Relationship among Energy, Bioenergy, and Agricultural Commodity Prices: Re-Considering Structural Changes

Mehdi Nemati
Department of Agricultural Economics
University of Kentucky
mehdi.nemati@uky.edu

Selected Poster prepared for presentation at the Southern Agricultural Economics Association's 2016 Annual Meeting, San Antonio, Texas, February 6-9, 2016

Relationship among Energy, Bioenergy, and Agricultural Commodity Prices: Re-Considering Structural Changes

Abstract

This study investigates the relationships among the prices of gasoline, ethanol, and agricultural products that includes soybeans and corn. By increasing production of ethanol using corn, concerns about emerging new relationship between agricultural products price and energy price increased. The result indicates that, without considering structural breaks, there is no long-run relationship between energy and agricultural products prices. However, after consideration of structural breaks not only, long-run relationship between energy and agricultural products exist, but also this relationship intensified during last decade. Also, energy price can be transmitted to agricultural products prices from the indirect and direct channel.

Keywords: Ethanol, Agricultural commodities, Structural changes, VECM modeling

JELJ codes: Q11; Q13; Q42; Q48

1. Introduction

As previous research shows, energy price changes can be transmitted to agricultural commodity prices through two important channels. Energy is an input for producing and transporting agricultural products, and changes in energy prices can affect agricultural products' prices indirectly through this channel (Hochman et al., 2010). Changes in energy prices can also affect agricultural product prices directly through biofuel channels (Senauer, 2008). Increases in the oil price can increase demand for biofuels and as a result demand and prices for agricultural products will increase. Some of the researchers found support for the long-run price relationship between energy and agricultural commodities prices, especially after huge increase in biofuel production that is began in 2005-2006 (e.g. Harri et al., 2009; Ciaian 2011).

Harri et al. (2009) examined the relationship between oil price, exchange rate and commodity prices (corn, soybeans, soybeans oil, cotton, and wheat) using VECM from 2000-2008. Their cointegration result shows that long-run relationship between oil price and prices of corn, soybeans, and soybeans oil started from 2006. Another example in this area is Campiche et al. (2007) study. They did not found any long-run relationship between prices during 2003-2005, but they did found cointegration between oil price and corn and soybeans prices in 2006-2007 period.

On the other hand some researchers did not found any long-run relationship between energy and agricultural commodity prices; however they did found short-run dynamics between these price series. For example studies by Saghaian (2010), Zhang et al. (2010), and Esmaeili and Shokoohi (2011) did not find any long-run relationship between energy and agricultural commodity prices.

Interestingly, studies that did not identify and considered structural breaks in the price series (Saghaian 2010; Zhang et al. 2010; Esmaeili and Shokoohi 2011); also did not found long-run relationships between energy and agricultural products prices. On the other side some studies, which they did consider structural breaks in their analysis; found long-run relationship in some periods of time and all of them found cointegration between energy price and agricultural commodity prices in at least one of the subsamples. (Harri et al. 2009; Ciaian 2011; Campiche et al. 2007; Baek and Koo 2010; Ciaian 2011a, and 2011b)). We can conclude from the result of current studies that considering structural breaks may affect the studying long-run relationship between energy and agricultural commodity prices. Consideration of structural breaks gets more important when we have increases in biofuel production and consumption. Consumption of biofuels has and continues to increase rapidly in the U.S. The U.S. Energy Information Administration data shows that biofuel consumption in the U.S. increased from 651 (TB/d[1]) in 2008 to 900 (TB/d) in 2012. Also, they showed that the U.S. is one of the major producers and consumers (50 percent) of biofuels in the world. This may affect the relationship between energy and agricultural commodity prices.

The main objective of this paper is testing whether linkages and price co-movements between energy and agricultural commodity prices statistically significantly exist or not. If there is a significant relationship between energy and agricultural commodity prices, we want to see if these prices are only in the short run or if they are sharing long run co-movements. Also, we want to test if structural changes (due to the economic crises or other types of shocks) have an effect on these relationships or not. Estimating models with and without considering structural breaks helps to find out the effect of structural breaks. Finally, if there is price transmission from

[1] Thousand Barrels Per Day

the energy sector to the agricultural products, is this price transmission coming from direct channel, indirect channel or both?

Finding these relationships will be useful for U.S. policymakers: For example, if there is a long-run relationship between energy and food prices they can use energy sector prices to stabilize food sector prices in the long run. Also, this will be helpful for deciding agricultural price policies in the U.S.

2. Data

Agricultural commodities that used for this study are corn and soybeans. Monthly prices for these commodities are from The United States Department of Agriculture (USDA) database. Ethanol will be looked at to explain biofuel price movement. Ethanol is one of the most important products of biofuel. Monthly ethanol price is coming from the USDA. Lastly, we will use oil and gasoline price as a representative of the energy sector; monthly prices are obtained from the U.S. Energy Information Administration (EIA). All the price series are from January 1986 to November 2014 (347 observations).

