https://doi.org/10.17221/285/2016-AGRICECON

The impact of biofuels production development in the European Union

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Makutenas V., Miceikiene A., Svetlanska T., Turcekova N., Sauciunas T. (2018): **The impact of biofuels production development in the European Union**. Agric. Econ. – Czech, 64: 170–185.

Abstract: The article analyses the effects of the development of biofuel production in the EU (European Union) countries. For this purpose, the authors develop and adapt methodology to determine biofuel production effects considering resource prices, the areas of distribution and employment in the EU. Twenty-seven EU member states are selected for empirical research. Over 98% of production is devoted to first-generation biofuels; therefore, second- and third-generation biofuels are not analysed. The empirical study is carried out by analysing the dynamics of quantitative indicators, and we assess changes in direction by setting the values of qualitative indicators. Quantitative and qualitative indicators are calculated using correlation analysis. The results suggest that the fastest growth of ethanol production in the EU took place in Finland, Ireland and the Netherlands. During the analysed period, Germany and France were the largest producers of ethanol and biodiesel. The regression analysis showed a very strong correlation between the number of jobs created and biofuel production. There is also a very strong correlation between the volume of production of biofuels and land used for biofuel feedstock production. The production of biofuel does not significantly affect food and feed crop prices.

Keywords: biodiesel, effect of production development, ethanol

Most of the world's resources are limited. Such resources as oil and gas are important for the world's economy as a whole, and they are also important elements of national economies: without fuel transport could not operate, freight transportation would be impossible and freedom of movement of people and international trade would diminish. Thus, it has been decided to use resources that are renewable as an alternative to oil and fossil resources.

One such renewable resource is biofuel that is produced from agricultural feedstock, e.g., rape seed, maize, wheat, palm oil and sugarcane. Biofuels in solid, liquid and gaseous forms have been intensively researched, produced and used over the past 15 years (Guo et al. 2014). However, the development of liquid biofuels derived from feedstocks has recently been identified as a threat to the environment and food security (Strümer et al. 2012; Piroli et al. 2015). The assessment of biofuels from an economic point of view reveals interactions between biofuel production volume and the prices of the above-mentioned crops. These interactions are the subjects of scientific discussions, as the increased demand for crops is likely to increase their price according to Bai et al. (2011). From the social aspect, the increase in crop prices may be assessed in two ways; on the one hand, it would increase growers' income and, consequently, social well-being. Ozdemir et al. (2009) stated that biofuel production may reduce the availability of food. From the environmental point of view, biofuel production should reduce carbon dioxide emissions into the atmosphere; however, the process of biofuel production consumes large quantities of water, which can be very valuable in supporting the biodiversity of a certain region; besides, timber harvesting may increase and, consequently, the absorption of CO_2 will decrease. Piroli et al. (2015) estimated the impact of rising bioenergy production on global CO_2 emissions. He claimed that in the medium to long run biofuels significantly reduce global CO_2 emissions; however, in the short-run they may increase CO_2 emissions temporarily.

https://doi.org/10.17221/285/2016-AGRICECON

In most countries that produce and consume biofuels, such production could not exist without state interference through subsidies and other political measures. Biofuel production is also considered to be controversial because of issues of sustainability, although the early literature on biofuels and sustainability stated that they were characterised by excellent sustainability, as biofuels pollute less compared to traditional fuels and are produced from renewable resources. However, in most recent scientific articles the development of biofuel production is no longer thought to be sustainable. They are not sustainable economically because of the above-mentioned state support; i.e., in the absence of direct or indirect state support this industry could not exist. From an environmental viewpoint, scientists such as Jarlet (2011) and Silalertruksa et al. (2012) argue that, in contrast to the assertions of the majority of authors, biofuels are more harmful to the atmosphere and the ozone layer than traditional fossil fuels. Therefore, the question arises of why different authors have assessed biofuel production so variously?

As stated by Lajdova et al. (2016), in times of slow economic growth, the production of renewable energy sources represents a threat for the competitiveness of EU producers as it increases their production costs. The controversial assessments and different assertions of authors raises the question of what impact the development of biofuel production has not only in theory, but also in practice, and which effects are manifested mostly in the EU. For the chosen investigation, the information from 27 EU member states will be used, although since 2013, upon the accession of Croatia, the number of countries has increased to 28 members. Croatia is not included because of the shortage of statistical information, and it is assumed that this will not affect the results obtained. First-generation biofuels account for more than 98% of total biofuel production; therefore, second- and third-generation biofuels are not considered in the course of this research.

The purpose of this study was to develop a research methodology that allows assessment of the impact of biofuel production development in terms of resource prices, land distribution and employment in the EU countries for period 2003–2013.

DATA AND METHODOLOGY

In order to prepare assessment methodology for the impact of biofuel production development in the EU, the methods of scientific literature analysis, logical analysis and synthesis were employed. In the course of the empirical investigation of the impact of biofuel production development in the EU, the methods of statistical data analysis, cluster analysis and regression analysis were applied.

Theoretically, the development of biofuel production should influence employment, the prices of corn and oil plants and the distribution of agricultural land. In this research, production development causes changes according to a theoretical analysis of the effects.

Baier et al. (2009) distinguishes two types of impact of biofuel production development on food prices, direct and indirect. The direct impact on food prices can be estimated using the formula derived from the equation method and the supply and demand indicators, in order to define the market.

$$\Delta p\% = \frac{((B / S(p)) \times B\%)}{(e_d - e_s)(D(p)/(D(p)+B)} \quad (1)$$

Table 1. Indicators selected for the investigation

Variables of the investigation	Databases
Ethanol and biodiesel production (millions of liters)(*x*)	FAO-OECD
Feedstock used for ethanol production (millions of tons)	USDA
Direct and indirect impact on employment caused by biofuel production (units) (*y*)	Euro observer
The amount of saved CO_2 (%)	Eur-Lex and USDA
The share of biofuel in EU market (%)	WEC
Oil price (Brent clause, 1 USD per barrel)	World Bank
Global grain price indices (*y*)	
Global wheat price indices (*y*)	IGC
Global maize price indices (*y*)	
Area dedicated for the growth of feedstock (thousands of ha) (*y*)	Agrilink-Cosimo
Biofuels production according to EU member states (millions of tons)	EIA

Source: composed by authors

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where: $B/S(p)$ is the quantity of EU rape seeds used in the production of biodiesel as a proportion of the global rape seed supply over a 10-year period; ΔB% indicates the percentage change in the EU over the past 10 years; e_s and e_d indicate rape seed supply and demand elasticity; $(D(p)/(D(p) + B))$ is the portion of global rapeseed demand allocated not to biofuel production, but to food and feed. Inserting data into the equation (1) allows us to calculate the percentage change in the price Δp, which reveals how a change in production volume affects the price of the feedstock.

Biofuel production should influence employment, the prices of grain and oil plants and the distribution of agricultural land. In this investigation, the effects of production development are determined according to the results of theoretical analysis of the effects. For the purpose of this investigation, statistical information for the period 2000–2013 from the OECD-FAO, USDA, IGC, World Bank and EUR-Lex databases is used (Table 1).

