

Table 1: Indicators used in the calculations

Description	**Method of calculation**
Income productivity *(HUF/ha)*	
Gross income (HUF/ha)	Revenue - Direct production cost (excluding land rent costs and depreciation)
Profitability *(%)*	
Direct-cost-proportional-profitability (%)	$\frac{Gross\ income}{Total\ direct\ costs} \times 100$
Operating return on sales (%)	$\frac{Gross\ income}{Sales\ revenue} \times 100$

Source: created by the author

Subsequently, I examined what relationships the calculated indicators might show with the natural and economic data, for which I used Spearman's rank correlation analysis. This correlation analysis has also been used in many field crop production related literature (LECHENET et al., 2017; MAESTRINI – BASSO, 2018; FAN et al., 2020; LAM et al., 2021). Another advantage of this method is that variables do not need to have a normal distribution (FIELD, 2009).

2.3. Methodological background of the nutrient supply impact assessment of the rapeseed sector

As a result of the rank correlation, from the input side, I selected two natural indicators (goldcrown value and fertilizer use) as grouping criteria, which had a significant relationship with income generating and profitability. Within the frames of this analysis, I sought to find out how the soil condition characterized by the goldcrown value, and the specific fertilizer use affect the income generating capacity and profitability of rapeseed production.

Along the yield-expenditure (fertilizer use) relationship, I examined how yield develops for arable soils with low, medium, and high goldcrown value. Using the percentile function, I determined the boundaries between each level and thus formed groups of nearly the same size, similar to the work of PESTI et al. (2010). Based on the limit values of this function, I formed three groups with similar numbers. As a result, plants with an average value of less than 19 goldcrowns per hectare were included in the low goldcrown group. In comparison, I classified in the medium goldcrown group farms with production areas of 19 goldcrowns or higher but less than 24 goldcrowns per hectare. The high goldcrown group included plants characterized by a rapeseed area with a value of at least 24 goldcrowns per hectare.

I determined the yield development along different fertilizer use intervals (class intervals). However, I determined the average yield and marginal yield for the given class, and I also paid special attention to the development of gross income and profitability. The average yield is the ratio of the total yield and total expenditure of the plants in each class, while the marginal yield expresses the change in the additional fertilizer use and yield between each class. As an illustration of the relationship between yield and fertilizer use, I also defined the production functions for soils with different goldcrown values.

For the nutrient supply analysis, I formed nine separate groups based on the goldcrown value and the levels of specific fertilizer use (low, medium, high) (*Table 2*) in order to determine the effect of taking soil quality and input increase together on income generating and profitability.

When grouped according to the amount of fertilizer use, low fertilizer use plants were those that applied less than 171 kilograms of fertilizer per hectare to their rapeseed area, while medium category plants were those that applied more than 171 kilograms but less than 245 kilograms per hectare. In the high fertilizer use category, I classified farms that used at least 245 kilograms of fertilizer per hectare.

For the nine separate groups formed in this way, I examined the weighted average of the determining cost items, the goldcrown value, fertilizer use, gross income, direct cost-proportional profitability, and revenue-proportional profitability indicator. After that, I determined in which group the income-generating ability and profitability developed the most favorably (highest value). I examined whether there was a statistically verifiable difference between the groups. For this, I used the Kruskal-Wallis test, which is a non-parametric statistical method and provides the opportunity to compare several groups at the same time with the non-normal distribution of variables (FIELD, 2009). Kruskal-Wallis is also suitable for comparing two groups (KRUSKAL – WALLIS, 1952).

Table 2: Groups of plants with different production conditions and different expenditure levels

Plant group code	**Goldcrown Value** *(GC/ha)*	**Fertilizer use** *(kg/ha)*
11	low	low
12	low	medium
13	low	high
21	medium	low
22	medium	medium
23	medium	high
31	high	low
32	high	medium
33	high	high

Source: created by the author based on FADN data

2.4. Methodological background of the plant protection impact assessment in the rapeseed sector

Since in addition to the cost of fertilizers, the cost of pesticides is the other most significant expenditure in terms of monetary value during rapeseed production, I divided this cost item into distinct levels using the percentile function – like what was described in the nutrient impact assessment (at the 2012 price level). Accordingly, the group with low pesticide costs included plants that spent less than 26,000 HUF per hectare on plant protection, while I classified in the medium level category agricultural holdings that spent 26,000 HUF or more but less than 43,000 HUF on pesticides. The category with high pesticide costs included plants with a pesticide cost of at least 43,000 HUF per hectare. Based on the data of the plants in each group, I determined the average values of their main production parameters, their average income generating capacity and profitability weighted by the rapeseed sowing area. In addition, I examined the production function based on yield and pesticide cost.

2.5. Methodological background of the impact assessment of the factors affecting the income-generating capacity of the rapeseed sector

To explore the factors affecting the income-generating capacity of the rapeseed sector, I used linear regression calculation. Using this, I sought to find out how both natural and economic data affect the development of gross income per hectare. For this approach, I first used univariate and then multivariate regression calculation, in which I determined gross income (HUF/ha) as a dependent variable, while yield (t/ha), goldcrown value (GC/ha), personnel costs (HUF/ha), machinery costs (HUF/ha) and fertilizer costs (HUF/ha) as independent variables.

In the multivariate regression analysis, I used the forward method, which during the calculation inserts the given variable into the model individually depending on its contribution to the *"explained variance"*. Accordingly, three independent variables (yield, machinery costs, personnel costs) were included. To determine which of the factors had a greater effect on income change, I considered ß as a relative weight, which made the effect of each variable on income generating ability comparable (SAJTOS – MITEV, 2007).

2.6. Methodological background for sectoral technical effectiveness analysis of rapeseed producing plants

To examine the technical efficiency of the sector, I used the DEA (Data Envelopment Analysis) method (relative efficiency analysis). DEA is a non-parametric statistical method that compares the efficiency of so-called “organizational units” (DMUs[1]) through linear programming. For my calculations, I used the BOGETOFT-OTTO (2022) benchmarking approach used within the “R” program. Benchmark plants are positioned at the boundary line of the pavement curve (cutting edge) and have 100 percent industry technical efficiency. The technical efficiency of the other plants is reflected in their lagging behind the parameters of these plants.

According to the findings of MORADI et al. (2018) and TOMA et al. (2015) – that input factors can be influenced more than outputs in agriculture – I decided to adopt an input-oriented approach when applying the DEA. The studies of LUIK et al. (2009) and FELKAI et al. (2013) were also conducted on a similar principle. The essence of input-oriented relative efficiency assessment is to use the lowest possible resource to achieve an existing output level (TOMA et al., 2015; NOWAK et al., 2015; TAMÁS – KOLTAI, 2020).

