FOOD-BIOFUELS INTERACTIONS: THE CASE OF THE U.S. BIOFUELS MARKET

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ABSTRACT

Corn refers to the main feedstock for U.S. biofuels production and together with soybean oil, as typical biofuel food commodity that can be converted into biodiesel, account for over 90 percent of biofuels production in the United States. The paper aims to explore the impact of U.S. biofuels prices on soybean oil, corn and wheat prices. Co-integration analysis and VECM are carried out in order to investigate the relationship between the price series. The results show that biofuels and food price levels are co-integrated in the long run. These links show that food prices increment with a rise in biofuels prices. Additionally, not only food prices are determined by biofuels prices, but also vice versa. Thus, bi-directional causal effect runs from one price to another in the short run.

Key words: biodiesel, ethanol, price, food

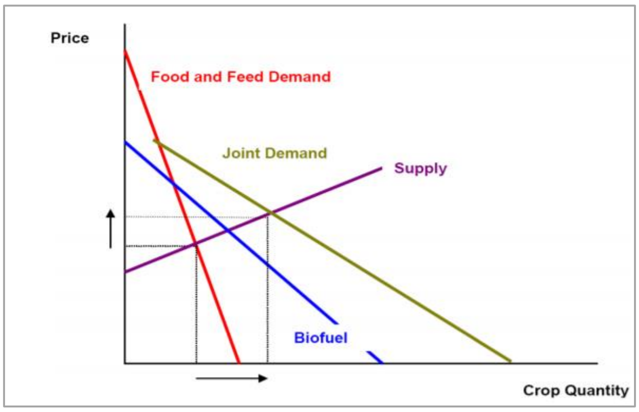
JEL codes: C32, Q11, Q41

INTRODUCTION

In recent years, the role of biofuel in the determination of the high agricultural commodity prices and in particular, the price linkages between the food, energy and biofuel markets, have become one of the ongoing issues debated by energy, environmental and agricultural economists interested in the question of the sustainable development of biofuels (Bentivoglio and Rasetti, 2015). Later on, Bentivoglio et al. (2016) add that the issue of food-biofuels interactions gained a new dimension and the research on price interdependencies between food, energy and biofuel markets has become a frequently debated topic since the food crisis.

Chakravorty et al. (2015) mention that biofuels have been blamed universally for past increases in world food prices, and many studies have shown that energy mandates in the United States and European Union may have a large (30–60 percent) impact on food prices. Alexander and Hurt (2007) state that the primary impact of biofuels on food inflation is from increases in the farm prices of commodities that contribute to producing our food supply, like corn, soybean meal, soybean oil, wheat, barley, and oats. Condon et al. (2013) conduct a meta-analysis to identify the factors that drive the variation in crop price impacts across studies and identify that the baseline and policy ethanol volumes, projection year, inclusion of ethanol co-products, biofuel production from other feedstocks, and modeling framework explain much of the differences in price effects across studies and scenarios. Pfuderer and Castillo (2008) show how new biofuel demand will shift the food and feed demand curve outwards, resulting not only in higher feedstock output but also higher prices (Figure 1).

Figure 1 Food crops´ demand and supply



Source: Pfuderer and Castillo (2008)

Baier et al. (2009) estimate that the increase in world biofuels production accounts for just over 12% of the rise in global food prices, with increased U.S. biofuel production accounting for roughly 60% of this total increase and conclude that nearly 90 percent of the price increase in global food prices is due to factors other than biofuels production. Flammini (2008) says the persistent critique of biofuels' impact upon global food price increases depends upon a number of factors and not least natural constraints, markets and policies development and, importantly, upcoming pipeline technologies. Moreover, the different projections of the impact of biofuel production on food prices are difficult to resolve due to the specific assumptions underlying each model, the scope of the studies, their time horizon, the choices of different policy scenarios, or even more simply the definition of "food prices" and of aggregate commodity prices as noted by Gerber et al. (2008). Also Ajanovic (2010) finds out that within the period 2000 - 2009 the volatility of feedstocks prices has not been only the consequence of continuously increasing biofuels production, but the largest part of these volatilities was caused by other impact parameters such as oil price and speculation. Furthermore, Zilberman et al. (2013) demonstrate that biofuels have not been the most dominant contributor to the recent food-price inflation and different biofuels have different impacts. Hochman et al. (2012) show that although biofuel was an important contributor to the food-price inflation of 2001–2008, its effect on food-commodity prices declined after the recession of 2008/09. Kristoufek et al. (2012) show that ethanol is positively affected by corn and it causes changes in the US gasoline. Additionally, their results confirm that biodiesel is very strongly influenced by German diesel prices and also by soybeans prices.

