The Impact of Biofuel Policies on Food Prices in the European Union[1]

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Abstract

In the EU, USA and elsewhere in the world a significant amount of public money is being devoted to support of biofuel production. Rising biofuel production is believed affects agricultural commodity prices as well as fossil fuel prices. The relationship between oil and food prices has been known for a long time. In this article we analyze the statistical relationship among the fuel prices (oil, gasoline, bioethanol) and selected food prices (maize, wheat and sugar). We conduct a series of statistical tests, starting with tests for unit roots, estimation of cointegrating relationships among the price series, evaluating the interrelationship among the variables using Vector Error Correction Model (VECM) and Variance decomposition. According to our results, there is a long-run cointegrating relationship among the selected time series in the later years while the interrelationship among the variables was weaker in earlier period.

Keywords: *biofuels, crude oil, food, cointegration*

JEL Classification: Q13, Q18, Q42

1. The Relationship between Food and Fuel Prices

There has been a tremendous increase in production of biofuels in recent years. Global production of biofuels reached 62 billion litres in 2007. Of this amount around 85% of liquid biofuels is bioethanol, while remaining 15% is biodiesel. In 2009 annual production of biofuels has already exceeded 100 billion litres. Incentives motivating the rise of biofuel production come from

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government support programs. Rising oil prices also provide a boost for production of biofuels as biofuels are substitutes to fossil fuels.

Governments in the USA, EU, and Brazil as well as in other developed but also developing countries use a plethora of instruments to support the production of biofuels. Among the most important instruments belong consumer excise-tax exemptions, mandatory blending of biofuels and fossil fuels, import tariffs on biofuels, production subsidies for biofuel feedstock (e.g., energy crops) and biofuels themselves (grants, loan guarantees, tax incentives, etc.), subsidies for Research and Development (R&D) of new technologies.

In the European Union, the biofuel directive (The Directive 2003/30/EC) sets that by 2010 the European Union should reach the reference target of 5.75% share of biofuels in total transport fuel use. By year 2020 the EU has a mandatory plan to achieve 10% share of biofuels in transport fuels. Member states in order to achieve the reference target can provide tax concession to support biofuel industry. European Union also uses import tariff on denaturated and undenaturated bioethanol imports of 10.20 EUR per hl and 19.20 EUR per hl respectively which is an equivalent of 33.2% and 62.4% respectively in ad valorem terms. The import tariff on biodiesel is 6.5%. European Union also provided 45 EUR per hectare to farmers that produce feedstock that are used for production of biofuels (energy crops) or to generate heat of power. Set aside land could have been used for production of feedstock for biofuels or for generation of heat of power. However the Common Agricultural Policy (CAP) revision, called „Health Check“, has abolished the energy crop premium and the set-aside scheme. This aid for growing (annual) energy crops thus does not exist anymore. Member states of the EU provide tax concessions. On average tax on biofuels is 50% lower than tax on fossil fuels.

Concurrently with rising biofuel production and biofuel support, agricultural commodity prices have risen sharply. By early 2008, real food prices were 64% above the levels of 2002 after four decades of predominantly declining or flat trends (FAO, 2008). Rising biofuel production affect production of agricultural commodities that are major inputs in biofuel production.

Biofuels are fuels derived from biomass that are provided by agriculture. Commodities that grow fast (willow), contain oil (palm, rapeseed) or have high content of sugar (sugarcane, maize) are the most efficient sources for production of biofuels. Bioethanol is mostly produced from sugarcane and maize. Sugar cane is favourite raw material for bioethanol production in Brazil, cereals and sugar beet in the USA, EU and other developed countries with temperate climate. Biodiesel is mostly produced from oilseed crops like rapeseed, palm, or soybeans.

Biofuels involve the tradeoff between using scarce resources to produce fuel and to produce food (Runge and Senauer, 2007; Msangi et al. 2006; Rajagopal and Zilberman, 2007). An estimated 93 million tons of wheat and coarse grains were used for bioethanol production in 2007, double the level of 2005 (OECD--FAO, 2008).

The literature considers rising biofuel production as one of the reasons be hind the agricultural price hike. Food demand increases in growing Asian economies and negative supply shocks caused by adverse weather in major production regions are believed also contributed to growing agricultural commodity prices.