Table 1 presents summary statistics for the data. In this table CP and SP respectively stand for corn price and soybeans price. The second panel in table 2 is energy panel, where respectively OP and GP indicate the price of crude oil and gasoline price. Lastly, ethanol price (EP) mean for this period was 1.59. In the rest of the paper, we will use these abbreviations for the price series.

Figure (1) shows a log of monthly prices for agricultural commodities (corn, soybeans), and energy commodities (oil, gasoline and ethanol) from 1986-2014. This graph shows that oil, gasoline and ethanol prices move together. For example prices of ethanol, oil and gasoline increased during the 2000s or the first period of 2011. In the case of agricultural prices and energy price (especially corn price) we can see that they moved together in some periods of time and in some other period they do not. For example, in 2008 all of the prices increased. However, there is not co-movement between these set of prices in second half of 2012 (energy prices decreased while agricultural commodity prices increased). This primary result shows that we need to investigate these relationships with more detail.

3. Model

Dynamic price systems are set up to study the impact of energy prices and biofuel price on agricultural products price. Time-series theories indicate that unit root test for indicating variables integration order must be tested before modeling. To test existing unit root in our price variables we used DF- GLS[2] proposed by Elliott, Rothenberg, and Stock (1996). Elliot and et.al (1996) have shown that this test has significantly greater power than the previous versions of the Augmented Dickey–Fuller test. The null of existing unit root in the series against the alternative of series is stationary around a mean or mean, and the linear trend will is testable by DF-GLS. This test includes 1 to k lag of the series in the model, where an optimal number of lags (k) can be determined using Schwartz (1989) method.

If the result of DF-GLS test indicates that all of the price variables are non-stationary and have one unit-root, we can employ vector error correction models (VECMs) to study long-run

[2] Dickey-Fuller generalized least-squares

relationships and short-run dynamics between price series. Following Johansen (1995), the VECM model gets the following form. In equation one we assumed r cointegration relations. y_t , is vector of price series, $\beta^`$(cointegration matrix) is cointegration vector and shows long run equilibrium, α (loading matrix) represents the speed of returning back to long-run equilibrium if the corresponding variables deviate from them. The term $\sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i}$ shows short-term dynamics. δ, is vector of coefficients and $\psi_t$shows deterministic part such as seasonal dummies and exogenous variables.

$$\Delta y_t = \alpha\beta^` \begin{bmatrix} y_{t-1} \\ 1 \end{bmatrix} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \delta\psi_t + \varepsilon_t \quad (1)$$

As we mentioned before considering, structural changes may affect the result of cointegration and long-run relationships. Therefore, we used the Quandt-Andrews breakpoint test (Andrews (1993)) for structural change with unknown date. After finding structural change dates, we repeat unit root test and VECM model for each sub-sample.

4. Empirical Result

To show the effect of structural changes on the relationship between energy and commodity prices two models, with considering and without considering structural changes, are estimated.

Table 2 shows DF-GLS test result. In 5% significance level, we cannot reject the null of existing unit root in price series. In other words all of our variables are integrated of order one, I(1). This allows us to go to our next step for finding a long-run relationship between price variables. To study the long-term equilibria and short-term dynamics among these price variables, we used VECM model.

Cointegration test that proposed by Johansen (1995) used to find the existence of a long-run relationship between price series. The optimal number of lag for price series determined using Bayesian information criterion (BIC). Table 3 shows the result of cointegration test. Trace statistics indicates that there are two cointegration relationships between four variables (LogEP, LogGP, LogCP, LogSP).

Cointegration relationships estimated using VECM and results are reported in Table 4. We assumed that oil price is exogenous to this system. In fact, agricultural products price and gasoline or ethanol price cannot affect oil price. Therefore, we used the first difference of oil price (the first difference is stationary) as an exogenous variable in our model. Model estimated with including two lags as specified by BIC criteria. The first part of Table 4 shows the speed of adjustment to the long run equilibrium (α) and the second part shows long-run relationships (β). The estimation of the cointegration matrix (β) from first cointegration relationship shows that, in the long run equilibrium, soybeans price (log SP) has a positive and significant effect on corn price (log CP). In terms of elasticity, if the soybean price changes by one percent, corn price would increase by 1.06 percent. In other words, in the long run, price shocks to the corn price would be fully transmitted to corn price. Also result indicates that ethanol price has no effect on corn price in the long-run. The estimation of the cointegration matrix (β) from second cointegration relationship shows the positive long-run relationship between ethanol and gasoline prices. In terms of elasticity if there is 1 percent increase in ethanol price, gasoline price will increase by 1.99 percent. Zhang et al. (2010) and Myers et al. (2014) found a similar result. Loading matrix (α) shows adjustment back to the long-run equilibrium if the corresponding variables deviate from them. Coefficients of logCP and logSP in loading matrix are significant and negative. This means that if there are deviations from long-run equilibrium, corn and soybean prices will adjust back to the long run equilibrium. Finally, the effect of oil price as an exogenous variable in the system on corn price is not significant; however it has a positive and significant effect on gasoline price. This indicates that increase in oil price by 10 percent, is associated with 8 percent increase in gasoline price.