The paper intends to explore the impact of biofuels on soybean oil, corn and wheat prices by using time series econometric methods (co-integration analysis and VECM).

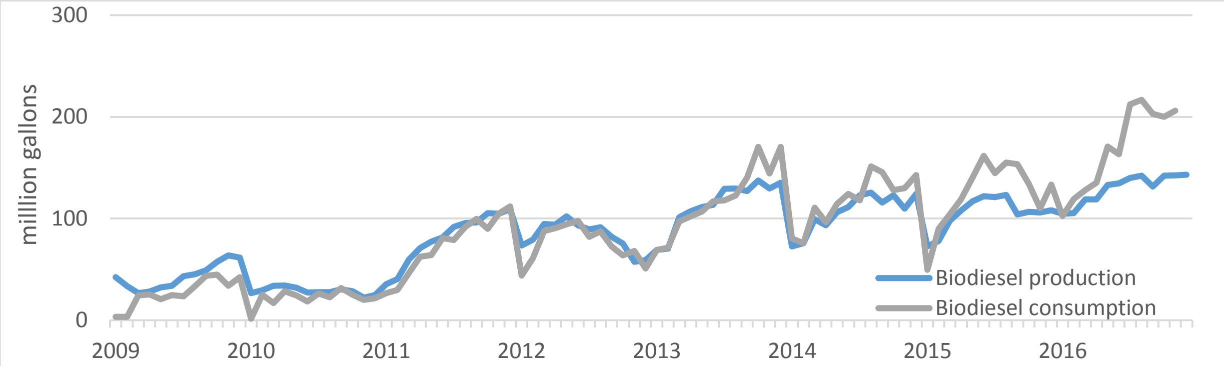
The paper is structured as follows: Section 2 presents an overview of U.S. biofuel market developments followed by Section 3 where the methodology approach, performed to estimate price relationships, as well as data needed for analysis are described (Materials and methods). The empirical results are presented in Section 4 (Results and discussion) and conclusion is provided in Section 5.

2 BIOFUEL MARKET DEVELOPMENTS

As stated by Wisner (2013), biodiesel production in the U.S. emerged in the early 2000s with growing concern about the need for energy independence and reduced greenhouse gas emissions. In 2010, the rapid drop down of biodiesel production, reaching the lowest level of 343 million gallons, was experienced partly due to the expiration of the biodiesel tax credit at the end of 2009. The biodiesel industry recovered and the production increased by 624 million gallons in 2011 because of a reinstatement of the credit retroactive passed late in 2010. Moreover, fuel blenders needed to meet an increased RFS2 volume of 1 billion gallons of biomass-based diesel which resulted in increased demand for biodiesel. In 2012, the biodiesel production recorded a very slight change, reaching a total of 991 million gallons. Later on, U.S. biodiesel production rose to 1 359 million gallons in 2013. During 2014, the production reached a volume of 1 279 million gallons and it remained largely at the same level (1 263 million gallons) also in the next year. In 2016, U.S. biodiesel production increased once again, reaching a volume of 1 556 million gallons, representing an increase of 123.15% (Figure 2).