The following variables were selected for the investigation: (y) are dependent variables, they depend on the changes in total biofuel production volume (x) (in some cases on the changes in the ethanol production volume or biodiesel production volume). Six one-dimensional and three multi-dimensional regression equations were formed in order to verify the claims of Bai et al. and Ajonavic (2011) regarding plant prices. According to Bai et al. (2012), prices are determined by biofuel production volumes, while Ajonavic (2011) argues that the long-term effect on crop prices is minimal, because many other factors also play a role, such as oil prices, crop yield, climate and others.

Research limitations:

– Twenty-seven EU member states were selected. Croatia was not included because during the period of 2003–2013 it was not a member state, meaning that we are faced with a lack of statistical data.
– The investigation includes only first-generation biofuels (ethanol and biodiesel).

Table 2. Equation indicators selected for the investigation

Result	Equation	Value
One-dimensional regression equations		
y (price index of oil plants)	= intercept +/– x (biodiesel production volume),	Determines how the changes in biodiesel production volume will change the price index of oil plants
y (area used for the production of biodiesel feedstock)	= intercept +/– x (biodiesel production volume)	Determines how the changes in biofuel production volume will change area used for the production of biodiesel feedstock
y (wheat price index)	= intercept +/- x (ethanol production volume)	Determines how the changes in biofuels production volume will change the price index of wheat
y (maize price index)	= intercept +/– x (ethanol production volume)	Determines how the changes in biofuel production volume will change the price index of maize
y (area used for the production of ethanol feedstock)	= intercept +/– x (ethanol production volume)	Determines how the changes in biofuel production volume will change area used for the production of ethanol feedstock
y (number of employees)	= intercept +/– x (biofuel production volume)	Determines how the changes in biofuel production volume will change the number of employees due to direct and indirect impact of biofuel production
Multi-dimensional regression equations		
y (price index of oil plants)	= intercept +/– x_1 (biodiesel production volume) +/-$_2$(oil price)	Determines how the changes in biodiesel production volume x_1 and oil price x_2 will change price index of oil plants
y (wheat price index)	= intercept +/– x_1 (ethanol production volume) + x_2(oil price)	Determines how the changes in ethanol production volume and oil price will change the price index of wheat
y (maize price index)	= intercept +/– x_1 (ethanol production volume) +/- x_2(oil price)	Determines how the changes in ethanol production volume and oil price will change the price index of maize

Source: composed by authors

https://doi.org/10.17221/285/2016-AGRICECON

– Because of the lack of statistical data, for the estimation of average growth rate statistical data from 2003 to 2012 were used.

The equations used in the empirical investigation are shown in Table 2.

RESULTS AND DISCUSSION

The EU has declared its support for sources of renewable energy, which include biofuels. In its program 20/20/20 the EU's goal is that biofuels will account for at least 10% of the total volume of fuel in the Union (European Commission 2014). The aim pursued by the programme is that 20% of the energy generated in the EU will come from renewable sources. This indicates that biofuels are not competitive enough to adequately replace fossil fuels, as it is planned to replace only 10% of fuel instead of 20%.

In order to determine the extent of the impact caused by biofuel production development, first we need to analyse biofuel production volumes within the EU and in individual member states. The pace of biofuel production development can be determined using the average growth rate index (Figure 1).

The analysis of ethanol and biodiesel production dynamics shows that, comparing 2003 to 2013, biodiesel production has grown more than 14 times – from 719 million litres in 2003 to 10 077 million litres in 2013, and ethanol production increased more than three times, from 1969 million litres in 2003 to 6746 million litres in 2013. The highest production volume was reached in 2010, when the total production volume was 17 116 million litres. Since 2011 production volume has declined, with one of the reasons being increasing grain prices and decreased production of biodiesel; in addition, changing EU policy, the guidelines of which were altered after rapid increases in grain and food prices, may have had some influence. Nevertheless, the total biofuel production volumes have not decreased significantly, and bioethanol production has grown, although not as rapidly as before. The reason for this might have been the increasing oil prices.

The EU has been supporting the production of biofuels with political measures since around 2003; at that time the production of biofuels was carried out in 10 states out of the 27 analysed in this work (Table 3). Therefore, for the calculation of the average growth rate in the base year, the year 2006 was chosen, when 26 of 27 EU member states were engaged in the production of ethanol (Luxembourg did not produce ethanol within the analysed period).

According to data of 2012, the largest ethanol producers in the EU are Germany and France, accounting for 1873 million litres and 1368 million litres, respectively (Table 3). This result is not surprising, since these two countries are among the largest in terms of area, population and number of vehicles in the EU.

Ethanol production grew fastest in Finland; from 2006 to 2012 ethanol production was increasing on average by 44.95% every year. However, ethanol production volumes did not grow in all member states. In Malta, ethanol was produced from 2006 to 2009; production was then discontinued because of unmet expectations. One of the reasons for the disappointing results is that Malta is an island with limited local resources.

Nine EU member states out of the 27 analysed were engaged in biodiesel production in 2003 (Table 4); from the beginning of the analysed period this production has been dominated by France and Germany. They produced 16 094 and 30 865 million litres of biodiesel, respectively.

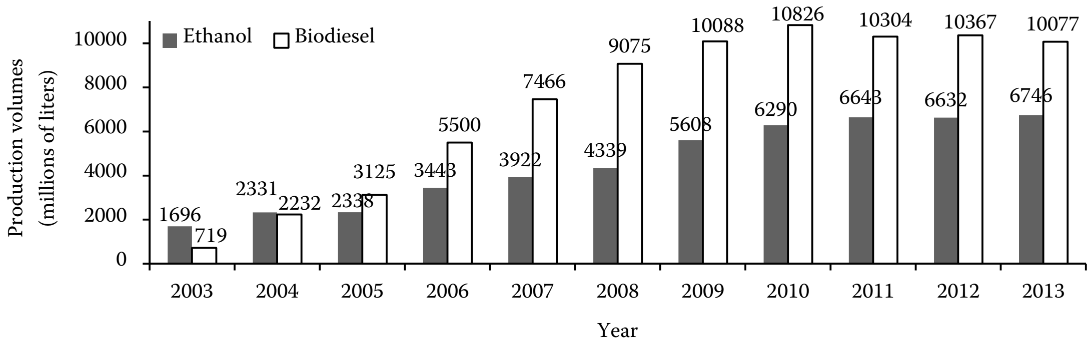

Figure 1. Ethanol and biodiesel production volumes in millions of liters during the period of 2003–2013

Source: composed by the authors according to FAO-OECD (2014)

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In 2012 biodiesel was produced in 25 out of 27 member states; Malta, as for bioethanol production, discontinued the production of biodiesel in 2008. Luxembourg was not engaged in biofuel production during the analysed period.

The most rapid growth of biodiesel production from 2006 to 2012 was in Ireland and the Netherlands; biodiesel production volumes in these countries increased on average by 73.5% and 52.6%, respectively. Biodiesel production volumes did not grow in all EU member states; for example, in Great Britain, biodiesel production volume decreased by approximately 15.2%, and in Italy by 1.7% yearly. In Italy biodiesel production began to decrease in 2009, in Great Britain the volume started decreasing in 2007.

