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Price linkages between biodiesel and vegetable oils

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Abstract
Biodiesel can work as an alternative form of traditional fuels. Currently, crude oil market situation is unstable due to significant decrease in crude oil prices. Thus, volatile prices of crude oil put pressure on agriculture and food industry and low prices of crude oil may cause food prices to decrease. Additionally, lower oil prices have an impact on vegetable oils used in biodiesel production. Consequently, the diminishing trend in crude oil prices might seem to be beneficial for biodiesel producers due to the fact that rapeseed oil, soybean oil, palm oil belong to dominating feedstocks for biodiesel production. However, diesel prices would decline with lower crude oil prices, meaning that low diesel prices push down biodiesel prices. Therefore, this paper focuses on long-run relationship between biodiesel prices and prices of vegetable oils used for biodiesel production. The aim of the paper is to investigate price development and price linkages between biodiesel prices and selected prices of vegetable oils based on linear modelling technique called ordinary least-squares regression.

Key words*: biodiesel, ordinary least squares, price, vegetable oils*

JEL classification: *Q11, Q57*

1. Introduction

The production of biofuels has affected the relationship between food and crude oil prices and high crude oil prices and biofuel production are boosting the price of many food commodities (Bracco, 2014). Gerber, N. et al. (2008) show that the increasing demand for feedstock from the biofuel sector is one among several factors (e.g. poor harvest, the structural change in food demand, population growth, high oil prices, etc.) that have impact on agricultural prices. Baffes, J. (2013) reports that oil price movements explain most of the price rise in biofuel feedstock prices over the past decade, with demand side factors (biofuels, expanded population, changing diets and stocks all lumped together) altogether account for less than 10% of the price increase.

The large body of literature that relies on simulation to assess the impact of introduction of biofuel on food prices has applied several approaches (Goldemberg et al., 2004). The first is *partial-equilibrium elasticity analysis* that assesses the impact of biofuel on food prices by using elasticities to assess the price changes resulting from the diversion of the supply from food commodities because of biofuel. A simple graph of this approach is provided in Figure 1. The initial demand, before biofuel, is D_F then, after biofuel, the total demand is $D_{F+}B$. The initial supply is S_0 but, after some adjustments, the supply may move to S_1. The introduction of biofuel may lead to an increase in price from P_A to P_B but, if supply is adjusted, then the price change is from P_A to P_C. In the case of sugarcane, for example, the introduction of biofuel leads both to increased demand for sugarcane as well as an increase in supply. Thus, the percentage price increase due to the introduction of biofuel on sugarcane is $(P_C–P_A)/P_A$. When there is substitution among crops (corn, soybeans), multimarket analysis is required.

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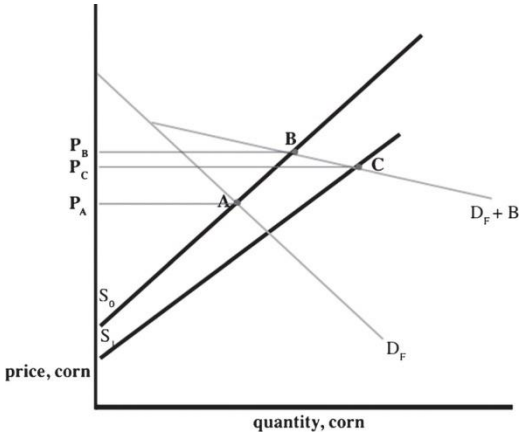
Figure 1: Biofuel and the food market



Source: Goldemberg et al., 2004

Chakravorty et al. (2010) perform a multimarket model to assess the future impacts of biofuel on fuel and food, emphasizing heterogeneity of land productivity and multiple crops and the relationship between crops and livestock. They argue that, while biofuel standards are important contributors to the rise of food prices, they are not the dominant one. They suggest that, with rising income, populations in developing countries will increase their consumption of animal products, which will further increase the demand for cereal. Thus, they expect that two-thirds of the increase in food prices will come from increased food demand and biofuel mandates will contribute only one-third.