Gardner (2007) models the interrelationship between biofuel markets and agricultural markets. He shows in a partial equilibrium model that increased demand for biofuels caused by biofuel subsidy leads to higher producer prices of bioethanol while the buyers' prices of bioethanol fall. This means that fuel users benefit from biofuel subsidy. The benefits to fuel buyers are higher if biofuel subsidy decreases also the price of fossil fuels. Agricultural producers of commodities used for biofuel production (wheat…) also gain because increased use of bioethanol increases derived demand for wheat. Because of higher prices of wheat the buyers of wheat for export or for food production are worse off.

Blends of biofuels and gasoline or diesel are applied into cars. Low bioethanol blends from 5% to 22% are applied without modifications of engines and with the existing infrastructure. E10 blend (10% bioethanol and the rest gasoline) is used in USA and Brazil while E5 is popular in Europe. High bioethanol blends of 85% require special engine modifications and are used in flexible fuel vehicles. Biodiesel application ranges from pure biodiesel known as B100 to low biodiesel blends B20.

De Gorter and Just (2008) shows that biofuel prices increase when fossil fuel prices go up. Biofuels are almost perfect substitutes to fossil fuels. In equilibrium the price of gasoline is therefore the same as the price of bioethanol. De Gorter also shows that the government can stimulate production of biofuels by lowering the excise tax on fuels or increasing tax exemption on biofuels.[2]

[2] For perfect substitutes $P_G = P_B$, where P_G is the price of gasoline and P_B is the price of bioethanol. However, 1 l of biofuel has lower energy content than 1 l of gasoline, which means that price of biofuels is lower than the price of gasoline. $P_B = kP_G$. When an excise tax is imposed the relationship between gasoline and biofuel prices becomes: $P_B + t = k(P_G + t)$, where t is an excise tax. To support biofuel production governments provide tax exemption on biofuels: $P_B + t - te = k (P_G + t)$, where te is tax exemption. By rearranging we can express the price of biofuels: $P_B = kP_G - t(1 - k) + te$. To increase the price of bioethanol and to stimulate its production the government can lower the excise tax on fuels, to increase the tax exemption on biofuels. P_B increases when P_G goes up.

O'Brien and Woolverton (2009) quantify the relationships between bioethanol and motor fuel prices and confirm that the maize market is closely related to the energy sector. A sizeable increase in maize processing for bioethanol now tends to strengthen maize prices much more significantly than in the past. The relationship of maize prices to various fuel prices has major implications for farmers and up and downstream industries like suppliers of fertilizers, seeds of food processors.

Msangi et al. (2006) show, that when the demand for biofuels is growing very rapidly, holding crop productivity unchanged, world prices for crops increase substantially. The impact is smaller when biofuels are produced by the second-generation cellulosic technologies or when crop productivity improves. Producing bioethanol for use in motor fuels increases the demand for maize or other bioethanol feedstock, which ultimately raises their prices.

According to Tokgoz and Elobeid bioethanol and agricultural commodity prices tend to move together. This study illustrates that the discussions about the role of bioethanol as a fuel source need to take into consideration the response of world agricultural markets (Tokgoz and Elobeid, 2006).

On the other hand, the report of Renewable Fuels Association shows that the role of maize prices and bioethanol production in rising food prices is minimal. Only 4% of the change in the food Consumer Price Index (CPI) is explained by fluctuations in maize futures prices, even when the maize price is lagged (RFA, 2008).

The impact is less significant in rich countries such as the United States because only 7.3% of income is spent on food. However, in developing countries, about 20% of income is used in food consumption (Bullock, 2007, Chapter 9).

Bioethanol in the EU is mainly produced from wheat and to a lesser extent sugar beet (production from maize is marginal). Bioethanol is still a very small market for EU cereals (more specifically wheat) since it represents less than 1% of end use of the latter. Price spikes are common in agricultural markets due to a combination of relatively inelastic demand and volatile supply. European Union bioethanol has had no discernible impact on the commodity price spike (ebio, 2008).

The world has consumed more wheat than has been produced in six of the last seven years. Rice consumption has been higher than rice production in five of the last seven years. The resulting drawdown in wheat and rice stocks is largely responsible for the large increase in rice and wheat prices because neither rice nor wheat is used in biofuels. It is difficult to find a link between the prices for these staple food crops and expanded biofuel production (Babcock, 2008).

An analysis made by the Energy Information Administration suggested that up to 16 billion gallons of maize-bioethanol could still be produced in 2015 without affecting the maize price (EIA, 2007).