The value of biofuel production is best described by its share of the common liquid fuels market (Figure 2). In 2003, that share was only 0.5%, quite small, because until 2003 the EU did not pursue active policies in this sector and did not apply support measures, such as quotas, subsidies and other actions. Although the greatest total volume of biofuels (ethanol and biodiesel) in the EU was produced in 2010 amounting to 17 116 million litres, the share of biofuels amounted to only 4.7% of total fuel production. In 2012, the share of biofuels amounted to 5.1%, the largest share of total transport fuel production throughout the entire period under study (16 936 million litres).

The share of biofuels in transportation has increased despite the decrease in production. It can be assumed that overall transportation fuel demand and production decreased, resulting in an increase in the share of biofuels, as the production of biofuels decreased at a slower pace compared to the decrease in fossil fuel production.

Table 3. Ethanol production volumes in millions of liters and average production pace in percent according to EU member states within the period of 2003–2012

Producing countries	Ethanol production volumes in millions of liters				Average rate of production growth in %
	2003	2006	2009	2012	
Austria	30.04	67.05	207.37	272.51	22.18
Belgium	0.00	13.69	255.60	426.66	63.45
Bulgaria	0.00	2.79	9.65	5.51	10.18
Cyprus	0.00	0.56	4.82	4.95	36.58
Czech Republic	111.66	69.85	120.57	162.41	12.81
Denmark	44.06	39.11	41.23	55.05	5.00
Estonia	0.00	0.56	12.06	1.38	13.74
Finland	0.00	11.18	108,51	143.14	43.95
France	450.66	463.78	1398.56	1368.08	16.71
Germany	701.03	1659.54	1398.56	1873.74	1.75
Greece	0.00	25.14	33.76	63.31	14.10
Hungary	0.00	16.76	122.98	118.92	32.30
Ireland	0.00	1.12	33.76	24.77	55.69
Italy	265.39	385.55	400.28	294.81	–3.76
Latvia	0.00	8.38	28.94	34.68	22.49
Lithuania	0.00	13.97	57.87	50.98	20.31
Malta	0.00	1.12	0.48	0.00	x
Netherlands	0.00	18.16	130.21	258.75	46.16
Poland	50.07	111.75	217.02	366.11	18.47
Portugal	0.00	44.70	118.15	143.14	18.09
Romania	0.00	5.59	16.88	52.30	37.64
Slovakia	2.00	47.50	96.45	74.18	6.58
Slovenia	0.00	2.79	3.38	2.75	–0.21
Spain	250.37	229.09	506.38	456.94	10.37
Sweden	54.08	64.26	156.74	217.46	19.02
Great Britain	10.01	139.69	127.80	159.65	1.93

Note: converted from barrels per day to millions of liters per year

Source: composed by the authors according to EIA (2014)

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Table 4. Biodiesel production volumes and average production pace according to EU member states during the period of 2003–2012

Producing countries	Biodiesel production volumes in millions of liters				Average rate of production growth in %
	2003	2006	2009	2012	
Austria	13.23	137.31	355.00	421.24	17.37
Belgium	0.00	28.03	471.39	523.54	51.92
Bulgaria	0.00	5.72	23.28	12.04	11.21
Cyprus	0.00	1.14	11.64	10.83	37.86
Czech Republic	49.16	125.87	174.59	180.53	5.29
Denmark	19.40	80.10	98.93	108.32	4.41
Estonia	0.00	1.14	29.10	3.01	14.81
Finland	0.00	0.00	250.24	312.92	–
France	160.94	663.68	2386.05	1967.78	16.80
Germany	308.65	2975.10	2618.84	3291.67	1.46
Greece	0.00	51.49	81.47	138.41	15.17
Hungary	0.00	0.00	145.49	168.49	–
Ireland	0.00	1.14	69.84	54.16	73.50
Italy	116.84	663.68	907.86	589.73	–1.67
Latvia	0.00	5.72	52.38	69.81	42.95
Lithuania	0.00	11.44	110.57	102.30	36.74
Malta	0.00	2.29	1.16	0.00	–
Netherlands	0.00	20.02	314.26	385.13	52.56
Poland	0.00	114.43	349.18	583.71	26.21
Portugal	0.00	91.54	285.16	312.92	19.20
Romania	0.00	11.44	34.92	90.27	34.32
Slovakia	0.88	91.54	116.39	108.32	2.43
Slovenia	0.00	5.72	8.15	6.02	0.72
Spain	44.09	68.66	756.55	523.54	33.67
Sweden	1.76	57.21	203.69	312.92	27.47
Great Britain	4.41	286.07	232.79	90.27	–15.19

Note: converted from barrels per day to millions of liters per year

Source: composed by the authors according to EIA (2014)

Taken together, the production of biofuels in the EU began to expand rapidly only since 2004, and the greatest number of biofuel-producing member states was reached in 2006. This can be attributed to the political measures introduced at the EU level, which have accelerated the development of biofuel production and increased biofuels' share of overall fuel production.

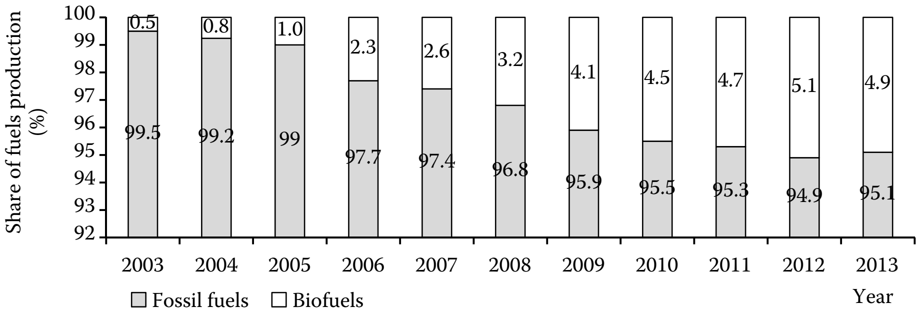

Figure 2. Share of biofuels and fossil fuels in the fuels production in the EU within the period of 2003–2013

Source: composed by the authors (WEC 2015)

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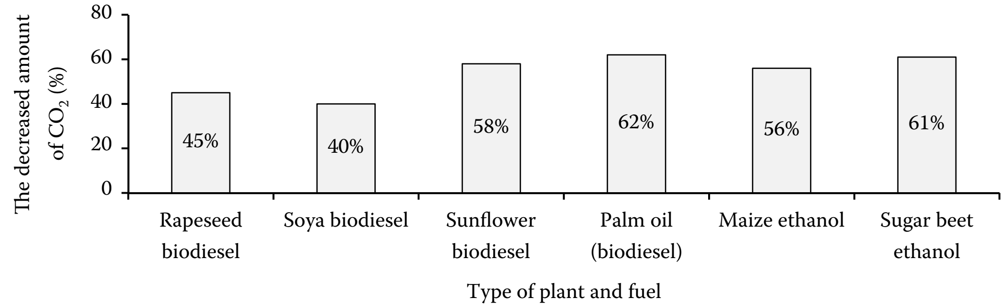

Figure 3. The amount of saved greenhouse gas emissions according to the type of biofuel and plant

Source: composed by the authors according to Eur-Lex (2009)

There are no accurate statistical data that could be used to determine the impact of biofuel production development on the environment. However, we use data, obtained using different methodologies that show the percentage decrease in CO_2 if biofuels were used.

