Szent István University

Theses of the Doctoral (PhD) Dissertation

THE ECONOMIC ISSUES OF PRODUCING CONVENTIONAL BIOFUELS

Anett Lászlók

Gödöllő
2019

Name of School: Doctoral School of Management and Business Administration

Branch of Science: management and business administration

Leader: Prof. Dr. Zoltán Lakner
professor, doctor of the Hungarian Academy of Sciences
Szent István University
Faculty of Food Science
Institute of Food Technology

Supervisor: Prof. Dr. István Takács
professor
Óbuda University
Keleti Károly Faculty of Economics
Institute of Economic and Social Sciences

…………………………………..   …………………………………
signature of the PhD school leader   signature of the supervisor

TABLE OF CONTENTS

1. ANTECENDENTS OF THE WORK, OBJECTIVES

Hungary's natural geography is very favourable for arable crop production. Climatic factors (precipitation, temperature, sunlight) and terrain conditions create favourable conditions for agriculture, including field crop production. However, the share of agriculture in gross domestic product (GDP) has fallen by almost half over the past 20 years due to the dynamic development of the industrial and service sectors, while absolute production value has increased. In 2016, agriculture contributed 3.7% to GDP, compared to 7.1% in 1995.

In Hungary, the agricultural area per capita is one and a half times the average of the European Union. In addition to supplying its own population, the country would also be able to produce a substantial agricultural export base. However, this has remained unexploited in the last 20-25 years, mainly due to the low profitability of the sector. Between 1970 and 1980, several agricultural products from Hungary (e.g. wheat, corn, sunflower) were among the top three in the world for per capita production, then export markets narrowed and domestic market demand declined steadily (SOMAI, 2004).

According to the forecasts, the population of Hungary will continue to decline. The world's population is expected to be around 9 billion people in 2030, so the increase in agricultural production is only justified if the resulting product surplus can be economically exported or replaced by some other resource (e.g. fuel).

The production of biofuels can be a good market for the surplus of arable crop production in addition to food and feed. Biodiesel can be produced from ethanol that derives from high starch crops (wheat, corn, potato, sugar beet) and vegetable oil directly from oily plants (oilseed rape, sunflower, soya) with esterification and adding methanol (HANCSÓK, 2004).

The amount of biofuel used is mostly influenced by the objectives set by the European Union. By 2020, the EU set the share of renewable energy in 20% of total energy consumption, with a target of 10% for transport. With its biofuel policy, the EU was looking forward to addressing the following issues:

- reducing dependence on fossil fuels and thereby improving security of energy supply;
- reducing greenhouse gas (GHG) emissions, thereby slowing down climate change;
- generate demand for agricultural surpluses and thus support farmers' income generation activity.

Biofuel production in the EU is now more than twenty years old. In parallel with the growing production of first-generation biofuels, serious scientific and social debates have arisen on their use. The discussions focused on food safety, land use change as well as environmental and economic issues.

Some researchers say that the rapid increase in biofuel production can have a major impact on and threaten agricultural and food production, as economic competition between the food, feed and energy industries occurs at the same time (CSIPKÉS, 2011).

While, according to other researchers, Hungarian biofuel production can contribute to stabilizing agricultural product lines and the market appearance of products with a higher degree of processing and value added, while also maintaining its income and employment impact (BAI - JOBBÁGY, 2011).

Based on the above, the main objective of the research is to examine the relationship between the efficiency of arable crop production and biofuel production.

The main purpose of the research was divided into the following sub-objectives:

O1. When writing my dissertation, my first goal was to investigate how biofuel production has changed in European countries where most biofuels were produced between 2004 and 2016 and whether further growth in production is expected.

O2. In order to meet the European Union's 2020 renewable energy target, more and more biofuels are needed. However, more raw materials are necessary to increase the production of biofuels. The increase in demand for arable crops makes producers to produce as many crops as possible at a lower cost. The increase in demand has a price-raising effect on raw materials, as competition between food, feed and biofuel industries starts. For this reason, my aim was to examine how the efficiency of arable crop production and the change in land use has evolved in some European countries producing most biofuels.

O3. In Hungary, after the decline of export markets, the start-up and growth of conventional biofuel production has improved the productivity of arable crop production. At the same time, there are still efficiency reserves for the production of arable crops that can be used for certain energy purposes.

In line with the aims of the research, I formulated the following hypotheses, which I wanted to prove during my investigations.

H1. The production of conventional biofuels in the European Union will not increase significantly.

H2. The production of conventional biofuels has an impact on the development of arable crops.

H2.1 There is a significant relationship between the efficiency of arable crop production and the quantity of first-generation biofuels produced.

H2.2 Plants engaged in energy crop production have higher profitability.

H2.3 The production of conventional biofuels has resulted in an increase in the area and yield of arable crops used as raw material.

H3. In Hungary, as a result of the increase in conventional biofuel production, the total factor productivity of arable crop production has increased.

H4. There is also an efficiency margin for plants producing conventional biofuels in Hungarian arable crop production.

2. MATERIAL AND METHODS

In the literature review I analysed the development and legal regulation of biofuel production, examined the energy balance of biofuels, the impact on food prices, the environment and employment. Then I studied in detail the methods of efficiency analysis, namely, the theoretical foundations of the Data Envelopment Analysis (DEA) and the Total Factor Productivity (TFP), and also presented the results of several authors' efficiency analysis of arable crop production.

2.1. Material

Several databases were used to justify the research hypotheses. I used the EUROSTAT database to select the European countries involved in the study. From the database for the years 2004 to 2015, the annual biofuel data for the primary production of renewable energy sources were filtered and ranked. Since more than half of the European biofuel production was produced in the first three countries during the period under review, these countries were included in the analysis.