The input-oriented model can be written as follows (KOLTAI (2023) cit. BANKERS et al. (1984)):

$$\begin{gathered} Min\ (\theta) \\ \text{Output: } Y\lambda \geq Y_0 \\ \text{Input: } X\lambda \leq \ \theta X_0 \\ \text{Normalization: } e\lambda = 1 \\ \lambda \geq 0 \end{gathered}$$

Based on the equation above, θBBC[2] stands for efficiency λ and DMU stands for dual variable.

The variables used in my calculation were determined similar to the Chinese rapeseed production study of LI — WANG (2022). The input data include the specific seed, fertilizer and pesticide costs, personnel costs, machinery costs (including the costs of foreign mechanical services) of rapeseed producing plants. Contrary to the work of LI — WANG

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[1] Decision Making Unit: Koltai (2023) also calls organizational units "decision-making units" or DMU due to the initials of the English name.

[2] BCC is an abbreviation of the initials of Bankers, Charnes, and Cooper.

(2022), I also included the average goldcrown value expressing soil condition in the model. For the output data, I considered the specific sales revenue and yield. If an income category (such as gross income) would have been used in the modeling, it would have violated one of the DEA's restrictive conditions, non-negativity, as this method cannot manage numbers less than zero. Although it would be logical to include the rapeseed area as input data, but since the other variables are included as specific values (HUF/ha; GC/ha; t/ha) in the model, the rapeseed area (hectare) interpreted as an absolute value would mislead the result (KOLTAI, 2023).

I also compared the average technical efficiency of the sample on an annual basis (2012-2022) by classifying it into two sectoral size categories (below 70 hectares or 70 hectares and above), for which the database interpreted at nominal value was used.

The sectoral technical efficiency was also examined throughout the period 2012-2021 (through a deflated database). Subsequently, in connection with my hypotheses, I also analyzed the technical efficiency of the rising phase of rapeseed production (2012-2018 period) and of the declining phase (2019-2021). To explore the factors affecting the technical efficiency of each section, correlation analysis and univariate and multivariate regression calculation were used.

I also analyzed the technical efficiency of the rapeseed sector of rapeseed producing plants in each statistical large region (through a deflated database) for the period 2012-2021, as well as for the rising and declining stages. Kruskal-Wallis test was used for the statistical examination of the differences, because it is also suitable for comparing two samples (KRUSKAL – WALLIS, 1952).

2.7. Methodological background for plant and sectoral concentration analysis of rapeseed producing farms

To determine the concentration of rapeseed producing plants, I examined the database of the Hungarian State Treasury (MÁK) used by AKI based on 2012, 2018, 2021 and 2022 data. The Farm Accountancy Data Network database characterized by the optimal Neyman allocation selection principle cannot be used due to this sapling method. Rapeseed producing holdings with arable land under 10 hectares were excluded because the purpose of the analysis was to assess the concentration of commodity-producing holdings. To determine the degree of concentration – like SZABÓ's (2017) dissertation – I used the Lorenz curve (HUNYADI– VITA, 2008) and the Gini index (HORVÁTH – KOPÁNYI, 2004). The value of the latter can vary between 0 and 1. It takes a value of 0 if there is perfect equality, and a value of 1 if there is absolute inequality.

The Gini index can be calculated as follows (WEISSTEIN, 2023):

$$G = \frac{\sum_i \sum_j \left| y_i - y_j \right|}{2n \sum_{i=1}^{n} y_i}$$

where n is the number of the companies, y represents the size of the company, i means the ith company in the rank and j is the ith company after the ith company

The presentation of the methodological background of the dissertation in a complex way is summarized in *Table 3*.

Table 3: Complex presentation of the material and methodological background of the dissertation

Research Question	Subject of the analysis	Hypothesis	Applied method	Source and type of database
Q1	Sectoral cost-income situation and profitability analysis by year	-	Descriptive statistical analysis, detailed presentation of weighted averages	Farm Accountancy Data Network database, nominal (2012-2022, annual breakdown)
	Evolution of sectoral technical efficiency based on sample average and sectoral size categories	H1	DEA, correlation analysis,	
	Comparison of sectoral income generating capacity and profitability with the top 3 crops	-	Moving averages for five-year periods	
Q2	Analysis of the sectoral cost-income situation over the period 2012-2021	-	Descriptive statistical analysis, detailed presentation of weighted averages	Farm Accountancy Data Network database, deflated (2012-2021 period as a whole)
	Analysis of sectoral income generating capacity and profitability	-	Spearman rank correlation analysis	
	Examination of linear relationships affecting sectoral income generating capacity	H2	Univariate and multivariate regression calculation	
Q3	Effect of nutrient supply on sectoral income generating capacity and profitability	H3	Group training based on goldcrown value and fertilizer use	
	Effect of plant protection cost on sectoral income generating capacity and profitability	-	Group training based on pesticide cost	
Q4	Examination of sectoral technical efficiency	-	DEA, class interval examination	
	Correlation analysis of sectoral technical efficiency with natural and economic data	-	Spearman rank correlation analysis	
	Comparison of sectoral technical efficiency in the rising (2012-2018) and declining (2019-2021) phases	H4	DEA	
	Exploring the influencing factors of sectoral technical efficiency in the rising and declining phases	-	Univariate and multivariate regression calculation	
Q5	Comparison of sectoral income generating capacity and profitability in the studied statistical large regions	-	Spearman's rank correlation, Kruskal-Wallis test	
	Comparison of sectoral technical efficiency in the examined statistical large regions	H5	Spearman's rank correlation, Kruskal-Wallis test	
Q6	Analysis of concentration at sectoral and plant level	H6a and H6b	Lorenz curve, Gini index	Hungarian State Treasury (MÁK) database (2012, 2018, 2021, 2022)

Source: created by the author

3. MAIN FINDINGS OF THE DISSERTATION

Conclusions and suggestions that can be deduced from my results are defined in the structure of the research questions presented in the "Topic and Objective" chapter and answer them.

1. How did the cost-income situation and profitability of rapeseed producing plants at sectoral level develop during the years 2012-2022? What is the income-generating capacity and profitability of the rapeseed sector compared to the sunflower, wheat, and maize sectors? How did the sectoral technical efficiency of rapeseed producing plants develop on an annual average (in nominal terms) and at different sectoral scales between 2012 and 2022?