When estimating the reductions in CO_2 emissions, the European Commission has included not only the amount of emitted carbon dioxide and compared it with the amount of carbon dioxide emitted from the burning of mineral fuels, but also assessed the amount of CO_2 emitted during the production process, i.e., during the refinement and distribution of biofuels. The greatest savings in greenhouse gas emissions are achieved through the production and use of palm oil; CO_2 emissions are 62% lower compared to traditional fossil fuels (Figure 3). The production of ethanol from sugar beet results in CO_2 emissions that are 61% lower compared to those from mineral fuels. The smallest savings in CO_2 are achieved by producing biodiesel from soybeans. Estimating CO_2 reduction using this methodology is quite accurate; however, the impact on areas and land distribution is not included, and thus emission results may still differ.

In the model created by Aglink-Cosimo (FAO 2014), the indirect impact on land distribution was assessed; he found that not only was CO_2 emission not reduced, but that an increased level of CO_2 was emitted into the environment (Figure 4).

In most of the analysed scenarios the amount of CO_2, when biofuels are used, decreases by between 4% and 80%; however, in some cases the development of biofuel production changes distribution, e.g., areas

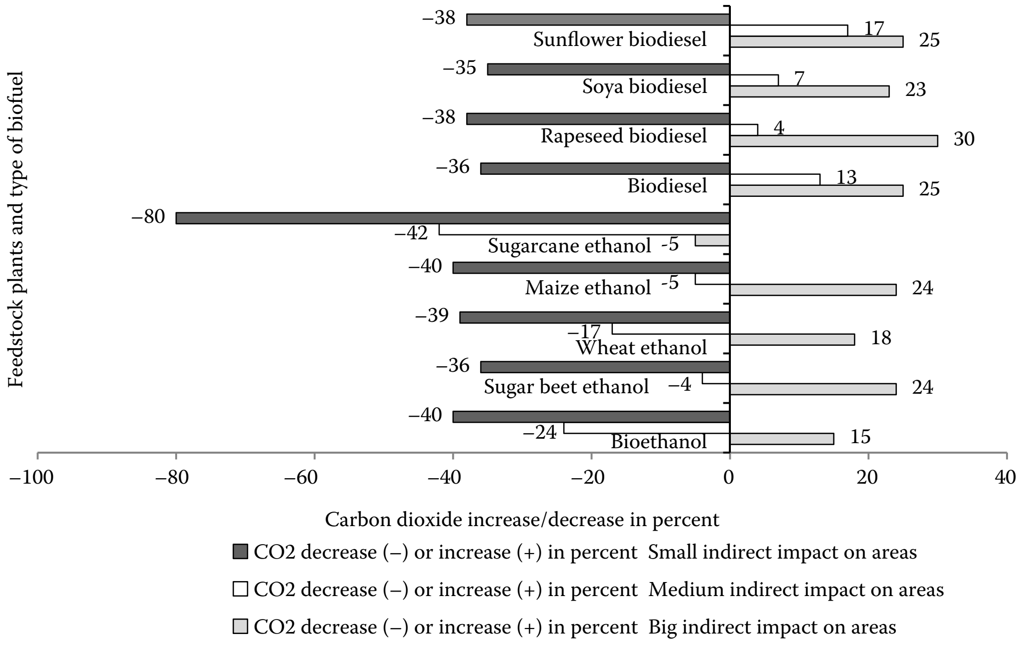

Figure 4. Percentage of carbon dioxide gas decrease or increase caused by indirect impact on land distribution

Source: composed by the authors according to FAO Aglink-Cosimo (2015)

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of feedstock plants expanding into wooded areas, in which case the amount of CO_2 does not decrease but instead increases, because due to land redistribution a smaller amount of carbon dioxide is absorbed.

Biodiesel reduces the amount of CO_2 emitted only when there is no effect on land distribution, or when the effect is relatively small; otherwise, CO_2 emission increase by 13% and 25%, respectively, and in case of ethanol production, by 24% and 40%, respectively (Figure 4). The greatest positive effect would be caused by ethanol use and production from sugarcane – carbon dioxide emissions should decrease by 80%; however, in the EU sugarcane is hardly grown because of climatic conditions, i.e., sugarcane would have to be imported in order to meet the demand for ethanol production. That would impair the balance of trade and cause indirect land use change. To sum up, the developed methodologies may be used to evaluate the benefits resulting from the changes in greenhouse gas emissions, but it is important to consider that different methodologies generate different results.

One of the major reasons why biofuels are so controversial is the fact that their production requires the same feedstock as the production of food and feed; this results in direct competition for resources, or indirect competition, for example, through land distribution, fertilisers, etc.

In the EU, the main feedstock for biodiesel production is rapeseed (Figure 5); during the analysed period this crop accounted for 75–80% of the total quantity of feedstock used to produce biodiesel. Soya or, more precisely, the soybean, is another plant species used to produce biodiesel; during the analysed period soybeans accounted for 7–15% of the total quantity of feedstock dedicated to the production of biodiesel. In the EU, soybeans are hardly grown; therefore, most of them have to be imported and this impairs the balance of trade. A similar situation is observed with palm oil; it is imported from Malaysia, where palm oil production is well developed. In such a case, the development of production increases feedstock imports, has a negative effect on the trade balance and has an indirect negative impact on employment, since the feedstock production and workplaces are located outside the EU.

In the EU, the dominant feedstock for ethanol production is sugar beet (Figure 6); its share during the analysed period ranged from 47% to 61% of the total quantity of feedstock used to produce ethanol. The largest amount – 10 198 million tons – was used in 2008.

Anther plant species used as feedstock is wheat, which is used not only for industrial purposes or feed, but for food as well. Thus, biofuel production results in direct competition for resources, as wheat is directly used in food industry. In the case of ethanol production, wheat accounted for 17–24% of overall feedstock used in production; the largest amount of wheat used to produce ethanol was reached at the