I used the FAOSTAT database to analyse land use change. From the database, the total area of the countries surveyed, the size of the arable land and the area size of the wheat, corn, sunflower and rape harvested were examined with the changes in yields between 2004 and 2016. The changes in land use and yields were examined by calculating five-year averages.

Comparative analysis of crop production in arable lands of the countries examined was based on the data of the European Commission’s Farm Accountancy Data Network (FADN). Data about a total of approximately 80,000 agricultural holdings were collected in 28 Member States of the European Union. The farms surveyed represent a population of approximately 5 million, which represents at least 90% of agricultural land and agricultural production. Data collection in the individual Member States differs from Community mandatory standards to a greater or lesser extent, depending on the specific situation and information needs of each country, but after certain conversions have been completed, each Member State is able to provide FADN data with uniform content and format. In order to compare the arable crop production of the selected countries, I calculated 12 efficiency indicators from the FADN database.

For the preparation of farm-level analyses, the Agricultural Economics Research Institute (in Hungarian: AKI) provided me with the cost and income data of the basic crop production plants. To facilitate the analysis, I have created three size categories from the 12 size categories (Table 1). The 3–5 SO (Standard Output) farms are small, with 6-9 SO medium-sized, and 10-14 SO farms are called large farms.

Table 1 Classification of farms by size categories

Size categories	Standard Output (SO) in Euro	Own grouping
I.	Below 2 000 EUR	-
II.	from 2 000 to 4 000 EUR	
III.	from 4 000 to 8 000 EUR	**Small farms**
IV.	from 8 000 to 15 000 EUR	
V.	from15 000 to 25 000 EUR	
VI.	from 25 000 to 50 000 EUR	**Medium-sized farms**
VII.	from 50 000 to 100 000 EUR	
VIII.	from 100 000 to 250 000 EUR	
IX.	from 250 000 to 500 000 EUR	
X.	from 500 000 to 750 000 EUR	**Large farms**
XI.	from 750 000 to 1 000 000 EUR	
XII.	from 1 000 000 to 1 500 000 EUR	
XIII.	from 1 500 000 to 3 000 000 EUR	
XIV.	3 000 000 EUR, or above	

Source: Author's own classification based on EC (2008) and EC (2012)

The following output data was used to calculate TFP and DEA from the database:

1. quantity of main product Code 190 in kilograms and
2. with Code 630 Total turnover of the sector in HUF, which is the product of the quantity of main and by-products sold, and the average selling price achieved.

The input data used for the calculations are:

1. Sowing area Code 110 in hectares
2. Code 170 The average gold crown value in GCr / ha
3. Cost of seed and propagation material Code 635 in HUF,
4. Fertilizer cost Code 645 in HUF,
5. Cost of plant protection product Code 655 in HUF,
6. Machine costs of Code 770 in forint, which includes the costs of lubricants and fuel, as well as current repair and maintenance costs;
7. The number of hours worked, which is the sum of Code 830 Family Work Wage Cost per Hour, the Regular Employees' Cost Per Hour of Code 840, and the Cost of Casual Work per Hour, Code 850.

For the calculation of the TFP, I used the data of the plants of the AKI, which performed economic activities between 2004 and 2015 in each year of the examined period. During the period under review, there were 398 plants that continuously engaged in production activities. Because the DEAP program used to calculate productivity is sensitive to zero, the database had to be cleaned of these extremities. Thus, the plants that did not charge machine costs were dropped from the database because they used other machine services, or did not use fertilizers and pesticides, and produced the grain for their own use, not for sale. After deleting the outliers 304 plants remained in the sample for which the calculations were made.

The DEA analysis from AKI's database was performed for the entire arable crop industry and for the following arable crops:

- Code 1111 Wheat and Spelled Wheat
- Code 1121 Grains of Corn
- Code 1311 Industrial Sunflower and
- Code 1312 Rape.

Output value and input data were deflated by the index of agricultural producer prices based on 2004, in order to eliminate the effect of price changes. In the database provided by AKI, a total of 38,129 data lines were reported during the period under review. Like the TFP calculation, DEA analysis can only be performed with values greater than zero, so plants with zero output or input have been deleted from the sample. After filtering out the outliers, there were 28,326 data lines remaining in the sample for which the calculations were made. I prepared the DEA analysis for the entire field crop production, because this method measures the efficiency of the plants relative to each other based on input and output data.

2.2. Methods

Statistical analyses were performed using Microsoft Excel, SPSS (Statistical Package for Social Science) and DEAP (Data Envelopment Analysis Computer Program) Version 2.1 programs.

Testing the hypotheses was performed by using the following methods:

- I used the logistic trend calculation to estimate the future development of biofuel production in the countries surveyed.
- With the help of the rank correlation coefficient I investigated whether there was a correlation between the efficiency of arable crop production in each country and the extent of biofuel production.

- The main component analysis was used to analyse the relationship between the profitability of field crop production and energy crop production. I used the main component analysis to reduce the number of variables and the cluster analysis of the size categories of the examined countries was performed with the main components thus obtained.
- Using the Malmquist index, I examined the development of the total factor productivity of Hungarian arable crops in the examined period. From the trend levelled by the triple moving averages, the variation of the total factor productivity of arable crop production by size category and total was calculated using a compound annual growth rate.
- DEA analysis was used to determine the effectiveness of arable crop production and the most typical arable crops suitable for energy production and the exploration of efficiency reserves. The effect of weather-induced fluctuations in yields was levelled off by triple moving averages.