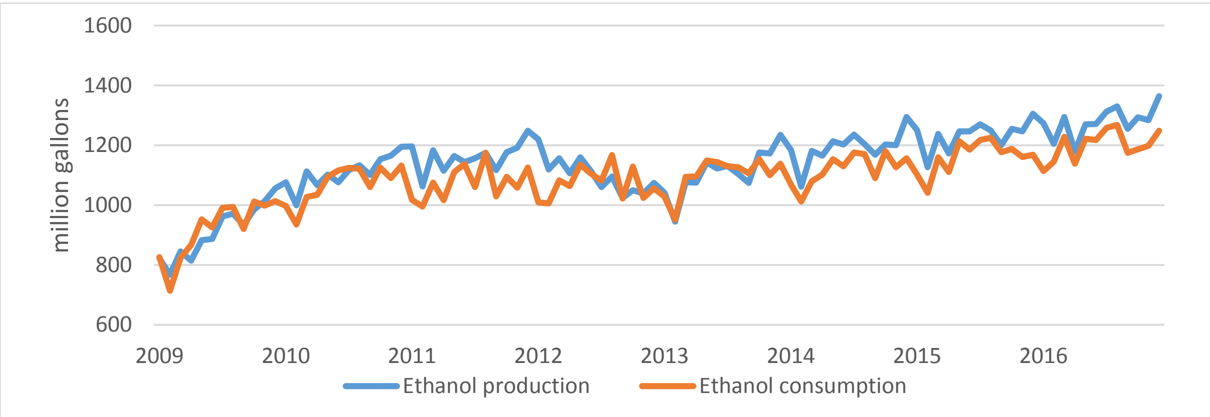
Ethanol production went up significantly from 10.930 billion gallons in 2009 to level of 15.329 billion gallons in 2016. Ethanol production experienced slowdown at the rates of prior years because of the saturation of the U.S. gasoline market with E10 coupled with less-favorable export markets during 2012 - 2013. Furthermore, a major drought across the Midwest, where most of the U.S. corn crop is grown, lowered ethanol production and increased prices. The U.S Energy Information Administration (EIA) indicates U.S. produced 13.217 billion gallons of ethanol in 2012, compared to 13.929 billion gallons in 2011. The production increased by 522 million gallons between 2014 and 2015 (Figure 3).

Figure 2 U.S. Biodiesel production and consumption



Source: U.S. Energy Information Administration, authors´ processing

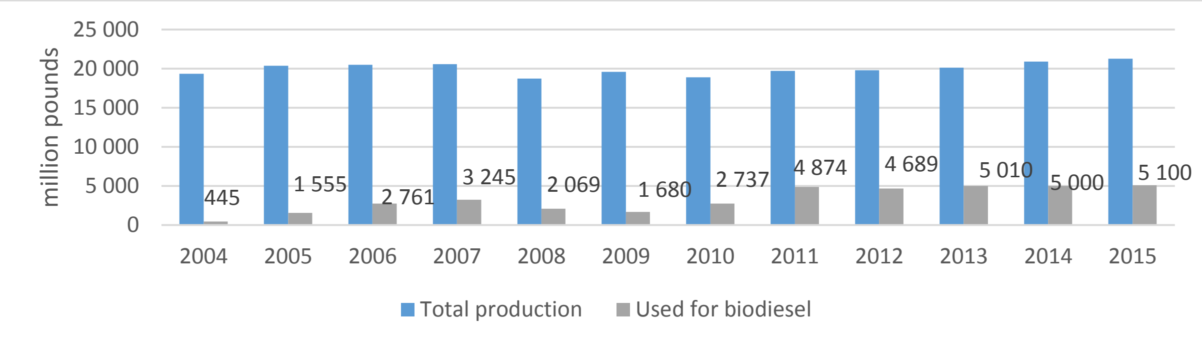
Figure 3 U.S. Ethanol production and consumption