Kristoufek, Janda, and Zilberman (2011) analyse correlations between a wide array of food and fuel commodity prices in the United States and European Union (EU) between 2003 and 2008. The results indicate that the dynamic interaction between different commodities varies significantly when analyzing weekly, monthly, and quarterly data. For the less-noisy quarterly data, a time series of commodity prices produced at closer proximity are more correlated. There are significant dynamic linkages between food prices and fuel prices with biofuels linking these markets. Saghaian (2010) show strong correlation among oil and other commodity prices (including food) but the evidence for a causal link from oil to other commodities is mixed. Gilbert (2010), based on quarterly data and Granger causality tests, found correlation between the oil price and food prices both in terms of levels and changes, but he also explains that it is the result of common causation and not of a direct causal link. In a recent study, Jansson and Wilhelmsson (2013) examine the detailed plans of the member countries for the expansion of biofuel production to achieve the EU targets. They conclude that, while these only involve a limited expansion in land use within the EU, there is, in addition to reallocation of land, a substantial increase in imports of primary agricultural products. They argue that the expansion of biofuels in Europe establishes a closer link between agricultural and fuel prices and leads to increases in prices of primary agricultural products, particularly vegetable oils used for biofuels.

2. Data and methodology

The main goal of this paper is to investigate long-run relationships among biodiesel price and prices of selected vegetable oils representing feedstock for biodiesel production, mainly rapeseed oil, soybean oil and palm oil. More specifically, the paper intends to find out if the relationships among the variables are statistically significant. Linear modelling technique called ordinary least-squares (OLS) regression is performed in order to investigate price

linkages. The paper also outlines price development and relationship of biodiesel price and crude oil price.

Monthly biodiesel and crude oil prices in Euros per 1000 litres are collected for period July 2005 - December 2015. The time period is divided into two sub periods to investigate whether the effects of vegetable oils price changes and crude oil price changes have become more prominent over the time (the unstable situation in oil crude market after 2013 caused again a decrease in prices of vegetable oils). The data are taken from UFOP. The crude oil price are taken from IndexMundi representing simple average of three spot prices: Dated Brent, West Texas Intermediate, and the Dubai Fateh. Prices of the chosen vegetable oils are taken from IndexMundi database as a world market commodity price and the prices are expressed in Euro per metric ton. Logarithmic transformation of the prices is used and one lagged independent variables are included in the equations to allow for the possibility that time might elapse between a change in the independent variable and the resulting change in the dependent variable. We assume that examined economic situations do not imply such instantaneous relationships between the dependent and independent variables.

The following hypothesis is formalized and reviewed in order to fulfil the main aim:

1) There is an evidence of a long run relationship between biodiesel price and prices of vegetable oils.
2) There is an evidence of a long run relationship between biodiesel price and crude oil price.

P-value determines if the relationships among the selected variables: biodiesel price and chosen commodity prices (rapeseed oil, soybean oil, palm oil and crude oil) are statistically significant. If P-value is lower than significance level alpha (0.05), H_0 hypothesis is rejected and H_1 hypothesis: is accepted, meaning that there is statistically significant relationship between our two examined variables. P-value stands for probability value, it is compared with the level of significance-alpha. If the P-value is > 0.05 – the referring coefficient is not statistically significant (-); if the P-value is <0.05 – the referring coefficient is statistically significant at the 0, 05 level of significance (+) and if P-value is <0.01 – the referring coefficient is statistically significant at the 0.01 level of significance (++) Cohen et al. (2002).

Montgomery et al. (2012) state that **s**imple linear regression model is a model with a single regressor x that has a relationship with response y that is a straight line. This simple linear regression model is

$$y = \beta_{0+}\beta_1 x + \varepsilon \qquad (1)$$

where the intercep β_0 and the slope β_1 are unknown constants and e is a random error component. The errors are assumed to have mean zero and unknown variance σ^2.