3. RESULTS

3.1. The production of conventional biofuels in the European Union will not increase significantly (H1)

In Europe, over half of biofuels were produced in Europe between 2004 and 2015 by six countries. These countries are France, Germany, Italy, Spain, Sweden and the Netherlands. I studied the biofuel production of these 6 countries and Hungary by using logistic trend calculation. In Germany, France and Sweden, according to the logistical function, biofuel production has already reached saturation levels and in other countries the function is in the phase of slowing growth.

3.2. There is a significant relationship between the efficiency of arable crop production and the quantity of first-generation biofuels produced (H2.1)

Using the FADN database, I calculated 12 efficiency indicators for the countries surveyed. These include 1. Return on Assets (ROA), 2. Return on Equity (ROE), 3. Return on Sales (ROS), 4. Capital Efficiency, 5. Labour Efficiency, 6. Wage cost per capita, 7. Labour intensity, 8 Amount of support per hectare, 9. Cost of fertilizer and herbicide product per hectare, 10, Number of working hours per hectare, 11. Earnings per hectare and 12. Production machine supply. I have ranked the average values for the metrics. I calculated the Spearman rank correlation coefficient between the order of the indicators and the order of the quantities of biofuels produced by the countries examined. Only in Hungary ($p = 0.042$) there is a real relationship between biofuel production and the efficiency of arable crop production. For the other countries, the significance level was above the 5% acceptability value, so the relationship between the two factors can only be considered as accidental.

3.3. Plants engaged in energy crop production have higher profitability (H2.2)

In order to prove the hypothesis, the average values of the above-mentioned indicators for the size classes of the profitability ratio (asset, equity ratio, and profit-to-sales ratio) and the energy crop production from the FADN database (the proportion of energy crop production area, the energy crop production turnover of all arable crops and profit from 1 hectare energy plant) can be verified. I performed a principal component analysis on the data. As a result of the analysis, I got two main components that can be easily interpreted. The first major component was the volume of energy crop production and the second main component was the profitability of arable crop production. Cluster analysis was performed on the main component analysis. The classes were united by the Ward method. I have created four clusters of the results with the following names: Cluster 1: Producers of energy crops, 2 clusters: Attendants, Cluster 3: Conservatives, Cluster 4: Developers. During the analysis, there was no clear cluster in which both major components were in the positive range. According to the cluster centroids, the plants of cluster 4 countries are closest to the assumption that high profitability is combined with high energy crop production.

3.4. The production of conventional biofuels has resulted in an increase in the area and yield of arable crops used as raw material (H2.3)

To prove the hypothesis, I examined how the proportion of arable land in most biofuel producing countries was developed, and how the share and yield of wheat, corn, sunflower and rape harvested changed and averaged over the years before and after the introduction of the RED Directive. As the proportion of arable land decreases as a result of urbanization, arable crops have to compete with each other in an increasingly smaller area. In most of the countries surveyed, wheat, corn, sunflower and rape have increased in most of them in the average of 2012-2016. The proportion of oilseed harvesting areas increased more than the area of alcoholic crops, which is due to the fact that biodiesel is produced in Europe at a higher rate than bioethanol, thus increasing the demand for oilseeds. In addition to the growth of the harvested area of certain crops, yields also increased. Rape yields increased the most. The yield of corn and wheat increased almost as much as the yield of sunflower decreased on average.

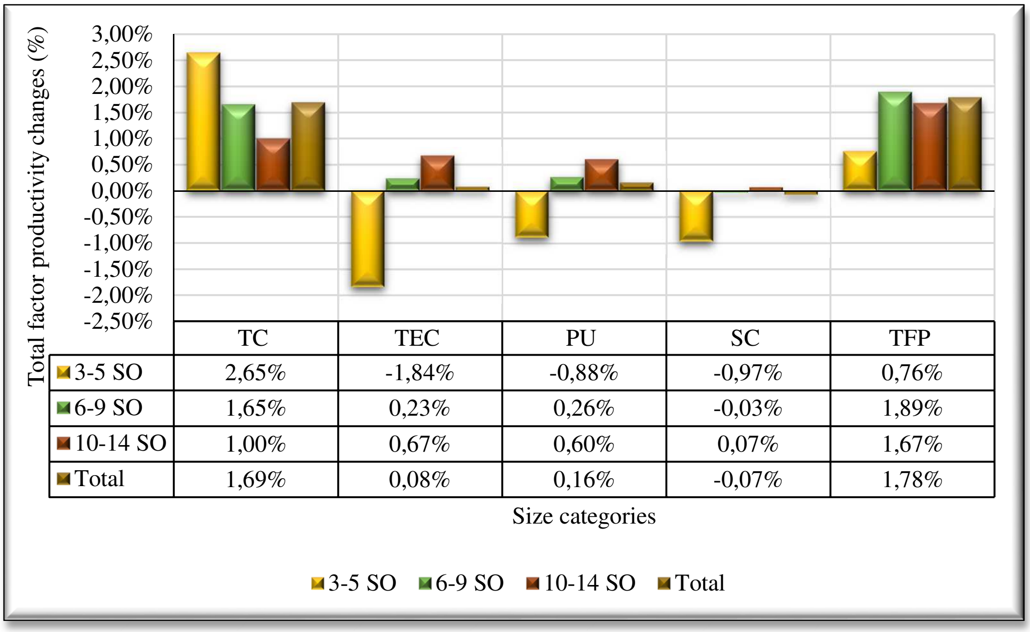
The European Union plans to reduce land-use change by cutting back on biofuels produced from food raw materials and shifting to advanced biofuels. Advanced biofuels are mostly made from agricultural and forestry waste and by-products. In my opinion, while biofuels are mostly produced from vegetable raw materials, it is not necessary to cause some land use change at some level, as farmers will always produce a larger proportion of the crops that the market is demanding.