Source: U.S. Energy Information Administration, authors´ processing

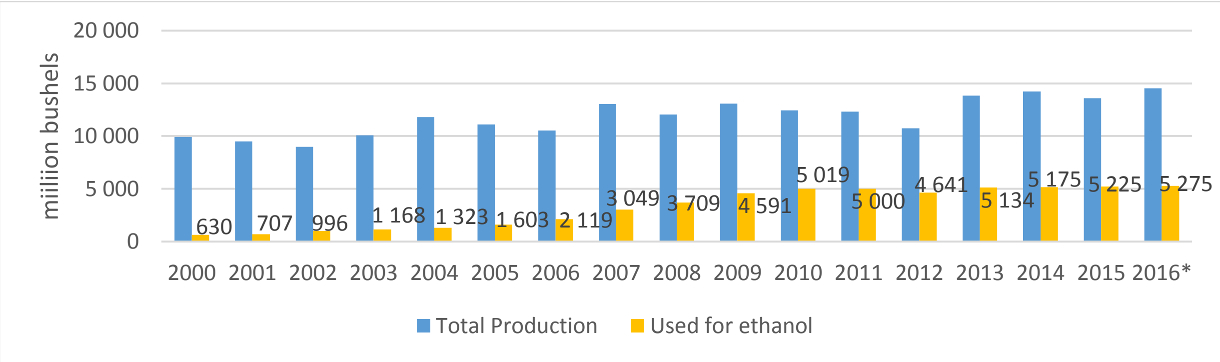
In the United States, corn and soybean oil account for over 90 percent of biofuels production with corn being the main feed stock for U.S. biofuels production (Baier et al., 2009). Brorsen (2015) explains that corn and soybeans are typically grown in a rotation where corn is grown either every other year or two out of three years. The corn ethanol program creates an incentive to grow more corn and less soybeans. Moreover, the dried distiller's grain (DDG) that is a byproduct of corn distilling is 30-35% protein and so feeding DDGs reduces the demand for soybean meal. Soybean oil has remained the largest biodiesel feedstock and its usage for biodiesel rose significantly year-to-year (Figure 4). The other three large feedstock inputs to biodiesel production are canola oil, corn oil, and yellow grease. Ethanol is mainly derived from corn and the amount of corn used for ethanol production increased substantially between 2001 and 2011, reaching a level of 4.9 billion bushels in 2011 (Figure 5). However, the drought of 2012 resulted in drop down of production, ethanol usage and feed usage. Since 2013, the trend of corn used for fuel ethanol production has been still increasing and stayed consistent from year to year.

Figure 4 U.S. Total soybean oil production and soybean oil used as a feedstock for biodiesel production



Source:http://www.ucsusa.org/sites/default/files/attach/2015/07/Brorsen-RFS-Biodiesel-Feedstock-Analysis.pdf, authors´ processing

Figure 5 U.S. Total corn production and corn used as a feedstock for ethanol production

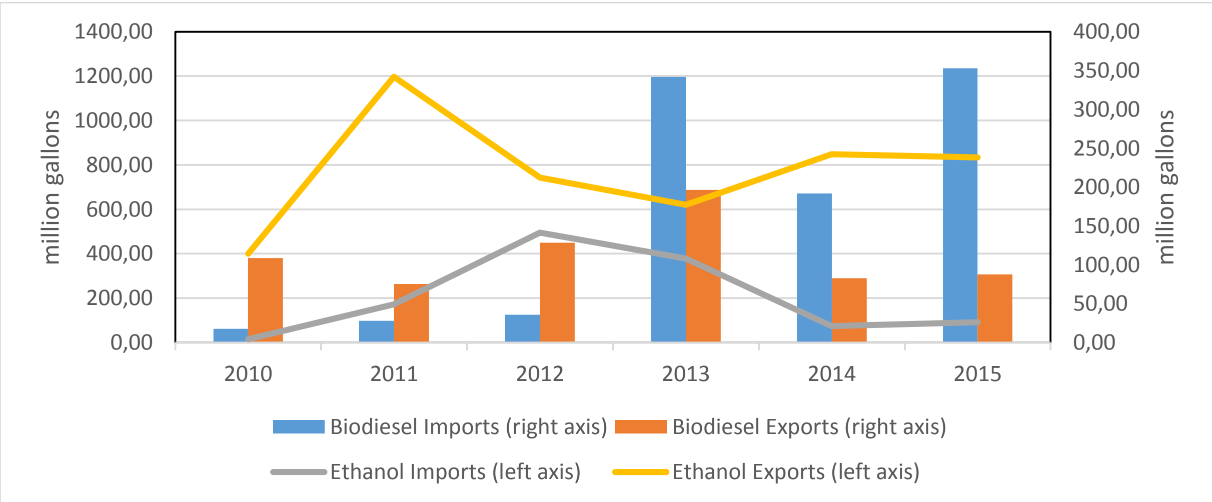


*Note: *values are preliminary*
Source: http://www.afdc.energy.gov/data/10339, authors´ processing