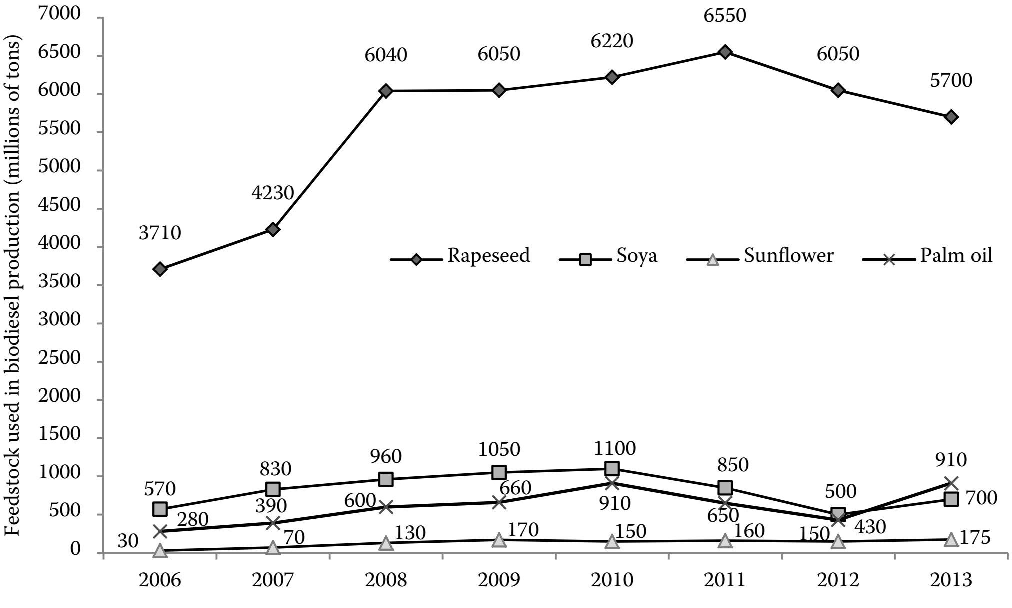

Figure 5. The amount of feedstock used in biodiesel production

Source: composed by the authors according to USDA (2015)

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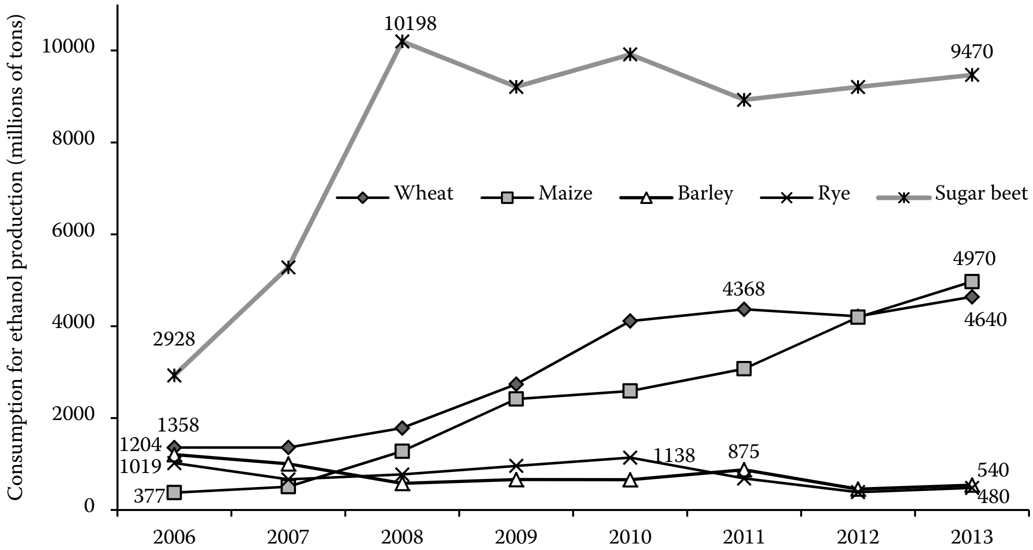

Figure 6. The amount of feedstock used in ethanol production in millions of liters

Source: composed by the authors according to USDA (2015)

end of the analysed period, in 2013, and amounted to 4640 million tons. Since 2013, the amount of maize feedstock has exceeded the wheat feedstock used in the production of biofuels and in 2013 it amounted to 4970 million tons.

Using the formula of Bairer et al. (2012) derived from an equality equation and applying data from the FAO-OECD database, it was estimated that during the analysed period, from 2003 to 2013, the price of oil plants increased by 7.2% as a result of biodiesel production, the price of wheat increased by 4.6% as result of ethanol production and the price of fodder plants increased by 5.1% (Table 5).

Hence, Figures 5 and 6 reveal that fodder plants and food plants such as wheat are the predominant feedstocks used in biofuel production, both of ethanol and biodiesel. The share of the indicated crops revealed that some of the feedstock is imported into

Table 5. Impact on prices expressed in equality method

Plant Group	Price increase Δp %
Oil plants	7.2
Wheat	4.6
Fodder plants	5.1

Source: composed by authors

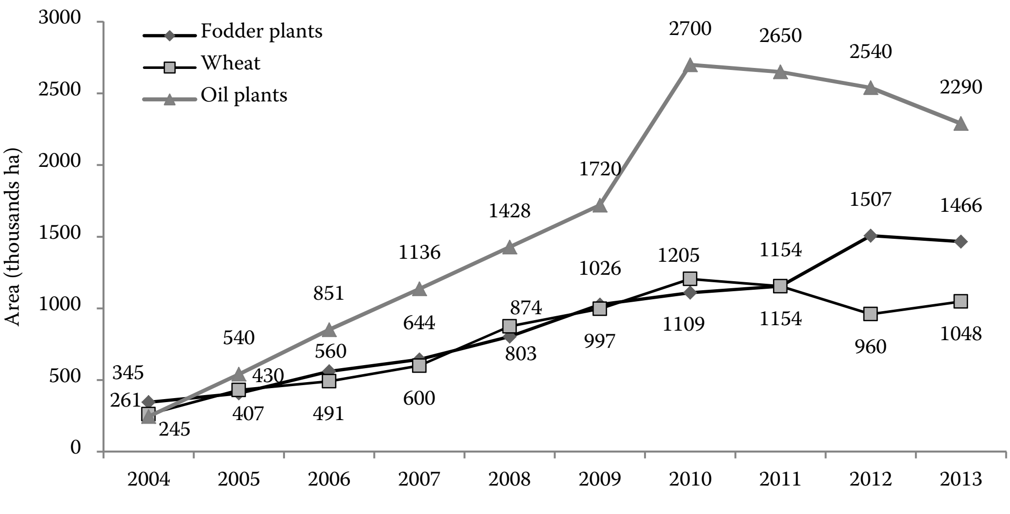

Figure 7. The area used to grow biofuels feedstock, thousands ha

Source: composed by the authors according to FAO Aglink-Cosimo (2014)

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the EU from third countries, as these plants and feedstock, such as soya and palm oil, are not widely grown or extracted in the EU. In fact, Europe is the largest importer of bioenergy with imports amounting to 485 PJ in 2011 (WBA 2014).

Biofuels and the development of their production are often criticised because they elicit direct and indirect competition for resources. One of the issues raising many debates is land distribution, as an increase in biofuel production expands the area of land used for feedstock production (Figure 7).

The expansion of areas intended for biofuel feedstock production reduces the availability of resources and, consequently, worsens food security. The largest areas intended for biofuels feedstock production were allocated to oil plants; the largest utilized area was reached in 2013, suggesting an increasing demand for oil plant feedstock (Figure 7).

Every new sector or production branch creates workplaces, and the biofuel production sector is no exception. It creates new job opportunities both directly and indirectly, in biofuel plants, i.e., refineries, etc. EuroObserver (2014) presents data on the number of workplaces directly or indirectly generated as a result of biofuel production (Table 6).