3.5. In Hungary, as a result of the increase in conventional biofuel production, the total factor productivity of arable crop production has increased (H3)

The change in total factor productivity (TFP) shows significant fluctuations every year, which is basically attributable to the change in weather. For most of the plants, TFP was high in 2008 and 2014 due to favourable yields, while in 2007 and 2012 low yields led to a decrease in TFP.

In the calculation of TFP, I used triple moving averages to level off the adverse weather effects that impact the TFP of each year. After calculating the moving averages in the examined period, the general tendency of TFP and its components remained the same, only the yearly disturbing effects were eliminated from the time series. In the examined period, the development of TFP changes in Hungarian arable crop production is shown in Figure 1 for size categories and total field crop production.

Figure 1 Changes in the total factor productivity of arable crop production in Hungary between 2004 and 2015 (%)



Source: author's own editing based on TR data, DEAP

In Hungary, the productivity of the plants producing permanent arable crops shows a slight improvement during the period under review. The productivity of medium-sized plants cultivating arable crops has been the most favourable, while the level of production of small-scale cutting-edge plants has come closer to the limit of the maximum production potential of the given technology. Large-scale plants, on the other hand, were much better able to use the production factors at their disposal. The management's preparedness and qualifications were higher, compared to small-scale enterprises, which were lagging behind in technology development.

The 1.78% value quantified by the Malmquist index contains aggregate growth of arable crop production for the period 2004-2015. In addition to the increase in biofuel production, a number of other factors have contributed to an increase in the productivity of arable crop production, such as changes in the production structure, changes in the use of the crops produced, and the changes in economic processes.

Table 2 Major uses of cereals in Hungary (%)

Way to use	2013	2014	2015	2016	2017	Average	Average annual growth rate
Industrial processing	15,13	13,78	14,88	17,10	16,94	15,22	2,87
- From this domestic food	9,67	8,02	7,84	7,48	7,21	8,25	-7,07
- From this not for food	5,46	5,76	7,05	9,62	9,73	6,97	15,54
Feed consumption	18,78	16,31	15,57	14,71	13,78	16,35	-7,44
Export	26,50	22,37	27,07	21,40	27,95	24,33	1,34

Source: KSH, 2019

In each year, on average, 15% of the cereal available in Hungary was used for food and industrial uses, 16% for feed and 24% for export purposes, and the remainder for stock (Table 2). The decline in livestock since the 1990s has led to a decline in the use of cereals for animal nutrition and a declining trend in food consumption. Growth occurred only in industrial use and export volumes, so productivity growth was basically due to these two factors. The increase in industrial use had a greater impact on productivity growth than export growth. Some of the exported grain is probably also used for biofuel production, but no data are available for this.

Table 3 Proportion of maize and rapeseed used for energy purposes in Hungary between 2009 and 2016

Denomination	2009	2010	2011	2012	2013	2014	2015	2016	Average
Corn harvested (1000 t)	7 528	6 985	7 992	4 763	6 756	9 315	6 633	8 730	7 338
Rapeseed harvested (1000 t)	579	531	527	415	533	700	590	925	600
Use of maize for energy purposes (1000 t)	400*	430*	400*	700*	1 000*	1 000*	1 253	1 350	817
Use of rapeseed for energy purposes (1000 t)	550*	550*	225*	210*	380*	380*	338	325	370
Proportion of maize used for energy purposes (%)	5,31	6,16	5,01	14,70	14,80	10,74	18,89	15,46	11,13
Proportion of rapeseed used for energy purposes (%)	94,93	103,65	42,72	50,65	71,36	54,31	57,16	35,14	61,63

* Estimated data

Source: author's own editing based on FAOSTAT data and progress report data

In the progress reports until 2014 only estimated data were available on the use of corn and rape for energy purposes (Table 3). The share of corn used for energy purposes has increased threefold compared to 2009, while the use of rape for energy purposes averaged 61.63%. In my opinion, the use of rape for energy purposes was significantly overestimated in 2009 and 2010, as it had to use imported raw material for biodiesel plants.

Industrial use had the greatest impact on the increase in the productivity of arable crop production. Since industrial use includes other industrial activities in addition to biofuel production, I assume that the production of biofuels has made a significant contribution to productivity growth.

3.6. There is also an efficiency margin for plants producing conventional biofuels in Hungarian arable crop production (H4)

In Hungary, biofuel production has grown dynamically in recent years. Most of the raw materials used for biofuel production were produced by Hungarian arable farmers. According to my hypothesis H4, there is still an efficiency margin for the production of wheat, corn, sunflower and rape, which is also suitable for the production of biofuels, so the production of biofuels in Hungary does not endanger food security.

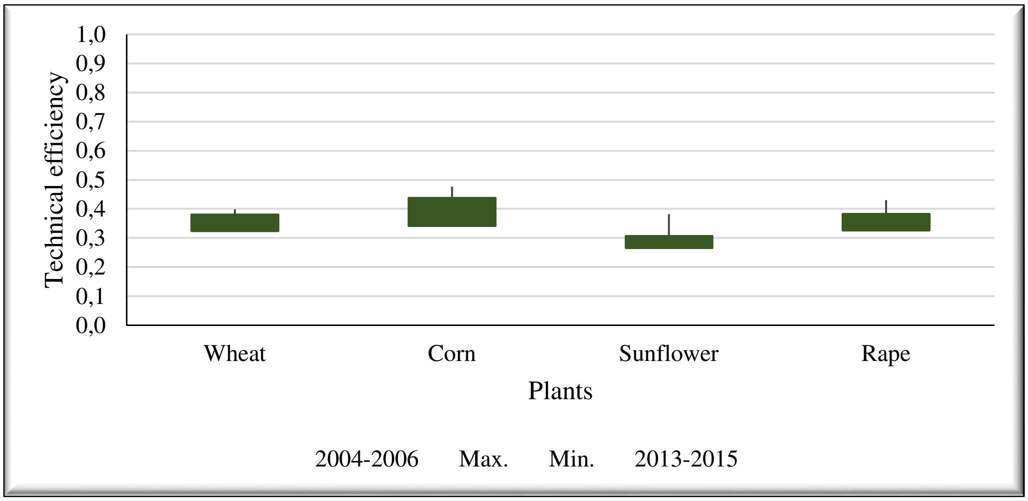


Figure 2 The technical efficiency of wheat, corn, sunflower and rape in Hungary
Source: author's own editing based on TR data, DEAP