Since 2007, the U.S. had been generally a net exporter of biodiesel, however the situation has changed and the U.S. has become a net importer since 2013 due to growing access to foreign biodiesel and increasing domestic demand as a consequence of meeting renewable fuel targets (Figure 6). According to EIA, biodiesel imports decreased in 2014 mainly in response to the uncertainty about the future of RFS target and lack of influx of Argentinian biodiesel by the end of the year. In 2014, U.S. biodiesel imports declined to 192 million gallons from 342 million gallons recorded in 2013. U.S. biodiesel imports rose again by 83.5% (353 million gallons) in 2015. Also, U.S. biodiesel exports rose by 5.9% in 2015, compared to the previous year. Export volumes peaked in 2008, reaching a value of 700 million gallons. The biodiesel exports experienced downward trend in 2010, as domestic consumption of domestically-produced biodiesel increased in order to meet the biomass-based diesel portion of the RFS2. Another key factor that affects the biodiesel exports was new European Union rule aimed to discourage imports of biodiesel that had received the U.S. blending tax credit. The majority of U.S. biodiesel exports since 2011 have gone to Europe, Canada, India, and China.

U.S. has remained net exporter of ethanol during the observed period 2010 – 2015 (Brazil was the largest recipient of U.S. ethanol). Ethanol exports fall significantly from their peak in 2011 (1 198 million gallons). During 2013, the U.S. exported the amount of 620 million gallons, compared to 743 million gallons in the previous year. In 2015, the U.S. exported 834 million gallons of ethanol, similar to 2014 (845 million gallons). To the top ten markets, where the U.S. ethanol was exported in 2015, belong Canada, Brazil, Philippines, China, S. Korea, India, Netherlands, Mexico, Oman, and Tunisia. The combination of increased ethanol production capacity in the United States with limited market blends greater that E10 has been the key factor influencing U.S. ethanol exports. The U.S. ethanol imports dropped down after reaching a peak of 495 million gallons in 2012 and remained at level of 92 million gallons in 2015. Among the driving forces behind the downturn were e.g. sugarcane ethanol imported from Brazil competing with U.S. corn ethanol in the world market, ethanol blending limits known as the ethanol blend wall (Figure 6).

Figure 6   U.S. Biofuels imports and exports



Source: U.S. Energy Information Administration, authors´ processing

MATERIAL AND METHODS

Corn, soybean oil, wheat refer to typical biofuel food commodities that can be (and have been) converted into biofuel and whose price links with biofuels (biodiesel, ethanol) are investigated in the paper. Monthly prices of ethanol (USD/gallons), biodiesel (USD/gallons), corn (USD/metric ton), soybean oil (USD/metric ton), wheat (USD/metric ton) are collected over the period January 2007 to February 2017. The food prices as well as prices of biofuels are extracted from United States Department of Agriculture (National Agricultural Statistics Service).

Time series model is an appropriate technique to study causal linkages between biofuels and food prices and to evaluate price level connections using co-integration analysis and VECM (Bentivoglio, 2016; Hassouneh et al., 2011; Lajdová et al., 2015).

Firstly the standard Augmented- Dickey Fuller test is used for testing stationarity. Bastianin et al. (2013) define that the null hypothesis of ADF is that the series has a unit root; therefore, in the case of ADF failing to reject of the null provides evidence of unit root behavior.

Then, Johansen co-integration test is performed for finding co-integrating relationships in case of food-biofuels interactions. The evidence of co-integration between food and fuel price series means that two series (commodity price series) ´move together´ over time towards equilibrium (Bracco, 2017; Bakhat and Würzburg, 2013).