The cost-income situation of rapeseed producing farms – interpreted based on nominal data – was volatile between 2012 and 2022. In the years (2012, 2015 and 2022) when there was drought and rainfall deficit, the specific yield developed lower (2.5-2.7 t/ha) compared to the average of the ten-year period examined (3.27 t/ha). Although the weather conditions in 2013 were more balanced, the low sales prices due to oversupply led to the lowest specific income of the period examined. In years with exceptionally high average yields, in 2014 (3.32 t/ha) and 2016 (3.60 t/ha), the specific gross income was 145 thousand and 190 thousand HUF per hectare, respectively. However, it was not the highest income in the period under review. In 2021, the gross income was 237 thousand HUF per hectare, while in 2022 it was 297 thousand HUF per hectare. Behind the increase in the producer price in 2021 can be mentioned the lower supply of palm oil, the lack of animal fats, the increased residential use of vegetable oils due to the coronavirus epidemic, the impact of the energy crisis on fertilizer prices, and the lower amount of rapeseed harvested in Canada, as well as the strong demand for rapeseed oil. On the other hand, in 2022, drought, rainfall deficit, and sunflower seed shortages due to the Russian-Ukrainian war also caused a drastic increase in the producer price, which could have a greater impact on income than the increase in input prices. First costs ranged from 56,000 HUF to 139,000 HUF per ton for the period 2012-2022. In the declining phase, it was increased by 24 percent from 2019 to 2021 to 88,000 HUF, and then by 57 percent to 139,000 HUF in 2022 compared to 2021.

Comparing the income generating capacity and profitability of rapeseed producing plants with the main arable crops (wheat, maize, sunflower), it can be concluded that, based on the examined five-year moving averages, a gross income of 150,000 HUF per hectare was available, like the maize sector, which exceeded that of sunflower by 25,000 HUF and that of wheat by 56,000 HUF per hectare. In addition, despite the extreme economic and environmental conditions in 2022, rapeseed can be considered the second most profitable sector among the main crops. Among arable crop producing plants with a high proportion of cereals, it is worth including rapeseed into the crop rotation, because it can be ideal not only from an economic point of view, but also from a plant health and plant production point of view, even though it is one of the most nutrient-intensive sectors. In addition, the rapeseed sector is not characterized by special equipment needs, so the capacity utilization of the machines can be increased by integrating them into the structure of the cropping system.

The technical efficiency of rapeseed producing plants fluctuated in the range of 0.77-0.88 between 2012 and 2022 (*Figure 1*). The lower technical efficiency in 2015 and 2020 could be explained with a higher degree of heterogeneity between plants caused by negative natural and economic conditions.

Figure 1: Evolution of the sectoral technical efficiency of rapeseed producing plants by sample average and sectoral size categories (2012-2022)

Note: Calculations based on nominal database.

Source own calculation based on FADN sectoral data

The farms in the two sectoral size classes followed the trend of the sample, it can be statistically verified that technically efficient production can be achieved regardless of sectoral size (between 77 and 88 percent). Based on the Kruskal-Wallis test, there was no significant difference between the technical efficiency of rapeseed producers operating in the two sectoral sizes, and according to the correlation analysis, in the years (2014, 2016, 2022) when the technical efficiency of rapeseed producers farming at least 70 hectares exceeded the technical efficiency of smaller sectoral producers, there was no correlation between the rapeseed area and technical efficiency.

Based on the above results, I reject my H1 hypothesis (*The sectoral technical efficiency of rapeseed producing plants was the most favorable in large sector-sized farms between 2012-2022.*).

2. How did the cost-income situation and profitability of rapeseed producing plants develop over the 2012-2021 period (based on deflated data)? What factors have affected the income generating capacity of rapeseed producing plants at the sectoral level?

After examining the annual nominal data, I also examined the data through the 2012 price level. On average, rapeseed producers farmed on lands with 22 goldcrown value per hectare, and the average fertilizer use was 221 kilograms per hectare. As a result, with a yield average of 3 tons, interpreted at the 2012 price level, sales revenue of approximately 399 thousand HUF per hectare could be realized. The biggest cost item (32%) for farmers was fertilizer (~63 thousand HUF/ha). At the same time, the machinery costs (~48 thousand HUF/ha; 24%) and the costs of pesticides (~40 thousand HUF/ha; 20%) were also significant cost items. The total direct cost of rapeseed producing plants averaged 195,000 HUF per hectare between 2012 and 2021, based on deflated data for 2012. Domestic rapeseed production was profitable on average over the ten-year period examined. The average specific gross income per hectare was 204,000 HUF. Direct cost-proportional profitability and operating return on sales also developed positively. The former was close to 105 percent, while the latter was 51 percent in the period under review.

3.1. Exploring the factors affecting the income generating capacity of the rapeseed sector

In addition to natural data, I examined how certain economic data affect the development of gross income per hectare. This was first described with univariate linear models (*Table* 4).

Based on the Spearman rank correlation analysis, there is a strong, positive, statistically proven relationship (r=0.740, p=0.000) between income-generating capacity (gross income per hectare) and yield. In contrast, the same income category showed a weak positive statistically proven relationship with the goldcrown value (r=0.176; p=0.000). There is a weak negative significant relationship between income generating capacity and fertilizer costs (r= -0.070; p=0.001; personnel costs (r= -0.051; p=0.012) and machinery costs (r= -0.067; p=0.001). No correlation can be established between income generating capacity and seed cost and income generating capacity and pesticide cost.

Based on the results obtained, among the natural data, yield explains the income-generating ability to the greatest extent (52.6%). Increasing the specific yield by 0.1 tons increases the gross income per hectare by 8.8 thousand HUF. Compared to this, the other variables do not (fertilizer cost) or hardly affect the value of gross income (goldcrown value, personnel costs, machinery costs). The explanatory power of the latter is only 1.2-3.5 percent. If the goldcrown value is increased by one unit, the gross income is increased by 3,000 HUF. If personnel costs or machinery costs were a thousand HUF higher per hectare, gross income would decrease by 1.0-1.3 thousand HUF (Table 4).

I extended my analysis to include several variables (yield, machinery costs, personnel costs) together. The explanatory power of the linear model is 57.6 percent. Among the factors examined, yield (x_1) affects income generating capacity to a greater extent (ß= 0.743) than machinery costs (x_2; ß= -0.168) and personnel costs (x_3; ß=-0.123). The relative weight of the latter is negligible.

$$y=90.733x_1-1.235x_2-1.411x_3-39.110$$

Based on the calculations, an increase in yield by one unit increases the gross income per hectare by nearly 91 thousand HUF, while an increase in personnel costs and machinery costs by one unit reduces the gross income per hectare by 1.2-1.4 thousand HUF. In the ten-year period examined, the income-generating capacity was more affected by the development of yield (ß= 0.743) than, among others, the development of machinery costs (ß= -0.168) and personnel costs (ß=-0.123).

Based on the above, I consider my **H2** hypothesis *(Compared to all other factors, the sectoral income generating capacity of rapeseed producing plants was more affected by the yield development in the period 2012-2021)* as justified.