Tests for heteroscedasticity and normality of residuals are used for diagnostic checking in regression relationships. According to Crown (1998), Breusch and Pagan (1979) presented a test for heteroscedasticity that can identify a broad range of functional forms for nonconstant error variance. In addition, their approach leads to a WLS specification for correcting heteroscedasticity with a broad range of functional forms. White test does not require additional structure on the alternative hypothesis and exploits further the idea of a heteroskedasticity-consistent covariance matrix for the OLS estimator. The White test is a generalization of the Breusch-Pagan test, which also involves an auxiliary regression of squared residuals, but excludes any higher-order terms (Verbeek, 2008).

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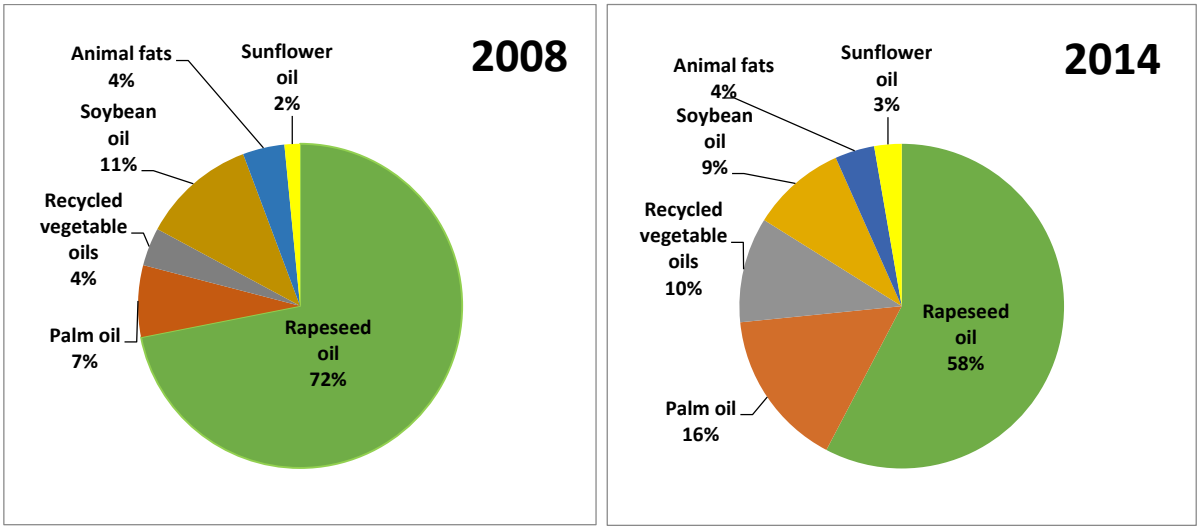
3. Results and discussion

3.1. Feedstock for biodiesel

Biodiesel is produced from vegetable oils, which are derived from the seeds or the pulp of a range of oil-bearing crops. These oil crops can be annual (rapeseed, sunflower, groundnut, and soybean) or perennials (oil palms, coconut palms, physical nut, Chinese tallow tree). Oil from the rapeseed was the first type used for biodiesel production.[1]

Suitable climatic, soil and rainfall conditions for growing rapeseed in European fields, mainly in Germany, mean that rapeseed oil have been a key oil crop for biodiesel production since its inception in EU. Sunflower oil is also one of the options for biodiesel production at a large scale, however, due to its high price it is not the main common feedstock. Soybean oil as a feedstock for biodiesel production is mainly used by producers in US, Brazil and Argentina. Palm oil recorded the most significant increase by 11 per cent as a feedstock for biodiesel production during the time period 2008-2014 (Figure 2).