However, co-integration does not reveal anything about the direction of causality (Avalos, 2013; Ciaian and Kancs, 2009). Thus, VECM is applied in order to evaluate the short run and long run properties of the co-integrated series. The regression equation form for VECM is as follows (Obadi and Korček, 2014):

$$\Delta X_t = \sum_{j=1}^{m-1} \alpha_j \, \Delta X_{t-j} + \sum_{j=1}^{m-1} \beta_j \, \Delta Y_{t-j} + \lambda_1 EC_{x\,t-1} + \varepsilon_{1t} \qquad (1)$$

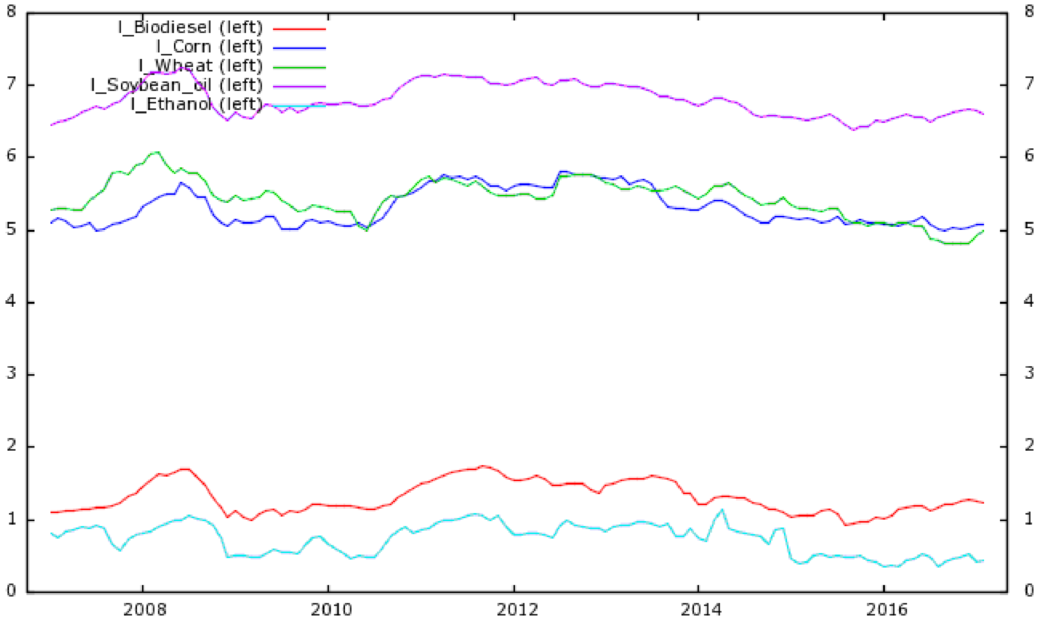
$$\Delta Y_t = \sum_{j=1}^{m-1} \gamma_j \, \Delta X_{t-j} + \sum_{j=1}^{m-1} \delta_j \, \Delta Y_{t-j} + \lambda_2 EC_{y\,t-1} + \varepsilon_{2t} \qquad (2)$$

In the models above; X and Y coefficients indicate dependent or independent variables, α_j, β_j, γ_j and δ_j indicate the parameters to be estimated, λ_1 and λ_2 indicate error correction coefficients, EC_{xt-1} and EC_{yt-1} indicate lagged residuals from co-integration regression.

RESULTS AND DISCUSSION

The econometric models mentioned earlier provide an alternative way to estimate the effect of biofuels price on food price. Food price have moved in a close relationship with biofuels prices apart from 2012 and the first two-thirds of 2013 when drought sharply reduced supplies (see logarithmic transformations of prices from January 2007 to February 2017 in Figure 7). The summary of descriptive statistics is shown in Table 1. In the next step the stationarity properties of the series will be discussed followed by the co-integration analysis.