Table 4: Linear relationships between the income-generating capacity of the rapeseed sector and the factors affecting it

Dependent variable	**Independent variable (x_1)**	**R (Spearman)**	**p**	**R^2**	**F**	**p**	**Constant**	**x_1**
Gross income (thousand HUF/ha)	Yield (t/ha)	0.740	0.000	0.526	2711.247	0.000	-117.686	88.513
	Goldcrown Value (GC/ha)	0.176	0.000	0.035	87.716	0.000	76.475	3.042
	Personnel costs (thousand HUF/ha)	-0.501	0.012	0.012	30.077	0.000	165.343	-1.267
	Machinery costs (thousand HUF/ha)	-0.067	0.001	0.019	47.277	0.000	192.213	-1.012
	Fertilizer costs (thousand HUF/ha)	0.063	0.001	0.000	0.002	0.968	142.713	0.003

Note: Calculations based on a deflated database, referring to the 2012 price level.

Source own calculation based on FADN sectoral data

Examining the income productivity and profitability of rapeseed production, regardless of the price level effect, the cultivation of this crop is recommended in the future, regardless of yield development (2.5-3.6 t/ha) due to its profitable production and favorable profitability.

3. How does the level of fertilizer use, and land quality (goldcrown value) affect the gross income per hectare and direct cost-proportional profitability of rapeseed producing plants at sectoral level? How does the sectoral cost of pesticides affect gross income per hectare and direct cost-proportional profitability?

It can be stated that fertilizer proved to be the highest cost item within the cost structure of the plant group with 9 different input levels (in terms of goldcrown value and fertilizer use) included in the study. At the same time, by increasing the level of fertilizer use, other costs (pesticide costs and other direct costs) also increased. A different goldcrown values, but with the same level of fertilizer use, resulted in similar total direct costs. However, as the goldcrown value and the level of fertilizer use increased, so does the gross income per hectare.

The application of the same amount of fertilizer on individual croplands with different goldcrown values results in increasing income generating. By applying 300-349 kilograms of fertilizer to low goldcrown value arable lands, 198 thousand HUF gross income can be achieved, which is the highest income within the arable lands with the same level of goldcrown value. Compared to this, using 300-349 kilograms of fertilizer, a gross income of 210 thousand HUF could be achieved in arable land with a medium goldcrown value, and 225 thousand HUF could be achieved in arable land with a high goldcrown value. In contrast, the highest profitability was achieved on fields with low and medium goldcrown value fields with a fertilizer use of less than 50 kilograms, while on fields with high goldcrown with a fertilizer application of 50-99 kilograms per hectare. This draws attention to the rational use of fertilizer. Although the yield also increases with the increase in fertilizer use, in addition to the decrease in the average yield, the marginal yield shows that the application of additional amount of fertilizer does not always provide an additional yield. Therefore, at the micro level, each business should exercise due caution when determining the optimal fertilizer level.

Combining the direct cost-proportional profitability that can be achieved on average in arable lands with different goldcrown value, 92 percent can be achieved with a low goldcrown value field, 103 percent with a medium goldcrown value field, and 125 percent with a high goldcrown value field.

However, the highest direct cost-proportional profitability among the nine groups with different expenditure levels can be achieved on land with a high goldcrown value by applying few fertilizers (*Table 5*). In comparison, with 9 different soil conditions and fertilizer use levels examined, the highest income per hectare was achieved in areas with high goldcrown value and high fertilizer use. This is all based on the principle of diminishing returns (Gossen's 1st Law). Based on this law, with the continuous increase of an input factor, the yield begins to decrease beyond a certain point (KOPÁNYI et al., 2008).

Table 5: Development of the rapeseed sector's site conditions, fertilizer use, income generating capacity and profitability for croplands with different goldcrown value and fertilizer use levels (2012-2021)

Group codes	**Goldcrown Value** *(GC/ha)*	**Fertilizer use** *(kg/ha)*	**Yield** *t/ha*	**Average yield** *(kg/kg)*	**Marginal yield** (kg/kg)	**Gross income*** *(HUF/ha)*	**Direct cost-proportional income**** *(%)*	**Operating return on sales ***** *(%)*
11 (n=290)	15.96	117	2.43	20.77	-	155,655	95.75	48.91
12 (n=265)	15.35	209	2.81	13.44	-96.27	171,832	89.05	47.10
13 (n=230)	15.95	291	3.15	10.84	665.88	201,385	91.14	47.68
21 (n=253)	21.09	123	2.78	22.67	-36.95	193,574	117.35	53.99
22 (n=262)	21.53	207	2.98	14.38	14.38	198,367	104.38	51.07
23 (n=274)	21.04	301	3.24	10.75	10.75	194,608	87.87	46.77
31 (n=256)	27.98	120	2.89	24.08	153.48	226,042	**145.57**	**59.28**
32 (n=284)	27.86	209	3.15	15.04	15.04	229,823	122.46	55.05
33 (n=332)	27.98	305	3.46	11.37	66.68	**239,193**	107.98	51.92

Note: Calculations based on a deflated database, referring to the 2012 price level.
11=low goldcrown value + low fertilizer use; 12=low goldcrown value +medium fertilizer use;13=low goldcrown value + high fertilizer use; 21= medium goldcrown value + low fertilizer use; 22=medium goldcrown value +medium fertilizer use; 23=medium goldcrown value +high fertilizer use;31=high goldcrown value +low fertilizer use;32=high goldcrown value +medium fertilizer use; 33=high goldcrown value +high fertilizer use
**Excludes land rent costs and depreciation.*
***The ratio of gross income to direct costs, expressed as a percentage.*
**** Ratio of gross income to sales revenue, expressed as a percentage.*

Source: own calculation based on FADN sectoral data

Within the grouping with different levels of pesticide inputs, expressed in monetary value, rapeseed producers with high pesticide costs had the highest income generating capacity, while those with low pesticide costs had the best profitability (*Table* 6).