The largest number of job opportunities that emerged as a result of the direct and indirect impacts of biofuel production were found in Germany and France in 2013, amounting to 30 000 and 25 600 workplaces, respectively (Table 5); this is to be expected because these two countries are the largest producers of biofuels in the EU. In 2013, the increases in the number of employees caused by the direct and indirect impacts of biofuel production were highest in Romania and Bulgaria, 355% and 257% higher, respectively, compared to 2008 levels. In Romania,

Table 6. The number of workplaces directly and indirectly created by biofuels production

Member state	Number of workplaces						Change in % comparing 2013 to 2008
	2008	2009	2010	2011	2012	2013	
France	21 000	27 800	28 000	29 900	30 000	30 000	43
Germany	20 600	20 900	23 200	23 200	22 700	25 600	24
Belgium	7 650	8 040	8 570	8 920	9 920	9 920	30
Spain	8 070	9 810	10 805	10 680	9 435	5 000	-38
Poland	4 560	4 850	4 970	4 750	5 480	7 500	64
Italy	3 330	3 580	3 755	3 860	5 270	5 000	50
Austria	4 100	4 250	4 320	4 320	4 580	4 925	20
United Kingdom	4 480	5 120	5 940	6 150	4 420	3 500	–22
Hungary	3 250	3 330	3 650	3 520	4 230	4 160	28
Sweden	3 200	3 500	3 500	3 700	4 140	5 000	56
Czech Republic	2 225	2 355	2 495	2 600	2 925	2 800	26
Slovakia	1 855	2 245	2 460	2 590	2 590	2 720	47
Portugal	975	1 450	1 800	1 775	1 830	1 750	79
Finland	1 260	1 260	1 540	1 540	1 540	1 000	–21
Romania	220	1 800	1 940	1 600	925	1 000	355
Lithuania	620	700	700	760	840	800	29
Bulgaria	210	260	310	310	790	750	257
Denmark	600	600	750	770	770	1500	150
Netherlands	500	640	709	700	700	600	20
Latvia	350	350	400	420	570	500	43
Greece	390	460	480	480	490	700	79
Ireland	270	270	270	310	310	400	48
Luxemburg	100	150	150	200	200	250	150
Slovenia	100	125	125	150	200	350	250
Cyprus	50	50	50	50	50	50	0
Estonia	50	50	50	50	50	50	0
Malta	20	20	0	0	0	0	–

Source: composed by the authors according to EuroObserver (2014)

https://doi.org/10.17221/285/2016-AGRICECON

the largest increase could be observed between the years 2008 and 2009. This can be attributed to the accession of Romania into EU in 2007. In the case of Bulgaria, the most obvious increase in the number of workplaces occurred between 2011 and 2012. This is due to the fact that the blending of biofuels with fossil fuels became mandatory in Bulgaria in 2012.

The numbers of employees were not increased in all member states of the EU in 2013 compared to 2008; for example, in Finland, a decreased of 21% was observed, and the number of workplaces decreased in 2013. Also in the UK, the number of workers engaged in the development of biofuel production decreased by 22% in 2013 compared to 2008 levels. This may be linked to the diminished production of biofuels in the country.

The extent of biofuel production development is defined by the total production volume of biofuels in millions of tons (x) or by the production volume of ethanol and biodiesel in millions of tons. For the analysis of the dependence among the prices of oil plants, biodiesel production volume was chosen as an intercept, and the price index of oil plants and area used for the biodiesel feedstock production in thousands of ha were denoted by (y).

Analysis of the numerical characteristics of indicators for the 2003–2013 period showed that the average price index of oil plants was 207.35. The average area utilised for biodiesel feedstock production during the period 2003–2013 amounted to 1477.35 thousand ha. The average wheat price index was 230.99, and maize price index – 202.19. The average area utilised for ethanol feedstock production during the period 2003–2013 amounted to 1510.70 thousand ha.

It may be noted that, on average, the area used for ethanol feedstock production is larger by nearly 33.4 thousand ha than the area used for biodiesel feedstock production in the EU. During the analysed period, employment related to biofuel production in the EU reached approximately 104 136 workplaces.

The indicator of concentration about the average is obtained by comparing the standard error to the average. The indicator of concentration about the average shows the accuracy of the sample average. From all the variables, area used for ethanol feedstock production and employment stand out; the estimated values of these indicators are 5.02% and 3.78%, respectively, i.e., less than 10%. The least accurate average is area used for biodiesel feedstock production, as the concentration about the average is 23.85%, i.e., more than 10%.

Based on the numerical characteristics of indicators it can be stated that largest dispersion is observed for the area used for biodiesel feedstock production (65.63%), the area used for ethanol feedstock production (52.02%), maize price index (40.53%), wheat price index (34.52%) and price index of oil plants (32.20%) as the coefficients of variation (CV) are higher than 20%. Employment dispersion is moderate, as 10% < CV < 20%.

After the analysis of numerical characteristics, correlation analysis was carried out, which allowed us to assess the impact of biofuel (biodiesel and ethanol) production development on areas, prices, employment and the interdependence of the factors (R); one-dimensional regression equations were formed and elasticity was estimated.

The credibility of the formed regression model is assessed at $p < 0.05$, which means that the results are statistically significant.

The average coefficient of elasticity was calculated in order to determine by how many percent the value of the dependent variable y (area, plant prices and the number of employees) will change in relation to the average when the value of the independent variable x (biofuel production, ethanol, biodiesel production)

Table 7. Numerical characteristics of indicators

Indicators	Average	Standard deviation	Standard error	Concentration about the average	Coefficient of variation (CV)
Price index of oil plants (y_1)	207.35	66.98	24.36	11.75	32.30
Area used for biodiesel feedstock production. thousands ha (y_2)	1 477.35	969.57	352.42	23.85	65.63
Wheat price index (y_3)	230.99	79.73	46.22	20.01	34.52
Maize price index (y_4)	202.19	81.95	26.73	13.22	40.53
Area used for ethanol feedstock production. thousands ha (y_5)	1 510.70	785.81	75.84	5.02	52.02
Number of workplaces (y_6)	104 136.25	14 068.92	3 940.00	3.78	13.51

Source: composed by the authors

https://doi.org/10.17221/285/2016-AGRICECON

Table 8. Impact of biofuels production development on areas, prices and employment

Indicators	R	R^2	Equation	P (significance of probability)	B (coefficient of regression)	E (coefficie-nt of elasticity)
Impact of biodiesel production						
Price index of oil plants (y_1)	0.939	0.88	$85.13 + 0.02x$	0.00002	0.017	0.59
Area used for the production of biodiesel feedstock. thousands ha (y_2)	0.939	0.88	$292.16 + 0.24x$	0.00002	0.244	1.20
Impact of ethanol production development						
Wheat price index (y_3)	0.835	0.70	$64.68 + 0.036x$	0.00137	0.036	0.72
Maize price index (y_4)	0.951	0.90	$7.59 + 0.042x$	0.00001	0.042	0.96
Area used for the production of ethanol feedstock. thousands ha (y_5)	0.996	0.99	$443.43 + 0.42x$	0.00001	0.424	1.29
Impact of biofuel production						
Employment (y_6)	0.966	0.93	$39919.80 + 4.38x$	0.00010	4.380	0.50

Source: composed by the authors

increases by 1% from the average; the results are presented in Table 8.