Figure 2: Comparison of feedstock for biodiesel production in EU-28 in 2008 and 2014



Source: Own calculation; data based on EU FAS Posts

The price of vegetable oils used for biodiesel production recorded a strong fluctuations on the commodity markets during period 2005-2015. Time series plot depicts that all price series recorded twice a rapid drop down and a sharp rise during the examined period. More specifically, a significant increase was shown during period 2005-2009. Due to the worldwide economy crisis, prices started to fall in 2009. Afterwards, the prices gradually increased, moreover prices of soybean and palm oil reached historic maximums in their price level in 2011 and 2012. The unstable situation in oil crude market after 2013 caused again a decrease in prices of vegetable oils (Figure 3). The month-on-month drop in vegetable oils price, mainly mirrors developments in the market for palm oil, the most widely traded vegetable oil. The recent slump in crude oil prices depressed demand for palm oil as a biodiesel feedstock, causing a sizeable drop in palm oil values. For year 2014 was characteristic two following factors: first, continued weakness in soybean oil prices due to abundant supply prospects in 2014/2015: and second, the recent setbacks in crude oil prices, which tend to reduce demand for vegetable oils as biofuel feedstock (FAO, 2014).

[1] http://www.eubia.org/index.php/about-biomass/biofuels-for-transport/biodiesel

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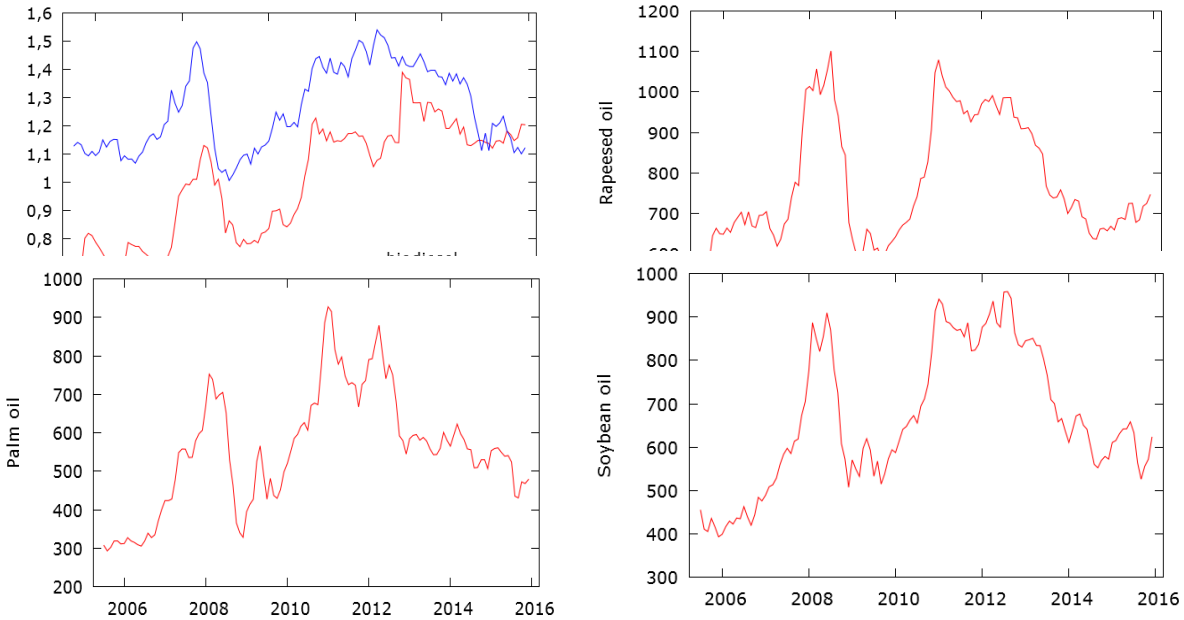
Figure 3: Development prices of selected vegetable oils



Source: Own calculation; data based on UFOP, index mundi

Table 1. Descriptive statistics

Variable	Mean	Min	Max	Skewness	Median	C.V	Ex.kurtosis
Biodiesel	98,856	64,81	139,01	0,0268	100,22	0,2035	-1,3798
Rapeseed oil	789,02	542,48	1101,2	0,3641	736,6	0,1946	-1,3369
Diesel	127,24	100,62	154,01	0,0109	127,34	0,1181	-1,4420
Palm oil	556,36	293,12	927,3	0,181	557,8	0,2738	-0,4775
Soybean oil	673,46	393,07	958,56	0,0594	649,06	24625	-1,2385
Crude oil	53,203	25,956	74,832	-0,1856	51,941	0,2308	-1,1552