Figure 7 Food and energy prices, January 2007 – February 2017 (logarithmic transformations)



Source: authors´ processing

Table 1 Descriptive Statistics

	Ethanol	Biodiesel	Corn	Soybean oil	Wheat
Mean	2.14149	3.80746	210.092	920.295	238.76
Median	2.21000	3.44625	179.215	860.820	237.70
Minimum	1.42000	2.55000	147.130	590.250	122.51
Maximum	3.15000	5.74200	332.950	1414.42	439.72
Std. Dev.	0.441215	0.852418	57.2397	214.518	63.043
C.V.	0.206032	0.223881	0.272450	0.233097	0.26405
Skewness	0.00951078	0.727826	0.727826	0.478245	0.43755
Ex. kurtosis	-1.19141	-0.979234	-0.979234	-1.06046	0.28773

Source: authors´ processing

The standard test proposed by Dickey and Fuller in its augmented form (ADF) is used in order to investigate the stationarity/non-stationarity properties of the selected price series. The ADF test tests the null hypothesis of a unit root process against the alternative of a stationary process. In our case, null hypothesis of ADF test is confirmed meaning that the level of price series has a unit root i.e. are integrated of order 1. On the contrary, the ADF provides evidence of stationarity of the first differences of the time series when the null cannot be rejected (Table 1). All tests are carried out without constant or including either just a constant, or a constant and a trend in the test equation. The lags of the variables were determined by Akaike criterion, Schwartz Bayesian criterion and Hannan-Quinn criterion.

Table 2 Augmented Dickey- Fuller test

	ADF		
	without C	C	C&T
Ethanol	0.3745	0.323	0.4966
Biodiesel	0.5081	0.0957	0.2309
Corn	0.4935	0.4357	0.7459
Soybean oil	0.4931	0.1151	0.1418
Wheat	0.4174	0.237	0.1392
d_ethanol	4.753e-019	1.163e-018	5.165e-019
d_biodiesel	2.439e-006	7.087e-005	0.0005627
d_corn	4.182e-010	1.139e-008	8.82e-008
d_soybean oil	2.025e-007	6.33e-006	4.821e-005
d_Wheat	1.713e-007	5.242e-006	3.307e-005

Note: "C" and "C&T" indicate whether a constant and a constant and a trend have been respectively included in the test equation
Source: authors´ processing

Co-integration test could be used for testing long run relationship of the time series because of proving non-stationarity of the level of variables by the above stationarity test (ADF test). Co-integration is tested by Johansen trace test and L-max test, where the null hypothesis of no co-integration can be rejected for the selected pairs, thus the test gives a strong evidence for a long-run relationship (Table 3).

Table 3 Johansen co-integration test

	L – max test		Trace text	
	r=0	r=1	r=0	r=1
Ethanol – Corn	14,815	2,5528***	17,368	2,5528***
Ethanol – Wheat	13,780	0,38211***	14,162	0,38211***
Biodiesel – Soybean oil	22,529	8,2981***	30,827	8,2981***

Source: authors´ processing

The prices are transformed into natural logarithms for the estimations, since the long-run coefficients can then be interpreted as long-run price transmission elasticities (Busse and Ihle, 2009). The coefficients in the long-run relationship are long-run elasticities. Thus, 1 percent increase in biodiesel price leads to 1.16 percent increase in the price of soybean oil (Table 4). On the contrary, the co-integrating parameter is 1.77 for the corn-ethanol price pair, implying that 1 percent rise in price of ethanol will bring about, in the long run, a 1.77 percent increase in the price of corn. Co-integration vector has a following form in wheat-ethanol price pair: (1.0000; -1.3609), meaning that an increase in price of ethanol by 1.00 percent results in a rise of wheat price by1.36%. Adjustment coefficient α represents the error correction term. The adjustment parameter of the corn error correction model is statistically significant and corn prices adjust to a change in ethanol prices by 9.9 percent in one month. The estimated coefficient α of the ethanol error correction model is also positive and statistically significant, meaning that maize prices are determined by ethanol prices and vice versa, with a long run bi-directional causal effect which runs from one price to another. Similar findings are confirmed by Merkusheva and Rapsomanikis (2014) who consider corn as quasi-fixed input in the production of ethanol, and thus its price can influence the price of ethanol. Given a change in the corn price, ethanol prices respond to a change in corn prices fast and adjust to a change by 22 percent each month. The alfa parameter is statistically significant for both variables in case of wheat-ethanol system. About 17 percent of the disequilibrium is corrected within one month in case of wheat. The relationship between wheat and ethanol prices is simultaneous. The error correction coefficient of biodiesel is negative and significant at 5 percent level. Soybean oil prices as well as biodiesel prices adjust to their long-run path by 31 percent each month. The relationship for soybean-biodiesel price pair is also simultaneous, the biodiesel price drives that of soybean oil, but also vice versa.