The annual value of technical efficiency for all four plants shows a downward trend during the period under review (Figure 2). Of the four main arable crops, the technical efficiency of corn was the highest in the period under review, and the technical efficiency of sunflower was the most unfavourable. By the end of the examined period the technical efficiency of corn production decreased by an average of 9.67%, the efficiency of rape production by 5.81%, and the efficiency of wheat production by 5.74% and the efficiency of sunflower by 4.21%. During the period under review, biofuel production did not increase the efficiency of individual plants but decreased.

Similarly to technical efficiency, economies of scale also show a decreasing trend for the plants examined (Figure 3).

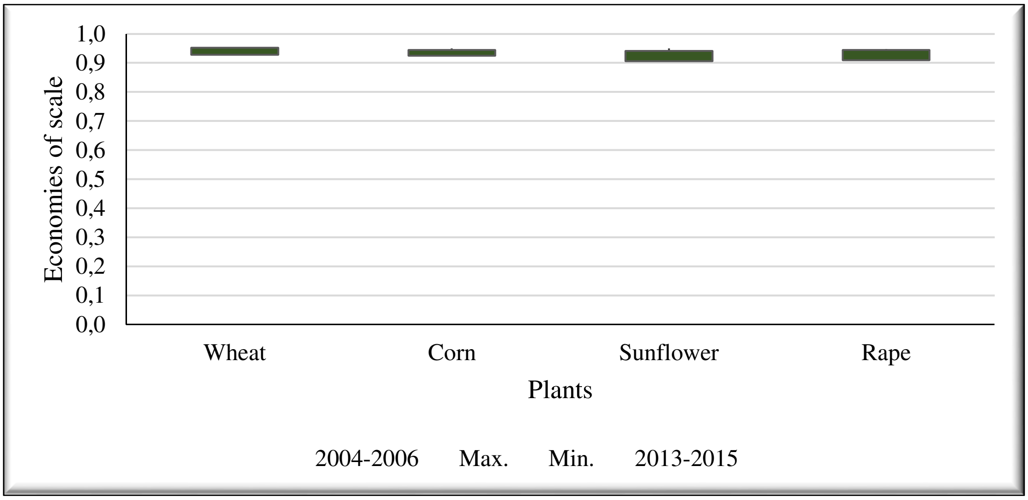


Figure 3 The economies of scale of wheat, corn, sunflower and rape in Hungary
Source: author's own editing based on TR data, DEAP

The efficiency of wheat production has best approached the optimum production level. The average efficiency of corn and rape in the average of 2004-2006 was the same, but by the end of the period the economies of scale of rape decreased more. Like technical efficiency, the size of the sunflower was the lowest.

The examination of plant sizes has led to similar results in the technical efficiency and economies of scale of the four plants I examined. The economies of scale of medium-sized plants was always closer to the optimal size than those of large plants. Efficiency gains only occurred in large-scale plants, and the efficiency of plant production in medium-sized and small-scale plants declined between 2004 and 2015.

4. NEW AND NOVEL SCIENTIFIC RESULTS

Based on the analysis of the relationship between arable crop production and traditional biofuel production, I have produced the following new and novel scientific findings.

R1. With the help of a correlation coefficient I found that there is no significant relationship between the efficiency of arable crop production of the examined countries and the quantity of first-generation biofuels produced. Thus, the amount of biofuel production does not depend on the performance of arable crops in a given country. In the countries surveyed, a significant amount of biofuels was produced from imported raw materials, which does not affect the efficiency of arable crop production in the biofuel country. Of the examined countries, only Hungary has a significant relationship between the two factors, from which it can be concluded that Hungary has optimally defined its biofuel policy in relation to its crop production potential. All in all, the more developed countries in the EU formulate their renewable energy policies with energy security, while in the less developed countries, achieving higher incomes motivates biofuel production processes.

R2. With the help of main component analysis and cluster analysis, I concluded that energy crop production does not lead to higher profitability for farmers. There is no significant difference between the production costs of crops for different uses, because the agrotechnology used for energy crops is the same as for industrial processing. Farmers' profitability would only increase if plants used for energy purposes could be sold more expensive than crops used for food and feed. Farmers usually have no influence on the final use, only the produced produce is sold on the market. Biofuel producers, on the other hand, are striving to get the best quality raw material at the lowest possible price, so it is in the interest of crop producers to produce the required crop at the lowest possible cost by making the best use of the resources at their disposal.

R3. As a result of urbanization, the proportion of arable land is constantly decreasing, so that arable crops have to compete in a smaller area. As a result of the change in the production structure, biodiesel is produced in the EU at a higher rate than bioethanol, as the harvested area of sunflower and rape as the raw material for biodiesel increased on average in a higher proportion than the harvested area of wheat and corn. With the exception of sunflower, the yields of the examined plants also increased. In the countries under review, there has been some indirect land use change in the years following the introduction of the RED Directive.