Analysis of data by correlation coefficients (R), allows us to state that a very strong positive relationship exists between biofuel production and the price index of oil plants, area used for the production of biodiesel feedstock, maize price index, area used for ethanol feedstock production and the number of employees ($0.9 \le |R| \ge 1$).

The very strong relationship between the price index of oil plants and biodiesel production is confirmed by the obtained correlation coefficient ($R = 0.94$), while the linear dependence and statistical significance is confirmed by the fact that $p < 0.05$. The coefficient of determination (R^2) shows that the regression equation $85.13 + 0.017x$ is suitable for predicting the impact of biodiesel production development, whereas 88% of the change in the oil plant price index can be explained by the change in biodiesel production volume. The estimated coefficient of elasticity (E) shows that if x (biofuel production) increases by 1%, y (price of plants) would increase by 0.59%.

Also, a very strong dependence between biodiesel production and area used for biodiesel feedstock production, is confirmed by the obtained correlation coefficient ($R = 0.94$); linear dependence and statistical significance is confirmed by $p < 0.05$. The coefficient of determination (R^2) shows that the regression equation $292.16 + 0.244x$ is suitable for predicting the production of biodiesel, whereas 88% of the changes in oil plant area can be explained by the change in biodiesel production volume. The coefficient of elasticity shows that if x (biodiesel production) increases by 1%, y (area used for the production of biodiesel feedstock) would increase by 1.2%.

A strong dependence between ethanol production and the wheat price index is confirmed by the obtained correlation coefficient ($R = 0.84$). Linear dependence and statistical significance is confirmed by $p < 0.05$. The coefficient of determination (R^2) shows that the regression equation $64.68 + 0.036x$ is suitable for predicting the development of ethanol production. The estimated coefficient of elasticity shows that if x (ethanol production) increases by 1%, y (wheat price) would increase by 0.72%.

A very strong dependence between ethanol production and the maize price index is confirmed by the obtained correlation coefficient ($R = 0.95$). Linear dependence and statistical significance is confirmed by $p < 0.05$. The coefficient of determination (R^2) shows that the regression equation $7.59 + 0.042x$ is suitable for predicting the development of ethanol production. The estimated coefficient of elasticity shows that if x (ethanol production) increases by 1%, the y (maize price) value would change by 0.96%.

A very strong dependence between ethanol production and area used for ethanol feedstock production is confirmed by the obtained correlation coefficient ($R = 0.996$). Linear dependence and statistical significance is confirmed by $p < 0.05$. The coefficient of determination (R^2) shows that the regression equation $-443.43 + 0.424x$ is suitable for predicting the development of ethanol production. The estimated coefficient of elasticity shows that if x (ethanol pro-

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duction) increases by 1%, the y (area used for ethanol feedstock production) value would increase by 1.29%.

A very strong dependence between employment and biofuel production is confirmed by the obtained correlation coefficient (R = 0.97). Linear dependence and statistical significance is confirmed by $p < 0.05$. The coefficient of determination (R^2) shows that the regression equation 39919.80 + 4.38x is suitable for predicting the development of biofuel production. The estimated coefficient of elasticity shows that if x (ethanol production) increases by 1%, the y (number of employees) value will change by 0.5%.

Thus, the completed statistical investigation and summarised data allow us to state that a very strong relationship links the price index of oil plants and area used for biodiesel feedstock production to the changes in biodiesel production. A very strong relationship exists between ethanol production and the maize price index, as well as the area used for ethanol feedstock production. Also, a very strong relationship exists between employment and biofuels, because $0.9 \leq |R| \geq 1$. A strong dependence exists between the wheat price index and ethanol production, because $0.7 \leq | E | \geq 0.9$. The estimated coefficients of elasticity show that the area used for ethanol feedstock production would change the most if the production of ethanol increased by 1% (the area would change by 1.29%). The area used for biodiesel feedstock production would also change significantly if the production of biodiesel increased by 1% (the area would be enlarged by 1.2%).

The one-dimensional regression analysis of the development of biofuel production allows us to state that ethanol production development has the greatest impact on the area intended for biofuel feedstock production. If ethanol production increases by 1 million litres, the area used for ethanol feedstock production would increase in size by 0.42 thousand ha, while an increase in biodiesel production by 1 million litres would increase the area by 0.24 thousand ha. Ethanol production volume also has the greatest impact on the price of food and feed plants; the greatest impact is on the price of maize – if ethanol production increases by 1 million litres, the maize price index would rise by 0.04. An increase in the volume of biofuel production by 1 million litres creates 4.38 new workplaces. Hence, the performed one-dimensional regression revealed that the development of biofuel production has an impact on prices, area and job creation in both food and feed plants. However, in order to verify the claims of Bai et al. (2012) and Ajonovic (2011), a multi-dimensional regression analysis needs to be performed.

Multi-dimensional regression analysis is applied when there is more than one independent interval variable. In such cases, multi-dimensional regression is applied in order to determine how biofuel production and oil price affects wheat, maize and oil plant prices.

A strong relationship exists between ethanol production, oil price and wheat price, as shown by the fact that R = 0.855; the coefficient of determination indicates that 73.1% of wheat price is determined by the selected variables. Linear dependence and statistical significance is confirmed by $p < 0.05$. The equation $52.16092 + + 0.99239x_1 + 0.02254x_2$ shows that oil price has the highest impact on wheat price; if the former rises by 1 USD/bbl., the grain price index would increase by 0.99, while an increase in ethanol production of 1 million tons would result in the grain price index increasing by 0.028%.

Table 9. The impact of biofuel production development and oil price on wheat, maize and oil plants prices (composed by the authors)

Indicators	R	R^2	Equation	p
Wheat price index (y)				
Oil price (Brent). USD/bbl. (x_1) Ethanol production. million liters (x_2)	0.855	0.731	$52.16092 + 0.99239x_1 + 0.02254x_2$	0.00523
Maize price index (y)				
Oil price (Brent). USD/bbl. (x_1) Ethanol production. million liters (x_2)	0.969	0.939	$55.5379 + 1.04063x_1 + 0.02802x_2$	0.00001
Price index of oil plants (y)				
Oil price (Brent). USD/bbl. (x_1) Biodiesel production, million liters (x_2)	0.947	0.898	$69.64638 + 0.57050x_1 + 0.01305x_2$	0.00011

Source: composed by authors

https://doi.org/10.17221/285/2016-AGRICECON

Table 10. The impact of biofuel production development and oil price on wheat, maize and oil plants prices

Variable	$\bar{y}_i$	$\bar{x}_j$	b_j	E_j	Description
					Impact on wheat price
X_1	230.99	75.51	0.99	0.32	If oil price increased by 1%, wheat price should increase by 0.32%.
X_2		231	0.02	0.02	If ethanol production increased by 1%, wheat price should increase by 0.02%.
					Impact on maize price
X_1	202.1855	75.51	1.04	0.39	If oil price increased by 1%, maize price would rise by 0.39%.
X_2		230.99	0.03	0.03	If ethanol production increased by 1%, wheat price should increase by 0.03%.
					Impact on oil plants price
X_1	207.3491	75.51	0.57	0.21	If oil price increased by 1%, oil plants price would rise by 0.21%.
X_2		207	0.13	0.13	If biodiesel production increased by 1% wheat price should increase by 0.13%.