Source : Own calculation

Table 2. Correlation matrix

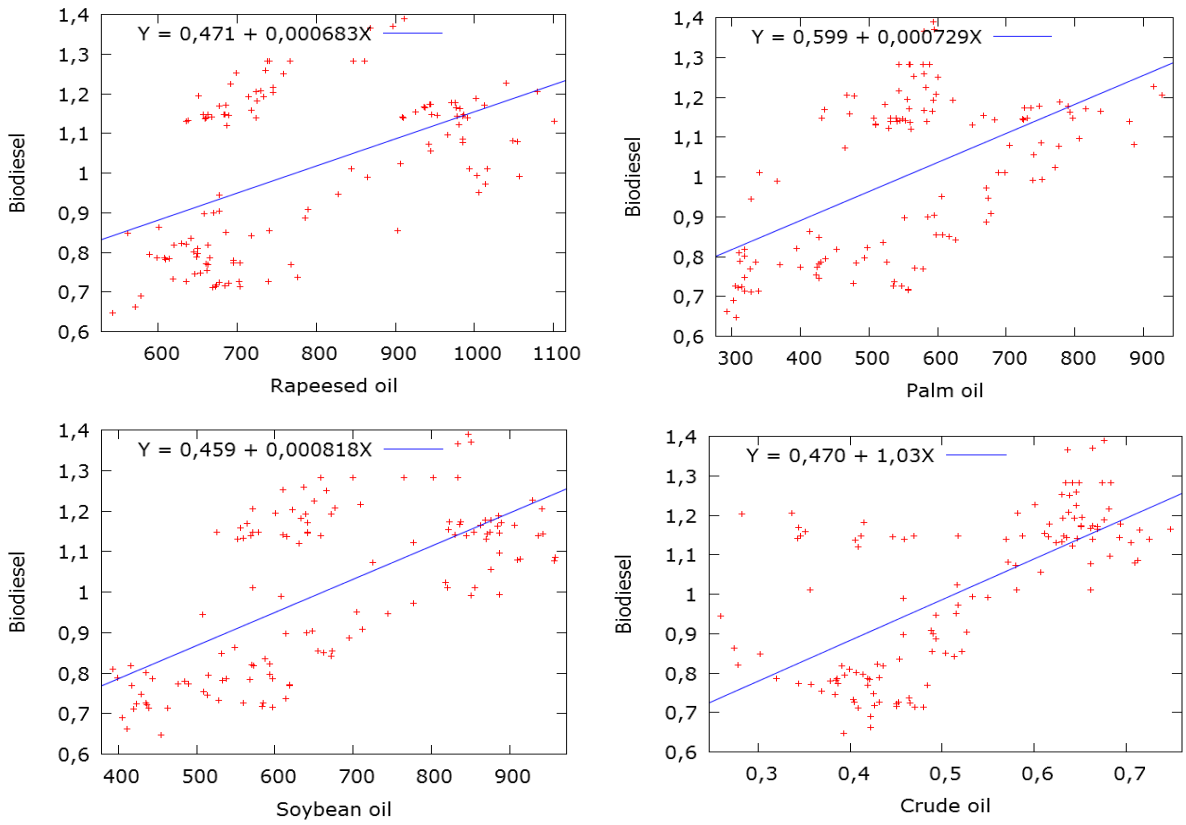
Variable	Biodiesel	Rapeseed oil	Palm oil	Soybean oil	Crude oil
Biodiesel	1.0000				
Rapeseed oil	0.8833	1.0000			
Palm oil	0.7890	0.8063	1.0000		
Soybean oil	0.9060	0.9027	0.9369	1.0000	
Crude oil	0.8268	0.8565	0.7711	0.8607	1.0000

Source: Own calculation

Correlation analysis revealed positive correlation between examined price series. The null hypothesis that the two variables are linearly independent or uncorrelated is rejected for all performed cases. It is also clear that that the vegetable oil prices (rapeseed, soy and palm) are correlated with each other (Table 2). Descriptive statistics of examined variables is shown in Table 1.