Table 6: Development of the main production parameters, income generating capacity and profitability of rapeseed producers with low, medium, and high pesticide costs over the period 2012-2021

Description	**Low pesticide costs**	**Medium pesticide costs**	**High pesticide costs**
Rapeseed area (HUF/ha)	41.85	57.36	81.15
Goldcrown Value (GC/ha)	21.96	22.00	22.35
Fertilizer use (kg/ha)	174.36	205.47	256.57
Yield (t/ha)	2.68	2.97	3.27
Average yield (kg/thousand HUF)	161.87	84.14	60.48
Marginal yield (kg/thousand HUF)	-	15.31	16.07
Gross income* (HUF/ha)	191,197	206,241	**209,542**
Direct cost-proportional profitability (%)**	**127.14**	112.41	93.07
Operating return on sales (%)***	**55.97**	52.92	48.21

Note: Calculations based on a deflated database, referring to the 2012 price level.
Low level= pesticide cost below HUF 26,000/ha; Medium level= pesticide cost above HUF 26,000 but below HUF 43,000/ha; High level= pesticide cost above HUF 43,000/ha
*Excludes land rent costs and depreciation.
***The ratio of gross income to direct costs, expressed as a percentage.*
**** Ratio of gross income to sales revenue, expressed as a percentage.*

Source: own calculation based on FADN sectoral data

Based on the above described, I do not accept my **H3** hypothesis *(In rapeseed producing plants, direct cost-proportional profitability was the most favorable in case of high golden crown value crop conditions and medium fertilizer use.)*.

Based on the calculated data, rational fertilizer use can be an important pillar of profitable rapeseed production, because it may be sufficient to apply a small amount of fertilizer on rapeseed areas with high goldcrown value, which can also contribute to more sustainable farming.

4. How did the average technical efficiency of the rapeseed sector develop in the 2012-2021 period, especially during its rising (2012-2018) and declining (2019-2021) phases? Which factors determined the technical efficiency of the rapeseed sector in the rising and declining stages?

The average technical efficiency of the rapeseed sectors in rapeseed producing plants was 70 percent over the period 2012-2021 (*Table 7*). Based on the class interval analysis, it can be concluded that the yields of rapeseed producers characterized by different technical efficiency vary. Farmers with a lower sectoral technical efficiency of 60-70 percent can harvest more than 3 tons of rapeseed per hectare, just like benchmark plants (best sectoral technical efficiency plants), the farms with the best sectoral technical efficiency.

Although income was not included in the DEA model, as a background variable, it can be concluded that the higher the income per hectare, the better the technical efficiency, and vice versa. The same relationship exists between technical efficiency and profitability indicators.

Breaking down the examined period into its rising (2012-2018) and declining (2019-2021) phases, it can be concluded that the sectoral technical efficiency was 71 percent in the rising phase and 67 percent in the declining phase (*Table* 7).

Table 7: Evolution of the average sectoral technical efficiency, income generating capacity and profitability of rapeseed producing plants in the examined periods

Name of the period	**Period**	**Gross income*** *(HUF/ha)*	**Direct-cost-proportional-profitability **** *(%)*	**Operating return on sales***** *(%)*	**Technical efficiency**
Entire period	2012-2021	204,298	109.58	47.01	0.7007
Rising phase	2012-2018	201,406	104.41	51.08	0.7118
Declining phase	2019 - 2021	211,405	105.87	51.43	0.6734

Note: Calculations based on a deflated database, referring to the 2012 price level.
**Excludes land rent costs and depreciation.*
***The ratio of gross income to direct costs, expressed as a percentage.*
**** Ratio of gross income to sales revenue, expressed as a percentage.*

Source: own calculation based on FADN sectoral data

Based on the ß values of the multivariate regression calculation, a total of 8 factors in the rising phase and 6 factors in the declining phase affected the technical efficiency of the plants. In the rising phase, the relative weight of yield, personnel costs, machinery, and seed costs had similar values (between 0.342 and 0.367). In contrast, in the declining stage, personnel costs alone were characterized by a higher relative weight (-0.433). In addition, the direct cost-proportional profitability was higher (0.378), while the relative weight of seed, pesticide and fertilizer costs was significantly reduced compared to the ß values of the rising phase. The Goldcrown Value was not included in the influencing factors in the declining phase. The high relative weight of personnel costs in the declining phase may draw attention to the existence of professional knowledge and skills. Due to the continuous development of agricultural technology, the use of increasingly modern precision tools can only provide additional income with appropriate expertise. For this reason, knowledge transfer can be a key factor, which includes close cooperation between producers, knowledge centers, professional organizations, innovative cultivation technology companies and research institutions.

Based on my conclusions explained above, I consider my **H4** hypothesis (*Sectoral technical efficiency of rapeseed producing plants was higher in the booming phase (2012-2018) than in the declining phase (2019-2021))* as justified.

5. Is there a difference in the technical efficiency of the rapeseed sector for each large region in Hungary?

Based on my calculations, the sectoral technical efficiency of the rapeseed producing plants in the Great Plain and North and Transdanubia statistical large regions was different throughout the 2012-2021 period. While the sectoral technical efficiency of producers in the Great Plain and North statistical large region was 71%, that of producers in the Transdanubia statistical large region was 69% (*Table 8*). Based on the Kruskal-Wallis test, the sectoral technical efficiency of rapeseed farms in these two statistical large regions are significantly different. The higher technical efficiency of rapeseed producers in the Great Plain and North statistical large region can be attributed to the fact that technical efficiency was significantly more closely related to fertilizer use (r= 0.483; p = 0.000), fertilizer costs (r = -0.219; p=0.000), pesticide costs (r= -0.473; p=0.000) and direct production costs (r= -0.611; p=0.000).

Table 8: Evolution of the sectoral technical efficiency of rapeseed producing plants in the Great Plain and North and Transdanubia statistical large regions over the period 2012-2021

Name of the period	Period	Great Plain and North	Transdanubia	Difference	Test Statistics	p
Entire period	2012-2021	0.7125	0.6896	0.0229*	34.933	0.000
Rising phase	2012-2018	0.7274	0.6982	0.0292*	39.728	0.000
Declining phase	2019 - 2021	0.6782	0.6675	0.0107	1.430	0.232

Note: Calculations based on a deflated database, referring to the 2012 price level.

Source: own calculation based on FADN sectoral data

Comparing the holdings engaged in rapeseed cultivation in the two statistical large regions, it can be concluded that rapeseed producers in the Great Plain and the North statistical large region had a lower yield (-0.37 t/ha) and lower income generating capacity (-35 thousand HUF/ha) during the period 2012-2021. However, in addition to lower yields, their production costs were also lower. Fertilizer costs were 21 percent lower; pesticide costs were 23 percent lower, and personnel costs were 12 percent lower in the Great Plain and North statistical large region than in the rapeseed sector of rapeseed producing farms in the Transdanubia statistical large region.