The changes in the amount of biofuel produced over the last 5 years have not been enough to cause the big prices changes we have seen in commodities (Saunders et al., 2008, 2009). European Union biofuel policies led to an increase in food prices in Brazil of 0.5% and European food prices increased by 0.14%. A US report has supported the view that the increased link between maize and energy markets is one factor driving food prices (Abbot, Hurt and Tyner, 2009).

2. Methods and Data

From literature review the following hypotheses follow:

- Food prices are positively related to fuel prices.
- Biofuel prices are positively related to fuel prices.
- Food prices are positively related to biofuel prices.

The main goal of our paper is to check whether the relationships among fuel, biofuel and food prices are statistically significant as suggested in the literature. Most of the literature derives a positive relationship between bioethanol, gasoline and oil prices and the prices of maize, wheat and sugar; in other words, it is expect that an increase in bioethanol price leads to an increase in the demand for maize, wheat and sugar beet and therefore, an increase in maize, wheat and sugar prices. In particular the paper evaluates the relationship among the following variables: fuel prices (oil, gasoline, bioethanol) and selected food prices (maize, wheat and sugar).

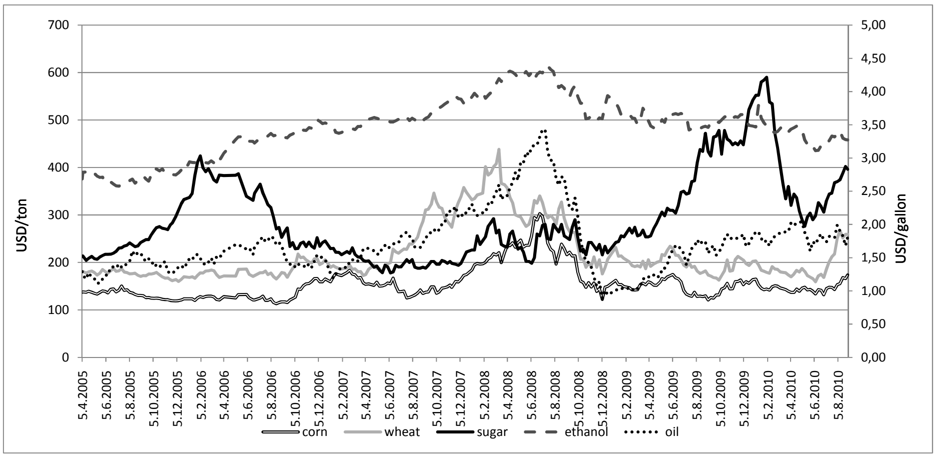
We conduct a series of statistical tests, starting with tests for unit roots, estimation of cointegrating relationships between price pairs, estimation of Vector Autoregression Model (VAR), Vector Error Correction Model (VECM) and Variance decomposition. The number of lags included in the models is determined based on the Akaike Information Criteria (AIC). AIC criterion is used because the sample size is small relative to the number of parameters. We use weekly data (April, 2005 to August, 2010) for oil, bioethanol, maize, wheat and sugar prices. Prices are expressed in USD per gallon of fuel and USD per ton of food. German bioethanol prices come from Bloomberg database (2005 – 2010). Europe Brent oil prices and gasoline prices are from Energy Information Administration (2005 – 2010) and German maize, wheat and sugar prices come from Deutsche Börse database (2005 – 2010). German prices are used because Germany has been one of the most important bioethanol producers in Europe during the observed period. Logarithmic transformation of the prices is used due to the assumed multiplicative effect (Johansen, 1995). The use of the logarithm of the variables of the model implies that the corresponding coefficients are now interpreted in percentage terms.

3. Results

Since early 2000 bioethanol prices in the European Union have widely fluctuated. The highest price reached 3.94 USD per gallon in March 2008, while the lowest price was 1.33 USD per gallon in September 2000. The bioethanol market in the EU was growing in 1990s. It took 10 years for production to grow from 60 million liters in 1993 to 525 million liters in 2004. High increase in production has been driven, according to the literature, by the combination of EU biofuel policy, reduction of production costs, and increase in oil prices.

F i g u r e 1

Development of Fuel and Food Prices



Source: Bloomberg – bioethanol prices (2010); EIA – oil prices (2010); Deutsche Börse – maize, wheat and sugar prices (2010)

Non-stationary time series can lead to statistically significant results due to purely spurious correlation. The existence of stochastic (or deterministic) trend invalidates correlation or regression analysis results. We therefore tested for the stationarity of the price series using augmented Dickey Fuller (ADF) and Phillips Perron (PP) tests. The lags of the dependent variable in the tests were determined by Akaike Information Criterion (AIC). Both tests show that all the time series (oil, gasoline, bioethanol, maize, wheat and sugar prices) are integrated of order 1, i.e. they are non-stationary. To make them stationary we therefore take the first differences. The tests indicated that all variables were stationary in first differences. (Results of the tests are available upon request from the corresponding authors.)