R4. On the basis of the operational database of the Hungarian test plant system, with the help of the Malmquist index I established that the total factor productivity of arable crop plants operating continuously during the examined period slightly increased during the examined period. Several factors contributed to the increase in the productivity of arable crop production, but the industrial use of cereals in Hungary increased the most in the examined period. Since biofuel production has increased significantly in Hungary since 2008, I assume that biofuel production has greatly contributed to the growth of arable crop production.

R5. With DEA analysis I proved that there are significant efficiency reserves in the field of crop production in Hungary, and in the production of crops (wheat, corn, sunflower and rape) that can be used for energy purposes. The technical efficiency of arable crop production was very low between 2004 and 2015. With the optimal use of available inputs, farmers would have been able to produce much more crops that could have been sold with additional sales, which would have increased their profitability. The resulting surplus of yield could have been used for export or biofuel production without endangering food security. In Hungary, the start-up of industrial biofuel production in small and medium-sized plants did not increase efficiency, while in the case of large-scale plants, the efficiency reserves in field crop production fell slightly.

5. CONCLUSIONS AND RECOMMENDATIONS

Biofuels have been increasingly used in the European Union for almost twenty years, but they have only been gaining ground in the last ten years. Along with the generalization of their application, there have been changes in land use, trade and industry, which have led to serious scientific and social debates around them. Despite the fierce scientific, political and social debate, the market for first-generation biofuels has been steadily developing, and its growth has not been halted by the global economic crisis.

In the literature review of my dissertation, the following conclusions were drawn from the results of the pro and con studies on the controversial issues of biofuels.

- Biofuel production is basically a political decision. The arguments for the production of biofuels include environmental, energy and agricultural policy objectives. Different countries are encouraged by different factors to increase the production and use of biofuels. Due to the mixing of many factors, national strategies are not entirely clear, as they are accompanied by the need for import promotion, environmental goals and protection of domestic producers. The contradiction is understandable, because the environmental and energy targets are most economically achievable by importing biofuels because the developing countries produce them at a much lower cost and in this case the emissions from the production also occur elsewhere. At the same time, the use of imported biofuels contradicts the interests of agriculture.

- The lack of accurate and reliable data makes the analysis of biofuels significantly more difficult. Depending on the energy lifecycle analysis used in energy production, many data can be found in the literature on the energy balance and the GHG emissions of biofuels. Considering that these indicators may differ significantly depending on the technology and raw material used, the effects of biofuel production in Hungary could be judged on the basis of measurements and calculations adapted to domestic conditions, cultivation practices, technologies, but these have not yet been prepared. Only with these calculations would it be possible to determine to what extent biofuels serve the purposes of energy security and climate protection.

- The exact determination of biomass potential for energy purposes is difficult to plan due to weather risks. In a worse year, in addition to feeding and foraging, there is less crop excess that can be used for energy purposes. Weather risk also affects the economical production of biofuels. The profitability of biofuels produced from cereals is largely determined by the changes of the price of raw materials, which is significantly dependent on the weather risk, among other factors. At the time of severe weather problems, there is an explosion in commodity prices, with the cost of producing biofuels not competitive against fossil fuels. As a result, biofuel production is a risky, difficult-to-plan activity for investors.

- The impact of biomass energy production on employment is more favourable than other renewable energy technologies but is no longer significant at the national economy level. The production of energy crops only gives more job opportunities if it is not on the land that is currently utilized, otherwise it has only a labour-saving role. The indirect employment effect is already higher, but more difficult to quantify.

H1. The production of conventional biofuels in the European Union will not increase significantly

I verified the hypothesis with the help of logistic trend calculation. According to the results, in Germany, France and Sweden the function has already reached saturation level, but biofuel production is also in the phase of slowing growth in the other countries examined. As a result, my H1 hypothesis was confirmed. The result obtained is also confirmed by the restrictive provision of the European Commission in 2017, which reduced the share of first-generation biofuels in final energy use by 7% and encourages the production of advanced biofuels, thereby reducing indirect land use change. Nevertheless, in the European Union by 2020, 10% of final energy consumption in the transport sector should come from renewable energy sources. In addition to the use of biofuels, biogas use, renewable energy and hybrid propulsion are included in 10%.

According to EUROSTAT data, the share of renewable energy used in transport in the EU28 average in 2016 was 7.1%. As far as possible, each country has used first-generation biofuels at different rates. If the legal environment does not change, the plants will be able to sell their surplus stocks of biofuel in Hungary only to countries that do not have sufficient stocks of grain to produce first-generation biofuels.

H2.1 There is a significant relationship between the efficiency of arable crop production and the quantity of first-generation biofuels produced.

My hypothesis H2.1 was investigated using Spearman's rank correlation coefficient. In the examined period, the relationship between the extent of biofuel production and the efficiency of arable crop production was only significant in Hungary. Based on the results obtained, hypothesis H2.1 was not verified.

The results show that biofuel production is not affected by a country's crop production performance. In addition to their own biofuel production, each country tries to meet its mandatory mixing rates either with cheaper imported biofuels or by purchasing imported raw materials.

Among the examined countries, there is a moderately strong correlation between the two examined factors in Hungary. Biofuel production in the country has an impact on the efficiency of arable crop production. The main goal of biofuel production in the country is to generate demand for producers.

H2.2 Plants engaged in energy crop production have higher profitability.

My hypothesis H2.2 was analysed with the help of principal component analysis and cluster analysis. The analysis was made more difficult by the fact that FADN's database only contains data on energy crop production by data providers. On the other hand, farmers generally have no control over the use of the produce they grow. Producers therefore do not produce biofuel plants specifically for energy purposes. Thus, the results of the analysis of the FADN database on energy crops should be handled with care. Nonetheless, key component analysis and cluster analysis have proven to be a useful tool for data analysis.