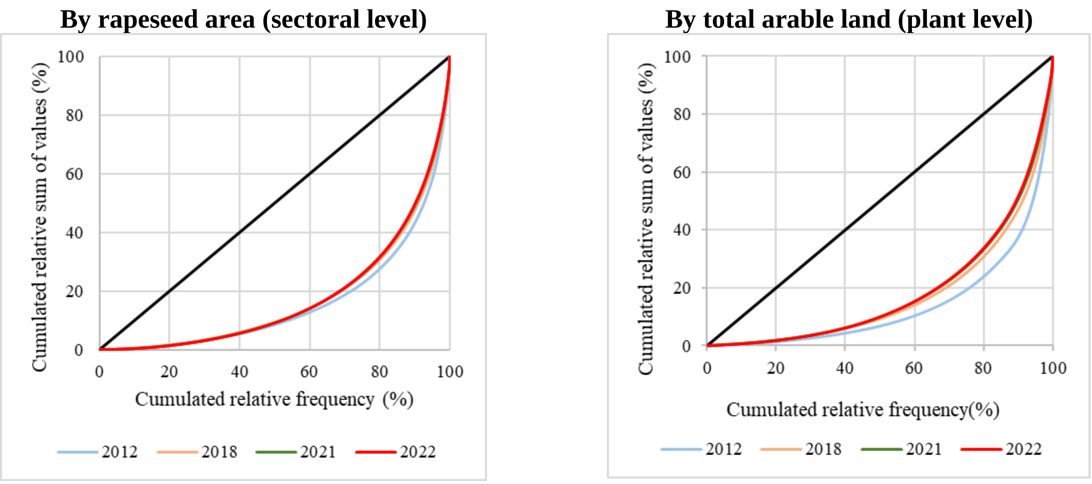
In the rising phase, the gap between income generating capacity increased (-42 thousand HUF/ha), and then in the declining phase, the gap between the income generating capacity of the two statistical large regions narrowed (-18 thousand HUF/ha). It can be statistically verified that the income generating capacity of the rapeseed producing plants in the two statistical large regions differed in each examined period. In the Transdanubia statistical large region, rapeseed producers had higher incomes, which can be attributed to significantly higher yields. In terms of profitability, only the operating return on sales of rapeseed producing farms was significantly different in the rising phase.

Based on my conclusions explained above, I reject my **H5** hypothesis *(The sectoral technical efficiency of rapeseed producing plants in the Transdanubia statistical large region is better than that of farms in the Great Plain and North statistical large region.*).

Based on the results of my analysis, rapeseed can be produced profitably in both the Great Plain and the North and the Transdanubia statistical large region. However, in case of rapeseed producing plants in the Transdanubia statistical large region, it should be considered to invest more rationally in fertilizer (both in quantity and monetary value) and plant protection (in monetary value) to increase their technical efficiency, which may also have a positive effect on income generating capacity in the future.

6. How did the concentration of arable crop producing plants, including the rapeseed sector, develop in the examined period?

While 10 percent of rapeseed producing plants accounted for about 60 percent of the area of arable land planted with rapeseed in 2012, this proportion decreased by almost half in 2018, 2021 and 2022, that is, both the pant and sectoral concentration decreased (*Figure 2*), which may be due to the termination of SAPS support for enterprises over 1200 hectares (SZILI – SZLOVÁK, 2018).



By rapeseed area (sectoral level)

By total arable land (plant level)

Figure 2: Development of the concentration of rapeseed farms based on their available rapeseed area and total arable land

Source: own calculation based on data of Hungarian State Treasury (MÁK)

Based on the Gini index values, the concentration degree of the examined plants is medium based on both the rapeseed area and total arable land, which is like the concentration degree of the individual and corporate farms in 2018 and 2020 (0.6) in the study of ERDŐS - SZŐLLŐSI (2023). The plant concentration based on the rapeseed area decreased from 2012 to 2018 and then stagnated, while it decreased continuously according to the total arable area (*Table* 9). These changes can be explained by the previously mentioned support policy (SZILI – SZLOVÁK, 2018).

Table 9: Gini indices of rapeseed producing farms at plant and sectoral level in the years examined

Years	By rapeseed area	By total arable land
2012	0.68	0.72
2018	0.65	0.65
2021	0.65	0.63
2022	0.65	0.62

Source: own calculation based on data of Hungarian State Treasury (MÁK)

Based on the above results, I accept my **H6a** hypothesis (*Field crop producing plants that are engaged in rape production, their concentration was at a medium level between 2012-2022.*).

Based on the above results, I reject my **H6b** hypothesis (*The concentration of rapeseed producing plants in Hungary has increased in the last ten years (2012-2022).*).

4. NEW AND NOVEL RESULTS OF THE DISSERTATION

The main objective of the dissertation is to reveal the factors causing the rise and later the decline of rapeseed production in Hungary through the analysis of natural and economic efficiency, primarily for the period 2012-2022.

In relation to the above-mentioned objective, the following new and novel results was identified:

1. Domestic rapeseed producing farms were profitable every year between 2012 and 2022, and the rapeseed sector is considered as the second most profitable sector among the main arable crops. In the sample I examined, the technical efficiency of rapeseed producers under 70 hectares and those with a minimum of 70 hectares does not differ significantly, and no correlation can be established between technical efficiency and sector size.
2. The gross income per hectare of rapeseed production in Hungary was influenced by the yield development to a greater extent than any other factor between 2012 and 2021.
3. I have proven by scientific method that the highest direct cost-proportional profitability was achieved on croplands with high goldcrown values and by low fertilizer use. In contrast, the most favorable gross income per hectare was realized in areas with high goldcrown value and by high fertilizer input levels.
4. Plants producing rapeseed in Hungary were characterized by an average sectoral technical efficiency of 70 percent in the 2012-2021 period. In the rising period of the sector (2012-2018), the sectoral technical efficiency of the plants was better (71 percent) than in the period of decline (2019-2021) (67 percent). While personnel costs, machinery and seed costs were the most determinant of technical efficiency in the rising phase, personnel costs were the most determinant in the declining phase.
5. The technical efficiency of the rapeseed producing plants in the Great Plain and North statistical large region is better than that of producers in the Transdanubia statistical large region in the 2012-2021 period.

6. The concentration rate of rapeseed sector of domestic rapeseed producing plants was medium, which decreased among rapeseed producers from 2012 to 2018 and then stagnated between 2018-2022.

5. PRACTICAL APPLICABILITY OF THE RESULTS

The research on the physical and economic efficiency of rapeseed production in Hungary is a gap-filling area. The Hungarian literature has not yet explored the factors influencing its rising and declining for the period 2012-2022.

The results of the effectiveness analysis of rapeseed, as the fourth most important arable crop, have additional information not only for rapeseed producers, but also for professional organizations, consultants, research institutions, universities, and policy makers.

Based on annual analyses, rapeseed production can be integrated into the crop rotation despite both economic and natural risk (even extreme) conditions, especially among plants with a high proportion of cereals. In addition, rapeseed cultivation can provide producers with a favorable income in the long run, depending on the change in yields. Of the four main arable crops, rapeseed is the second most profitable, regardless of farm size. In addition, rapeseed cultivation is recommended in both the Great Plain and North and the Transdanubian Region.