The stationarity tests showed that the original time series are non-stationary and could be used for cointegration analysis. Johansen Cointegration Test allows for testing the cointegration of several time series. We use two Johansen likelihood ratio tests for determining the number of cointegrating vectors, the lambda max test and the trace test. Both tests use eigenvalues to compute associated test statistics.

T a b l e 1

Johansen Cointegration Test

Maximum rank	L-max test		Trace test	
	max statistic	1% critical value	trace statistic	1% critical value
0	62.6022	46.82	114.6384	111.01
1	29.3040	39.79	52.0362	84.45
2	10.9815	33.24	22.7322	60.16
3	7.1606	26.81	11.7507	41.07
4	3.1406	20.20	4.5901	24.60
5	1.4496	12.97	1.4496	12.97

Source: Own calculation.

As shown in the Table 1, there is one cointegrating relationship bounding the variables. When a cointegrating relationship is found, we estimate a vector error correction (VEC) model as follows,

$$\Delta p_t = \Pi p_{t-1} + \Gamma_1 \Delta p_{t-1} + \ldots + \Gamma_{j-1} \Delta p_{t-j+1} + u_t$$

where

$\Delta p_t = (\Delta p_{1t},\ldots\Delta p_{6t})$ – a vector of 6 price series (bioethanol, gasoline, oil, wheat, maize, sugar), each including T observations,

$p_{t-1} = (p_{1t-1},\ldots p_{6t-1})$ – a vector of 6 one-lagged prices,

each $\Delta p_{t-j} = (\Delta p_{1t-j},\ldots\Delta p_{6t-j})$ – a vector 6 of j-lagged differenced prices,

$j = 1\ldots J$, Π – a (6 x 6) matrix of long-run coefficients,

each Γ_j – a (6 x 6) matrix of short-run coefficients,

$u_t = (u_{1t},\ldots u_{6t})$ – a vector of 6 residual series.

The number of lags j included in the model is determined based on the Akaike Information Criteria.

To check the adequacy of our model, we implement a series of tests. First, we run Lagrange-multiplier (LM) test for autocorrelation in the residuals. Next, we employ Jarque-Berra test to check if the residuals in the VECM are normally distributed and the test of stability of the model. The results prove the suitability of the model.

There is a negative and highly significant coefficient for error correction term for gasoline and crude oil. This means that there is a force causing these variables return to the long-run relation when they deviate from it. The deviation from the long-run equilibrium is corrected at a low speed.

T a b l e 2

Vector Error-Correction Model

	Equation					
	Δ bioethanol	Δ gasoline	Δ oil	Δ maize	Δ wheat	Δ sugar
Δ $bioethanol_{t-1}$	–0.001	0.192	–0.089	–0.035	0.245	–0.352*
Δ $gasoline_{t-1}$	0.038*	–0.083	0.074	0.091*	–0.017	0.064
Δ oil_{t-1}	0.004	0.360***	0.021	–0.156**	–0.052	–0.078
Δ $maize_{t-1}$	0.051*	–0.039	0.096	0.063	–0.029	0.122
Δ $wheat_{t-1}$	–0.042	0.091	0.006	–0.084	0.018	0.011
Δ $sugar_{t-1}$	0.018	0.006	–0.037	–0.065	–0.034	–0.030
ECT_{t-1}	0.003	–0.020***	–0.027***	0.012*	0.000	–0.006

Significance: 1% (***), 5% (**), and 10% (*).

Source: Own calculation.

We find significant short-run effects of changes in oil and gasoline prices on change of maize prices as well the short-run effect of bioethanol price on sugar prices. However, the short-run effect of agricultural markets on fuel prices has not been confirmed. There is only a small impact of maize prices on bioethanol prices. The coefficient is only significant at the ten % level. This may be due to enhanced use of maize in the production of bioethanol.

Similar results were found by Frank and Garcia (2010) who identified the oil effects on maize in the period from September 2006 to November 2009. However they have found also significant short-run influence of maize and live cattle on oil prices.