During the analysis, based on the average data on the size classes used for the field crop plants used, I got two main components that can be clearly interpreted. The first major component is the volume of energy crop production and the second main component is the profitability of arable crop production. Using cluster analysis on the data of the two main components, I created four clusters. There was no cluster in which high energy crop production would be coupled with high profitability, so I rejected my H2.2 hypothesis. Thus, the production of energy crops does not lead to higher profitability, but rather serves to increase farmers' income through the sale of hard-to-sell crop surpluses and by-products for energy purposes.

H2.3 The production of conventional biofuels has resulted in an increase in the area and yield of arable crops used as raw material.

To verify hypothesis H2.3, I examined how the proportion of arable land in most biofuel producing countries was developed, and how the share and yield of wheat, corn, sunflower and rape harvested changed and averaged over the years before and after the introduction of the RED Directive. As the proportion of arable land decreases as a result of urbanization, arable crops have to compete with each other in an increasingly smaller area. In most of the countries surveyed, wheat, corn, sunflower and rape have increased in most countries in the average of 2012-2016. The proportion of oilseed harvested areas increased more than the area of alcoholic crops, which is due to the fact that biodiesel is produced in Europe at a higher rate than bioethanol, thus increasing the demand for oilseeds. In addition to the growth of the harvested area of individual crops, yields also increased. Rape yields increased the most. The yield of corn and wheat increased almost as much as the yield of sunflower decreased on average.

The European Union plans to reduce land-use change by cutting back on biofuels produced from food raw materials and shifting to advanced biofuels. Advanced biofuels are mostly made from agricultural and forestry waste and by-products. In my opinion, while biofuels are mostly produced from vegetable raw materials, it is not necessary to cause some land use change at some level, as farmers will always produce a larger proportion of the crops that the market is demanding.

There is a strong argument that the raw materials for biofuels should be produced in less-favoured areas that are not used to produce food products, because energy crops will not compete for the land. The quality of the crops produced in these areas is much weaker due to soil characteristics, which is more difficult to sell on the market. Profit maximizing producers will therefore always compete for the highest quality areas.

H3. In Hungary, the total factor productivity of arable crop production has increased in the period under review.

I used the Malmquist index to calculate the total factor productivity of arable crop production. During the period under review, there were 304 plants in the sample that were continuously engaged in arable crop production. The productivity of Hungarian field crop production increased by 1.78% between 2004 and 2015, so I accepted the third hypothesis. This value is aggregated to increase the productivity of the plants that are continuously engaged in crop production. In Hungary, the decline in the use of livestock has led to a decline in the use of cereals for animal feed, and food use has been declining. Growth occurred only in industrial use and export volumes, so productivity growth was basically due to these two factors. Industrial use increased at a higher rate than exports. Industrial uses include biofuel production and other industrial activities. In Hungary, biofuel production has increased significantly since 2008, so I assume that biofuel production has contributed greatly to productivity growth. Some of the exported grain is probably also used for biofuel production.

In Hungary, the increase in the productivity of arable crop production could be further improved by increasing technical efficiency. This should be done by improving the efficiency of the production, i.e. the more efficient use of the production factors, and, on the other hand, by increasing the management's preparedness. The use of new technologies is not enough for tradition-based management, but it also needs the expertise that farmers can gain through further training and management skills. Increasing technical efficiency would be most important for small-scale farms, because the technical efficiency of the plants in this size category decreased during the period under review.

H4. There is also an efficiency margin for plants producing conventional biofuels in Hungarian arable crop production.

The fourth hypothesis was verified by DEA analysis. The relative effectiveness of the most typical field crops (wheat, corn, sunflower and rape) was investigated during the study. Efficacy values for all four plants were very volatile, caused by yield losses due to adverse weather conditions in each year. The increasing state subsidies paid to the farms did not have a positive effect on the relative efficiency of arable crop production. For all four plants, the efficiency test was almost the same as a result of similar production technology. Overall, technical efficiency and economies of scale have been reduced, so there are significant efficiency reserves for the plants under investigation.

Examining the efficacy by size category, it can be stated that the technical efficiency and economies of scale of large plants were the most favourable and the smallest ones were the most unfavourable. There was no significant difference between the efficiency of small and medium-sized plants, while in the case of large plants, the economies of scale increased with the exception of corn. In Hungary, the start-up of industrial biofuel production in small and medium-sized plants did not lead to an increase in efficiency, while in the case of large-scale plants, the efficiency reserves in field crop production fell slightly.

By using the production factors at their disposal, the Hungarian plants and farms could significantly increase the amount of produced crops. Surplus production could be used for export without jeopardizing food security or providing an additional source of income for plants to produce biofuels. The surplus biofuels produced could be sold to countries that do not have the capacity to produce biofuels.

In 2017, the European Commission limited the use of conventional biofuels to 7%. The intention of the Union was to phase out food raw materials and replace it with advanced biofuels, hydrogen cells and electric batteries. However, these advanced systems are still not technologically mature, so for the time being, biofuels have a real justification.

REFERENCES

BAI A., JOBBÁGY P. (2011): Az első generációs bio- üzemanyagok módosuló megítélése, Szakértői tanulmány, Debrecen: GKI Energiakutató és tanácsadó Kft., 70 p.

CSIPKÉS M. (2011): Egyes energianövények gazdasági elemzése, valamint hatásuk a földhasználatra, Doktori (PhD) értekezés, Debrecen: Ihrig Károly Gazdálkodás és Szervezéstudományok Doktori Iskola, 221 p.

HANCSÓK J. (2004): Korszerű motor- és sugárhajtómű üzemanyagok III., Alternatív motorhajtóanyagok, Veszprém: Veszprémi Egyetemi Kiadó, p. 430

SOMAI M. (2004): A magyar mezőgazdaság átalakulása I., Biológiai alapok, struktúraváltás, termelői jövedelmek, Magyar Tudományos Akadémia, Világgazdasági Kutatóintézet, *Műhelytanulmányok*, 64., 22 p.