In the declining phase it is worth focusing on knowledge transfer, which means cooperation between rapeseed producers, knowledge centers professional organisations, innovative crop technology companies and research institutes. This could convince the producers of the need for higher proportion of rapeseed in the rotation.

Moreover, the obtained results draw attention to more rational use of fertilizer and plant protection inputs for rapeseed production, which can contribute to the shift towards sustainability on the one hand, and to meeting the expectations related to the European Green Deal strategy of the Common Agricultural Policy for the 2023-2027 budget cycle on the other.

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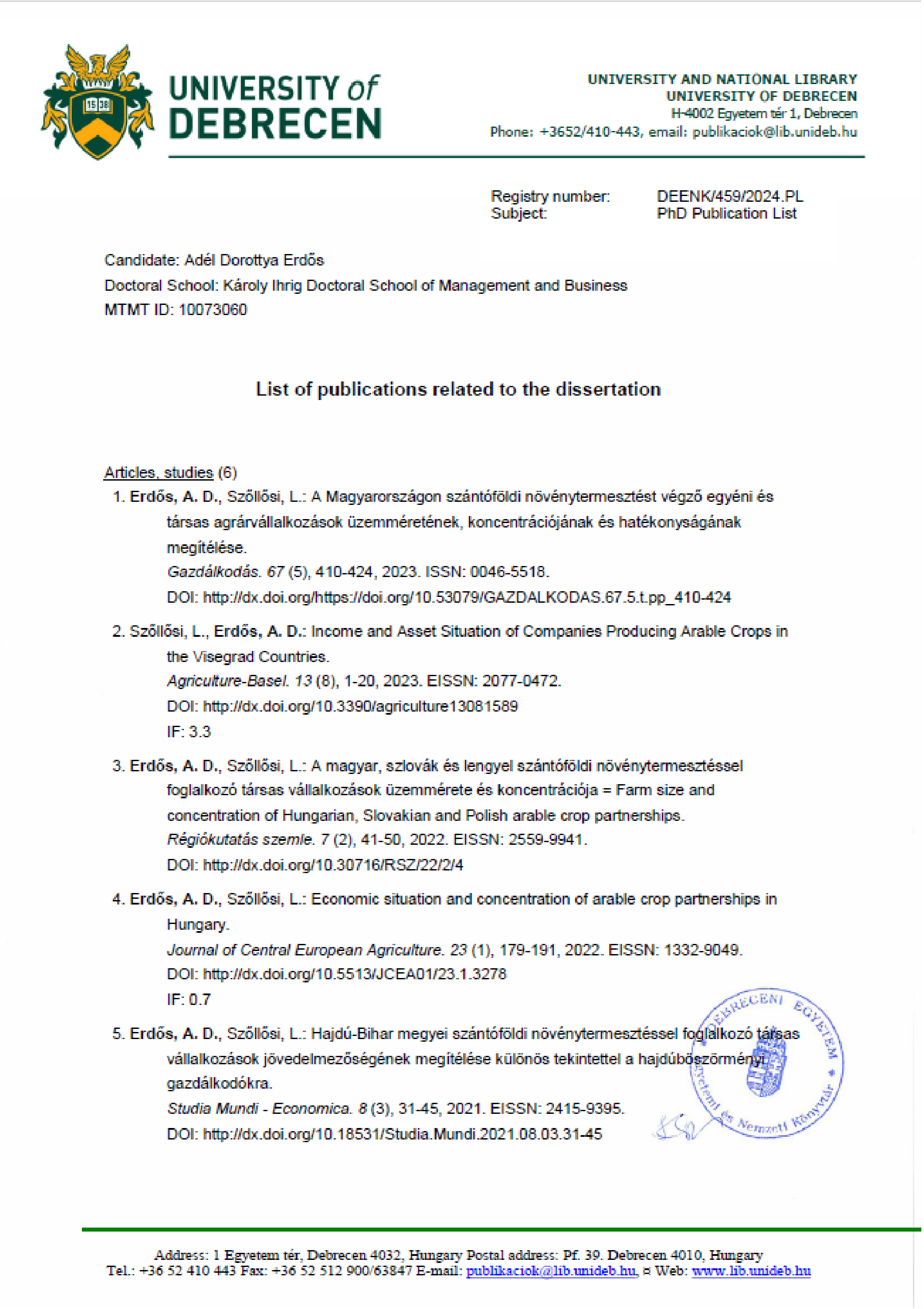
7. LIST OF PUBLICATIONS RELATED TO THE DISSERTATION



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List of publications related to the dissertation

Articles, studies (6)