Variance decomposition provides information on the relative magnitude of the causation influence of one price on another. The results of variance decomposition indicate the effect of shocks in each price on the current and future values of a given price. As seen from the Table 3, the variance of oil price explains 16.22% and 15.95% of the variance of the gasoline and maize prices after 12 weeks, respectively. In contrast the relative variance in fuel prices caused by shocks in food prices is only around 1% and less. The variance decomposition results further support the influence of gasoline and bioethanol prices on oil prices while the impact of oil on bioethanol is rather small because only 2.41% of variation in bioethanol prices is explained by variation in oil prices. This means that there are still stronger variables influencing bioethanol prices than oil prices. Currently biofuel policies have the strongest impact on bioethanol prices. Most of the variance in maize can be explained by its own innovations (82.13 – 78.21%). The variance in wheat is mostly explained by its own innovations (50.68 – 51.61%); however the contribution of maize to the wheat forecast error variance is also considerable (34.60 – 31.94%). Our results are consistent with Zhang et al. (2009) supporting the influence of gasoline prices on oil prices and bioethanol, and lack or minor causality relations of bioethanol prices on any agricultural commodity prices. Frank and Garcia (2010) suggest also that the shocks from oil prices contribute to explain agricultural commodities forecast errors, although the effect is smaller between one to two % for grains and roughly six % for livestock.

Table 3

Variance Decomposition

Weeks	Relative variance in (response)	Percentage of forecast variance explained by innovations in (impulse)					
		Δ bioethanol	Δ gasoline	Δ oil	Δ maize	Δ wheat	Δ sugar
1	Δ bioethanol	100.00	0.00	0.00	0.00	0.00	0.00
4		97.76	0.45	0.94	0.16	0.55	0.13
12		96.37	0.19	2.41	0.08	0.84	0.11
1	Δ gasoline	3.60	96.40	0.00	0.00	0.00	0.00
4		10.72	77.21	12.81	0.01	0.17	0.02
12		12.11	71.46	16.22	0.00	0.14	0.05
1	Δ oil	12.53	12.44	75.02	0.00	0.00	0.00
4		11.75	28.03	58.88	1.25	0.03	0.06
12		11.71	42.83	42.81	2.42	0.13	0.04
1	Δ maize	4.53	1.61	11.73	82.13	0.00	0.00
4		3.53	0.85	10.53	84.16	0.06	0.42
12		3.05	1.22	15.95	78.21	0.95	0.62
1	Δ wheat	4.62	0.20	9.89	34.60	50.68	0.00
4		6.96	0.73	7.74	32.76	51.74	0.06
12		7.51	1.09	1.93	31.94	51.61	0.07
1	Δ sugar	1.64	0.82	3.73	2.00	0.46	91.34
4		0.46	1.87	2.40	5.03	0.61	89.63
12		0.19	2.26	1.93	5.69	0.69	89.23

Source: Own calculation.

Because production of biofuels have been rising strongly recently it can be expected that the nature of relations between the prices of fossil fuels, biofuels, and agricultural commodity prices could have changed with the passing of time. We used Zivot-Andrews (ZA) unit root test to check for the presence of structural break in the data. According to the results of ZA test we decided to divide the observed period into two time periods (August 2008 was identified as a breaking point in the time series). (Results of the tests are available upon request from the corresponding authors.)

As shown in the Table 4, there is no cointegrating relationship in the first period (2005 – 2008) while all of the analyzed time series are cointegrated in the second period, except for the sugar-bioethanol and wheat – bioethanol price relationship. This may be a result of the fact that EU production of bioethanol from wheat only began in 2003. Cereal consumption for bioethanol in the EU in 2007 – 2008 only accounted for 0.09% of the global cereal production with over 40% of it being grown on set-aside land where food production was forbidden. Lack of cointegration among price series in 2005 – 2008 implies that their short-run dynamics may be examined using an unconstrained VAR model with first-differenced variables. (Estimated VAR model is available upon request from the corresponding authors.)

Table 4
Johansen Cointegration Test (bivariate)

	April 2005 – July 2008				August 2008 – August 2010			
	L-max test		trace test		L-max test		trace test	
	r = 0	r = 1	r = 0	r = 1	r = 0	r = 1	r = 0	r = 1
Bioethanol Oil	4.07***	1.35	5.42***	1.35	16.66	0.89**	17.56	0.89**
Bioethanol Maize	5.07***	1.51	6.59***	1.51	12.22	4.44*	16.66	4.44**
Bioethanol Wheat	5.93***	1.14	4.79***	1.14	9.65***	1.45	11.10***	1.45
Bioethanol Sugar	5.61***	1.96	7.57***	1.96	6.80***	1.92	8.71***	1.92
Oil Maize	7.93***	1.06	9.02***	1.06	16.23	1.54**	17.76	1.54**
Oil Wheat	7.48***	1.41	8.89***	1.41	24.73	2.00**	26.74	2.00**
Oil Sugar	3.75***	1.13	4.88***	1.13	12.95	2.36*	15.31	2.36*

Note: *** significance at 1% level, ** significance at 5% level, * significance at 10% level.
Source: Own calculation.