The diagnostic tests of VECM equations are computed in order to check autocorrelation (Breusch-Godfrey test), heteroscedasticity (ARCH test) and whether the residuals are normally distributed. The null hypothesis of homoscedasticity, no autocorrelation and normally distributed residuals was not rejected. The regression models account approximately for more than 70 percent of the variance in the equations (Table 5).

Table 4 VECM

	VECM estimation		
	α adjustment coefficient	β co-integrating vectors	Constant
Δsoybean_oil	0.312848*	l_soybean_oil 1.0000	-1.65360**
Δbiodiesel	-0.315790**	l_biodiesel -1.1640	1.67738**

Δcorn	0.0989273**	l_corn 1.0000	-0.398943**
Δethanol	0.220637***	l_ethanol -1.7725	-0.888609***
Δwheat	-0.171532***	l_wheat 1.0000	0.758232***
Δethanol	0.100318*	l_ethanol -1.3609	-0.448981*

*Note: ***/**/* statistically significant at the 1% 5% and 10% levels*
Source: authors´ processing

Table 5 VECM diagnostic checks

Equation	Diagnostic test			
	Unadjusted R^2	Normality of residuals (p-value)	ARCH test (p-value)	Breusch-Godfrey test (p-value)
Δsoybean_oil	0.73652	0.512156	0.964784	0.202463
Δbiodiesel	0.87755		0.801994	0.195568
Δcorn	0.697842	0.569274	0.973204	0.344744
Δethanol	0.706623		0.889009	0.0124104
Δwheat	0.323228	0.00208567	0.285868	0.205473
Δethanol	0.42279		0.799891	0.217322

Source: authors´ processing

CONCLUSION

In the United States, corn and soybean oil account for over 90 percent of biofuels production with corn being the main feed stock for U.S. biofuels production. Corn and soybeans are typically grown in a rotation where corn is grown either every other year or two out of three years; however, the corn ethanol program creates an incentive to grow more corn and less soybeans. Soybean oil has remained the largest biodiesel feedstock and its usage for biodiesel rose significantly year-to-year.

The paper investigates price relationship in the food-biofuel nexus using time series modelling. Corn, soybean oil, wheat refer to typical biofuel food commodities that can be (and have been) converted into biofuel and whose price links with biofuels (biodiesel, ethanol) are investigated in the paper. The results of Johansen co-integration test provided a strong evidence for a long-run relationship between food and biofuels prices. Co-integrating parameters showed that implying rise in price of biofuels would bring, in the long run, an increase in food price. Thus, biodiesel and ethanol have a positive impact on food prices. However, the VECM also showed a long run bi-directional causal effect which runs from one price to another, indicating that not only the prices of biofuels drive food prices, but also vice versa. Furthermore, the speed of the reaction of corn, wheat prices upon the deviation of the system from the state of equilibrium is low in comparison to soybean oil prices that adjusted to their long-run path by 31 percent each month.

Our findings contribute to the debate concerning the issue of food-biofuels interactions and brings new evidence on price interdependencies between food and biofuel markets that have become a frequently debated topic since the food crisis. The support system aimed to the development of production and use of biofuels through standards that affect the proportion of bio-components in fuels used in the country should not create an incentive to grow more e.g. corn and less soybeans as in case of U.S.

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