1. **Erdős, A. D.**, Szőllősi, L.: A Magyarországon szántóföldi növénytermesztést végző egyéni és társas agrárvállalkozások üzemméretének, koncentrációjának és hatékonyságának megítélése.
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2. Szőllősi, L., **Erdős, A. D.**: Income and Asset Situation of Companies Producing Arable Crops in the Visegrad Countries.
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3. **Erdős, A. D.**, Szőllősi, L.: A magyar, szlovák és lengyel szántóföldi növénytermesztéssel foglalkozó társas vállalkozások üzemmérete és koncentrációja = Farm size and concentration of Hungarian, Slovakian and Polish arable crop partnerships.
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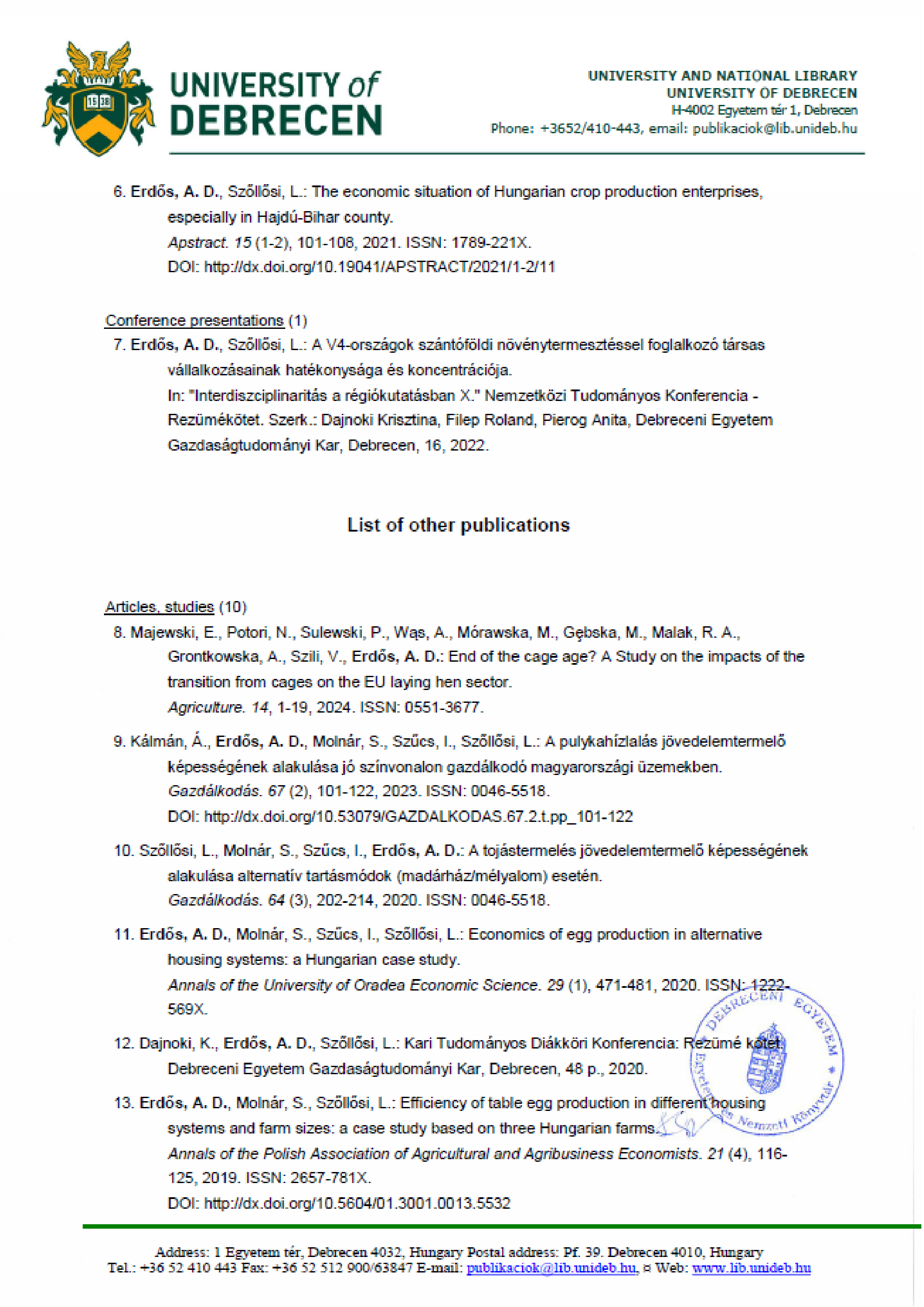

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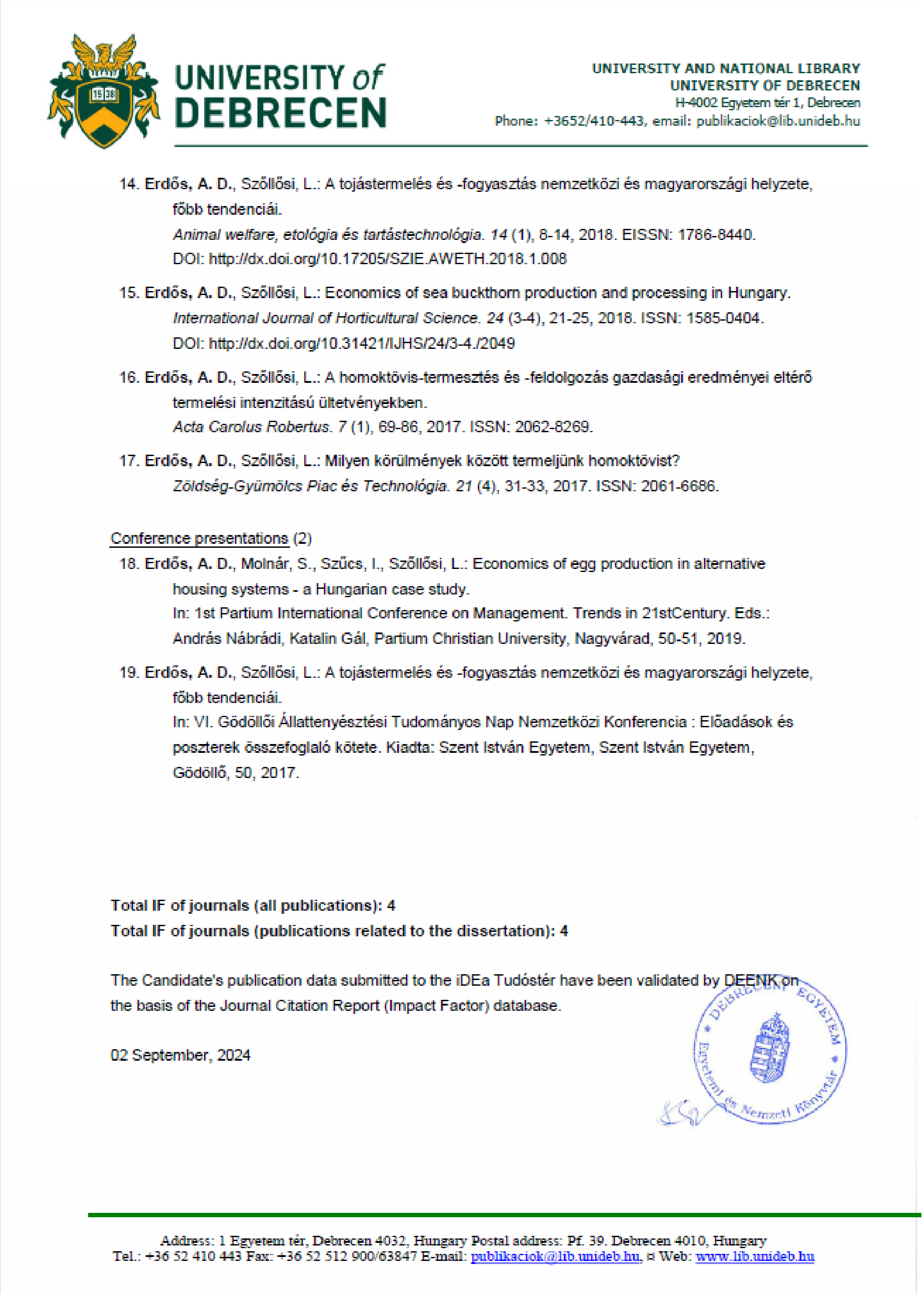

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    In: VI. Gödöllői Állattenyésztési Tudományos Nap Nemzetközi Konferencia : Előadások és poszterek összefoglaló kötete. Kiadta: Szent István Egyetem, Szent István Egyetem, Gödöllő, 50, 2017.

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