On the other hand, there are five cointegrating relationships in the second period between bioethanol and oil prices, bioethanol and maize prices, oil and maize prices, oil and wheat and oil and sugar prices. Results from Zhang et al. (2010) yield cointegration relationship between US bioethanol and maize prices for the 1989 – 1999 period. In contrast, results indicate no long-run relation between bioethanol and maize prices in the 2000 – 2007 period. In contrast to popular belief, between 2000 and 2007 bioethanol and maize do not appear to have any long-run price relationships. However, short-run relations may exist where bioethanol prices do influence maize prices and vice versa.

To estimate parameters of the relationship between price time series in the first period we used Vector Autoregression (VAR) model because the variables were not cointegrated. Based on the AIC criterion, we estimated VAR(1) model on the first differences of the logarithms of each variable. To check the model fitness we performed a series of tests (Lagrange Multiplier test for the presence of autocorrelation, Jarque-Bera test and the VAR model stability test). The results prove the suitability of the model and state that all the eigenvalues lie inside the unit circle and VAR satisfies stability condition. In order to explore if there is a „Granger causality" among the analyzed variables we run Granger causality test. The direction of causality between the prices in the second period is revealed through the parameter estimates from the VECM.

Table 5

Granger Causality Results

April 2005 – July 2008	August 2008 – August 2010
Oil → Bioethanol	Oil → Bioethanol***
Oil → Maize **	Oil → Maize **
Oil → Wheat	Oil → Wheat*
Oil → Sugar	Oil → Sugar
Bioethanol → Oil	Bioethanol → Oil***
Bioethanol → Maize	Bioethanol → Maize*
Bioethanol → Wheat	Bioethanol → Wheat*
Bioethanol → Sugar	Bioethanol → Sugar

Note: *** significance at 1% level, ** significance at 5% level, * significance at 10% level.

Source: Own calculation.

We found a casual relationship between oil and maize prices in the first period (Table 5). The Granger causality tests for the second period suggest long run unidirectional causality from energy prices to agricultural commodity prices and a bidirectional relationship between bioethanol and oil prices. The coefficients of the error correction terms are statistically significant implying, that the integrated variables tend to return to their long run equilibrium when they deviate from it in all cases, except for sugar. The magnitude of the error correction term is small indicating that the integrated variables tend to return slowly to their long run relations.

Balcombe and Rapsomanikis'(2008) also determined bioethanol prices to be Granger caused by oil prices. The results of Granger causality tests in Arshad and Hameed (2009) show that there exist a long run unidirectional causality from oil price to the three cereals prices, i.e., maize, rice and wheat. The said is not true for the reverse.

Conclusion

The main purpose of this paper was to analyze the statistical relationship among the fuel prices (oil, gasoline, bioethanol) and selected food prices (maize, wheat and sugar). In order to achieve our goal, we first collected weekly data for oil, gasoline, bioethanol, maize, wheat and sugar prices from April, 2005 to August, 2010. We conducted a series of statistical tests, starting with tests for unit roots, estimation of cointegrating relationships among the price series, evaluating the inter-relationship among the variables using (VECM) and Variance decomposition. Our results show that there is a single cointegrating relationship bounding the variables. We found significant short-run effects of changes in oil and gasoline prices on change of maize prices as well the short-run effect of bioethanol price on sugar prices. However, the short-run effect of agricultural markets on fuel prices has not been confirmed. There is only a small impact of maize prices on bioethanol prices. Similar results were achieved also by the Variance decomposition; the variance of oil price explained 16.22% and 15.95% of the variance of the gasoline and maize prices after 12 weeks, respectively. In contrast the relative variance in fuel prices caused by shocks in food prices was only around 1% and less. Because the interrelationship between fuel and food prices grows with rising biofuel production we divided the observed period into two periods with structural break in August 2008. There was no cointegrating relationship in the first period (2005 – 2008) while most of the analyzed time series are cointegrated in the second period, which means that biofuel production is starting to exert influence on fuel and food prices.

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