Scatter diagrams (Figure 4) show the development of the monthly biodiesel prices and prices of selected vegetable oils in July 2005 – December 2015.

Figure 4 Relationship between biodiesel price and diesel and selected vegetable oils



The results based on OLS show that prices of vegetable oils have a significant positive effect on the biodiesel prices. The coefficients of all vegetable oil prices and intercept are statistically significant at even 1% level of significance in all examined equations during the period 2005-2012 (Table 3, Table 4, and Table 5). One percent increase in rapeseed oil price is associated with 0.79% increase in biodiesel price. The l_palm_oil_1 coefficient (0.44) and l_soybean_oil_1 coefficient (0.60) show that biodiesel price rose by 0.44% for every 1% increase in palm oil price and by 0.60% for every 1% rise in soybean oil price. The findings are consistent with the strong upward trend in prices of vegetable oils from 2005-2008, reflecting increasing demand for biofuels. R-squared is also high (0.80) signifying a strong positive relationship between the biodiesel and rapeseed oil price and 83% of variance is explained by the model with soybean oil price series for the observation period (7/2005 - 12/2012). The regression model accounts for 65% of variance in equation with palm oil prices. The null hypothesis that the residuals are normally distributed is accepted for all examined equations. The Breusch-Pagan test reveals homoskedasticity at 5% significant level, except the equation with l_ soybean_oil-1 where the null hypothesis is rejected at the 5 % but not at the 1 % level. White´s test for heteroscedasticity confirms the null hypothesis for equations with the following variables: l_soybean oil_1 and l_rapeseed_oil_1. Therefore, the model is considered to be valid and reliable.

The results obtained for the second period 2013-2015 prove vegetable oils prices to be significant as well (Table 3, Table 4 and Table 5). If rapeseed oil is increased by 1%, then biodiesel price is expected to increase by 54%. The variable l_palm_oil_1 has a coefficient

equal to 0.32 which means that 1% increase in palm oil price will lead to a 0.32% increase in biodiesel price. Soybean oil price has also a positive effect on biodiesel price, as its regression coefficient is 0.36. Additionally, diagnostic checks were computed in order to consider the model stable and reliable. Adjusted R- squared value decreases to 0.19 and the regression explains less of variation in biodiesel price in case of equation with palm oil price variable than the first. R-squared is higher (0.87) for the second observed period signifying that 89% of variance is explained by the model with rapeseed oil variable for the observation period 2013 – 2015. Additionally, R-squared value indicates that 70% of the variation in the biodiesel price variable is explained by the soybean oil price. The Breusch Pagan test and White´s test are again computed in order to test the heteroskedasticity and the null hypothesis of homoscedasticity cannot be rejected in all cases. The null hypothesis that the residuals are normally distributed is accepted for all examined equations as well.

The crude oil price proved to have a significant effect even at 1%- level during the both examined periods (Table 6). Heteroskedasticity is corrected in OLS model with variable l_crude_oil_1 for the period 2005-2012, due to the fact that the null hypothesis: heteroskedasticity is not presented was rejected in OLS model without heteroscedasticity correction. The coefficient of crude oil price equals to 0.71 which means that one percent increase in crude oil price leads to an increase of 0.71 in biodiesel price. When comparing the value to the results of regression covering the second period, it is evident that changes in crude oil price had smaller effect on the biodiesel price in 2013-2015. The adjusted R-squared value decrease to 0.27 and the regression explains less of the variation for the period 2013-2015 in comparison to the period 2005-2012 (R^2 = 0.64). The null hypothesis that the residuals are normally distributed is accepted and White´s test indicates that the null hypothesis of homoscedasticity is accepted in the second examined period.