PUBLICATIONS ON THE TOPIC OF THE DISSERTATION

Articles in scientific journals in English

1. **Lászlók Anett** (2012): The impact of energy crop production on land use in Hungary, Scientific Journal, Warsaw University of Life Sciences – SGGW, Problems of world agriculture, Volume12 (XXVII) 2012 Number 3, p. 59-67., ISSN 2081-6960
2. **Lászlók Anett** (2013): Energy consumption and energy intensity in regard to sustainability in some Central and Eastern European countries, Journal of International Scientific Publications: Economy & Business, Volume 7, Part 1, p. 34-46., ISSN 1313-2555
3. **Lászlók Anett** (2013): Impact of energy crop production on land use in Hungary, Journal of International Scientific Publications: Economy & Business, Volume 7, Part 1, p. 26-33., ISSN 1313-2555

Articles in scientific journals in Hungarian

4. **Lászlók Anett** (2014): A földgázfogyasztás várható alakulása a magyar energiamixben, Journal of Central European Green Innovation**,** 2 (3) p. 81-92., ISSN 2064-3004
5. **Lászlók Anett** (2015): Megújulóenergiaforrás-felhasználás: tervek és tények, A 2020-as célkitűzések jelenlegi és várható teljesítése Magyarországon és a szomszédos országokban, MezőHír Független Agrárinformációs Szaklap, XIX. évfolyam, július, p. 120-122, ISSN 1587-060X
6. **Lászlók Anett** (2019): A szántóföldi növénytermelés teljes tényezős termelékenységének változása Magyarországon 2004 és 2015 között, Acta Carolus Robertus, 9 (1) (megjelenés alatt)

Books, chapters and monographies in a foreign language

7. **Lászlók Anett** (2013): Analysing sustainable energy consumption in Europe from the oil crisis until today, Human Capital and Corporate Responsibility, Challenges for Future, Monograph, Poland, p. 125-141, ISBN 978-83-63500-56-6

Presentations at scientific conferences published in proceedings in a foreign language

8. **Lászlók Anett** (2012): Impact of energy crop production on employment, 7th International Conference for Young Researchers, Breakthrough Points of World Economy in the 21st Century, Gödöllő, CD kiadvány, p. 688-699., ISBN 978-963-269-319-4
9. **Lászlók Anett** (2013): Analysing sustainable energy consumption in Europe, International Scientific Conference "Business Management – Practice and Theory in the 21st Century", Nitra, CD kiadvány, ISBN 978-80-552-1026-1
10. **Lászlók Anett**, Takács István (2019): Prediction of energy cropping trends in some EU countries, 18th Alps Adria Scientific Workshop, 1st - 6th April 2019, Rimini - Cattolica, Italy (megjelenés alatt)

Presentations at scientific conferences published in proceedings in Hungarian

11. **Lászlók Anett** (2012): A bioenergia felhasználás lehetőségei és kockázata: nemzetközi tapasztalatok és felvetések, „Zöld gazdaság és versenyképesség?”, XIII. Nemzetközi Tudományos Napok, Gyöngyös, CD kiadvány, p. 215-222., ISBN 978-963-9941-54-0
12. **Lászlók Anett** (2013): Európa energiafogyasztásának elemzése, Gazdálkodás és Menedzsment Tudományos Konferencia, „Környezettudatos gazdálkodás és Menedzsment”, Kecskemét, p. 960-964., ISBN 978-615-5192-21-0 (II. kötet)
13. **Lászlók Anett** (2014): Energiafogyasztás, energiaintenzitás és gazdasági növekedés Közép-Kelet-Európa egyes országaiban, „Az átalakuló, alkalmazkodó mezőgazdaság és vidék”, XIV. Nemzetközi Tudományos Napok, Gyöngyös, CD kiadvány, ISBN 978-963-9941-76-2
14. **Lászlók Anett** (2014): A földgázfogyasztás várható alakulása Magyarországon, „Az átalakuló, alkalmazkodó mezőgazdaság és vidék”, XIV. Nemzetközi Tudományos Napok, Gyöngyös, CD kiadvány, ISBN 978-963-9941-76-2
15. **Lászlók Anett** (2014): Megújuló energia célkitűzések várható teljesítése, „A magyar és nemzetközi agrár- és élelmiszer-gazdaság lehetőségei”, XXXV. Óvári Tudományos nap, Mosonmagyaróvár, CD kiadvány, p. 347-352., ISBN 978-963-334-193-3 (Tudományos Nap összefoglalók), ISBN 978-963-334-194-0 (Tudományos Nap előadások és poszterek teljes anyaga CD)

16. **Lászlók Anett** (2015): Energianövény termelés a szántóföldön, „A vidék él és élni akar”, II. Gazdálkodás és Menedzsment Tudományos konferencia, Kecskemét, p. 824-828., ISBN 978-615-5192-34-0 (II. kötet)
17. **Lászlók Anett** (2016): Az elsődleges biomassza termelés alakulása Magyarországon, „Innovációs kihívások és lehetőségek 2014-2020 között”, XV. Nemzetközi Tudományos Napok, Gyöngyös, p. 1017-1024., ISBN: 978-963-9941-92-2

Other publications

18. **Lászlók Anett** (2011): A hazai élelmiszergazdaság versenyképessége az élelmiszerek feldolgozottságának függvényében, a világgazdasági folyamatok tükrében, Világgazdasági Kutatóintézet, Bognár József Közgazdaság-kutató Alapítvány pályázata, I. helyezés p. 53