Source: composed by authors

A strong relationship exists between ethanol production, oil price and wheat price, which is demonstrated by the fact that R = 0855; the coefficient of determination indicates that 73.1% of the wheat price is determined by the selected variables. Linear dependence and statistical significance is confirmed by $p < 0.05$. The equation $52.16092 + + 0.99239x_1 + 0.02254x_2$ shows that oil price has the highest impact on wheat price, if the former rises by 1 USD/bbl., the grain price index would increase by 0.99, while an increase in ethanol production of 1 million tons would result in the grain price index increasing by 0.028%.

Maize price is influenced by oil price and ethanol production volume, which is indicated by a very strong correlation coefficient, $R = 0.97$, and coefficient of determination $R^2 = 0.94$; the change of 0.94% can be explained by the changes in oil price and ethanol production volume. Linear dependence and statistical significance is confirmed by $p < 0.05$. The equation $55.53 + 1.04063x_1 + 0.02802x_2$ shows that a rise in the oil price by 1 USD/bbl. causes the maize price index to rise by 1.04.

The relationship between the oil plant price index and the oil price is very strong; $R = 0.95$, coefficient of determination $R^2 = 0.90$. Linear dependence and statistical significance is confirmed by $p < 0.05$. Autocorrelation is not present; thus, the $69.64638 + 0.57050x_1 + 0.01305x_2$ equation can be considered credible.

In order to estimate coefficients of elasticity of multi-dimensional regression variables the numerical characteristics were used. These were obtained using the statistical software package Statistica and the results have been discussed above. The obtained coefficients of elasticity and their descriptions are presented in Table 10.

The obtained results show that the greatest impact on biofuel feedstock price is caused by oil price, and not by biofuel volume. The calculation of the coefficient of elasticity allows us to state that if the oil price rises by 1%, then the wheat price should increase by 0.32%. If ethanol production increases by 1%, wheat price should increase by 0.02%. If oil price increases by 1%, maize price will rise by 0.39%. If ethanol production increases by 1%, wheat price should increase by 0.02%. If oil price increases by 1%, the price of oil plants will rise by 0.21%, while a 1% increase in biodiesel production will elicit a 0.13% increase in the price of wheat.

In summary, it can be concluded that the development of biofuel production during the period 2003–2013 did not have a significant impact on the prices of food and feed crops, although a strong or very strong relationship exists between the price of food and feed crops and production volume. The multi-dimensional regression analysis revealed that when more factors are considered, and not just the production volumes of biofuels (x_1), changes in ethanol or biodiesel production volumes have less impact on the price of feedstock crops than, for instance, oil price x_2. Thus, our investigation has revealed that a relationship does exist between grain price, oil price and biofuel production volume, but the prices of food and feed crops are more influenced by oil price than biofuel production volume; indeed, it should be borne in mind that grain price is affected by many other factors, e.g., crop yield.

https://doi.org/10.17221/285/2016-AGRICECON

CONCLUSION

The research methodology that we employed here to determine the impact of biofuel production is based on the work of scientists who had previously researched this issue (Baier et al. 2009; Ajonavic 2011; Bai et al. 2012). The impact on feedstock price was analysed by linking biofuel production volume to the prices of oil and maize using a balance equation, which reveals what portion of price change is caused by production volume change. The chosen method of elasticity ought to reveal how a 1% change in biofuel (ethanol and biodiesel) production volumes would change the price of biofuel feedstock crops. The impact on land distribution is linked to the production volume, as well as the analysis of the impact on the number of workplaces.

The aim of this study was to analyse changes in biofuel production, their extent and significance to the EU and the effects caused by the development of biofuel production. It can be concluded that in the case of ethanol production, sugar beet, wheat and maize were the main feedstocks during the analysed period. On the other hand, for biodiesel production, rapeseed, soya and palm oil were mainly used. Hence, in most cases, fodder plants as well as food plants, for example, wheat, are used as feedstocks for the production of both ethanol and biodiesel. A proportion of the used feedstock is imported into the EU from third countries, as soybean oil and palm oil are not widely grown within the EU. Thus, the desired effect of improving trade balance by increasing biofuel production volume is not fully achieved, because a part of the feedstock needs to be imported.

The calculation of the average growth rate allows us to state that ethanol production grew fastest in Finland; from 2006 to 2012 ethanol production increased on average by 44.95% every year. The most rapid rates of growth in biodiesel production between 2006 and 2012 were observed in Ireland and the Netherlands; biodiesel production volumes in these countries increased on average by 73.5% and 52.6%, respectively, every year. Biodiesel production volumes did not grow in all EU member states; for example, in Great Britain biodiesel production volumes decreased by approximately 15.2%, and in Italy – by 1.7% yearly. The largest ethanol and biofuel producers in the EU during the analysed period were Germany and France.

According to WEC data, in 2003 biofuels accounted for 0.5% of overall transportation fuel production. Until 2003, the EU did not pursue active policies in this sector and did not apply support measures such as quotas and subsidies, etc. Following the introduction of political measures in 2003, and the permission granted to member states to support this sector, biofuel's share of total fuel production increased almost 10-fold by 2013.

Using the balance equation formula of Barier et al. (2009) and applying data from the FAO-OECD database, it was estimated that during the analysed period 2003–2013 the development of biodiesel production caused a 7.2% increase in the price of oil plants; the development of ethanol production resulted in a 4.6% increase in the price of wheat; and the price of fodder plants increased by 5.1%. Furthermore, the one-dimensional regression analysis showed a very strong dependence between the number of created workplaces and biofuel production volume. Also, a very strong dependence was identified between the biodiesel production volume and area used for the production of biodiesel feedstock. Finally, a very strong dependence was found to exist between the ethanol production volume and area used for the production of ethanol feedstock.

The performed multi-dimensional regression analysis allows us to state that the development of biofuel production during the period 2003–2013 did not have any significant impact on the prices of food and feed crops, although a strong or very strong relationship exists between the price of food and feed plants and production volume. Regression analysis revealed that when more factors are involved instead of just biofuel production volume, the changes in ethanol or biodiesel production volume have less impact on the price of feedstocks than, for instance, oil price. The presented research reveals that there exists a relationship between grain price, oil price and biofuel production volume, but that the prices of food and feed grain are influenced by oil price rather than biofuel production volume. Taking into account the fact that grain price is affected by many other factors such as crop yield, climate, etc., it may be concluded that the development of biofuel production does not have a significant effect on the prices of food and feed crops.

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Received September 5, 2016
Accepted January 19, 2017
Published online December 16, 2017