Table 3: OLS model with independent variable l_rapeseed_oil_1

	2005:07-2012:12			2013:01 -2015:12		
	Coefficient	*Std. Error*	*t-ratio*	*Coefficient*	*Std. Error*	*t-ratio*
const	1.52956***	0.281607	5.432	3.53914***	0.239379	14.78
l_rapeseed_oil_1	0.793414***	0.0422500	18.78	0.539751***	0.0363282	14.86
R-squared	0,802116			0.869950		
Adjusted R-squared	0.799841			0.866010		
White´s test	2.71565 (0.25722)			6.462826 (0.039502)		
Breusch-Pagan test	0.864941(0.35236)			1.936148 (0.164087)		
Test for normality	7.40682 (0.0246393)			2.08673 (0.352267)		

Source: Own calculation

Table 4: OLS model with independent variable l_palm_oil_1

	2005:07-2012:12			2013:01 -2015:12		
	Coefficient	*Std. Error*	*t-ratio*	*Coefficient*	*Std. Error*	*t-ratio*
const	4.06576***	0.214636	18,94	5.10198 ***	0.659330	7.738
l_palm_oil_1	0.438230***	0.0341599	12,83	0.316213***	0.104582	3.024
R-squared	0.654183			0.216936		
Adjusted R-squared	0.650208			0.193207		

Test for normality	0.748924 (0.687659	4.0953 (0.129038)
White´s test	12.9149 (0.0015688)	2.296564 (0.317181)
Breusch- Pagan test	0.231346 (0.630528)	1.513334 (0.218631)

Source: Own calculation

Table 5: OLS model with independent variable l_soybean_oil_1

	2005:07-2012:12			2013:01 -2015:12		
	Coefficient	*Std. Error*	*t-ratio*	*Coefficient*	*Std. Error*	*t-ratio*
const	2.92343***	0.190634	15.34	4.76542***	0.264262	18.03
l_ soybean _oil_1	0.601774***	0.0294496	20.43	0.359345***	0.0407485	8.819
R-squared	0.827569			0.702080		
Adjusted R-squared	0.825587			0.693052		
Test for normality	1.02585 (0.598742)			2.86136 (0.239146)		
White´s test	6.233984 (0.044290)			0.267708 (0.874718)		
Breusch_Pagan test	5.183104 (0.022808)			0.112752 (0.737033)		

Source: Own calculation

Table 6: OLS model with independent variable l_crude_oil_1

	2005:07-2012:12			2013:01 -2015:12		
	Coefficient	*Std. Error*	*t-ratio*	*Coefficient*	*Std. Error*	*t-ratio*
Const	2.41378***	0.279887	8.624	6.29326***	0.216968	29.01
l_ crude _oil_1	0.709501***	0.0441130	16.08	0.127455***	0.0344507	3.700
R-squared	0.639523			0.293168		
Adjusted R-squared	0.635380			0.271749		
Test for normality	8.40516 (0.0149569)			1.26676 (0.530795)		
White´s test	-			4.715149 (0.094649)		

Source: Own calculation

4. Conclusion

The main goal of the paper was to explore links between price of biodiesel and prices of selected vegetable oils representing feedstock for biodiesel production; mainly rapeseed oil, soybean oil and palm oil. The paper also focused on the price development and relationship of biofuel and crude oil prices. The stated hypotheses were confirmed due to the fact that the research confirmed that there was an evidence of long run relationships among biodiesel price and vegetable oils prices, and between biodiesel price and crude oil price. The results showed that prices of vegetable oils had a significant positive effect on the biodiesel prices during the period 2005-2015. Moreover, the crude oil price proved to have a significant effect even at 1%- level during the both examined periods. Unstable situation in oil crude market after 2013 caused again a decrease in prices of vegetable oils. According to the obtained results, these price changes have been also reflected in biodiesel sector, thus, making producing biofuel more profitable if price of vegetable oils are cheaper than gas oil. The findings are in line with e.g. Demirbas (2005) who states that costs of biodiesel varies depending on the base stock,

geographic area, variability in crop production from season to season, and the price of crude oil. Moreover, high price of biodiesel is due to the high price of feedstock. Knothe et al. (2009) explain that economic reasons have been one of the major obstacles in the use of biodiesel due to the fact that the feedstock for biodiesel is more expensive than conventional diesel fuel (in US, a gallon of soybean oil costs approximately two to three times as much as a gallon of conventional diesel fuel).

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