We used the Quandt-Andrews breakpoint test (Andrews (1993)) for finding unknown structural change dates in price series. The test result suggests that structural break for corn price happened in February 2007 and for soybean price occurred in October 2007. This result is interesting because the breakpoint identified by the Quandt-Andrews breakpoint test coincides with the 2007-2008 financial crises and food price boom during that period. In the case of ethanol, the structural break occurred in July 2005. In 2005, the first phase of the national Renewable Fuels Standard (RFS1) passed by Congress. According to this law transportation fuel sold in the U.S. should contain a minimum volume of renewable fuel. Also Energy Policy Act of 2005 passed by Congress in July 2005 and according to this act the U.S. energy policy changed and they started to provide tax credits for ethanol production. In terms of price, we can see a huge change in ethanol price that is started from July 2005 (EIA, 2014). Structural change in gasoline price occurred in April 2004; this is also coinciding with a dramatic change in gasoline price. According to federal trade commission (FTC) report (2005): "During 2004 and 2005, U.S. consumers spent millions of dollars more on gasoline than they had anticipated. In the spring of 2005, the national weekly average price of gasoline at the pump, including taxes rose as high as $2.28 per gallon."

After finding structural break points, we used two different time sets to estimate our model. In the first model, we considered from January 1986 to March 2004 and the second one is from November 2007 until November 2014. For each period, we did DFGLS unit root test for all the price series, and test result indicates that we have unit root in our variables. In the second step, we used Johansen (1995) cointegration test to find the existence of a long run relationship among price series in each period. Table 6 shows the result for both periods. As we can see result indicates that there is only one cointegration relationship between price series in both periods. Comparing to full sample, here we have one less cointegration relationship.

Cointegration relationships estimated using VECM model and results are reported in Table 7. Ethanol price has a negative and significant effect on corn price in both periods, but this effect is stronger in the second period. In terms of elasticity, in the long run if ethanol price changes by one percent, corn price will change by -3.19 and -3.88 percent respectively in the first and second period. This means that in the long run, because of the rise in ethanol price, and considering corn as an input for producing ethanol, more and more farmers will switch to corn farming and this leads to decrease in corn price. We can conclude from this result that energy price has an effect on corn price, and this effect is from a direct channel that we mentioned about that.

The relationship between soybeans and corn price is positive in both periods (same as full sample model); however this positive effect is intensified in the second period. Gasoline price has a positive effect on corn price in both periods, but this effect decreased in the second period. Considering that Gasoline is used in agriculture as input for different purposes such as transportation. This shows that energy price can affect agricultural products price (corn price) from the indirect channel as well. Oil as an exogenous variable in the system has a positive effect on corn price only in the second period. In terms of elasticity, if 10 percent increases in oil price in the second period, corn price will increase by 1.7 percent.

5. Conclusion

We used monthly prices of energy and agricultural products prices to indicate the relationship between these prices in the short and long run. Using VECM we found that there is not any long run relationship between price series without consideration of structural breaks. In the second part of our paper, we considered structural changes in price series. Estimation result for two sub-samples shows that ethanol price has a negative effect on corn price in the long run. The result indicates that this negative effect increased in the second period (2007-2014). Gasoline and oil have a positive and significant effect on corn price. To sum up, we found that energy prices have a negative effect on corn price from the direct channel and positive effect from the indirect channel.

6. References

Andrews, D. W. (1993). Tests for parameter instability and structural change with unknown change point. *Econometrica: Journal of the Econometric Society,* 821-856.

Baek, J., & Koo, W. W. (2010). Analyzing factors affecting US food price inflation. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 58*(3), 303-320.

Campiche, J. L., Bryant, H. L., Richardson, J. W., & Outlaw, J. L. (2007). *Examining the evolving correspondence between petroleum prices and agricultural commodity prices.* Paper presented at the The American Agricultural Economics Association Annual Meeting, Portland, OR.

Ciaian, P. (2011). Food, energy and environment: Is bioenergy the missing link? *Food Policy, 36*(5), 571-580.

Ciaian, P. (2011). Interdependencies in the energy–bioenergy–food price systems: A cointegration analysis. *Resource and energy Economics, 33*(1), 326-348.

Clemente, J., Montanes, A., & Reyes, M. (1998). Testing for a unit root in variables with a double change in the mean. *Economics Letters, 59*(2), 175-182.

Elliott, G., Rothenberg, T. J., & Stock, J. H. (1996). Efficient Tests for an Autoregressive Unit Root. *Econometrica: Journal of the Econometric Society*, 813-836.

Esmaeili, A., & Shokoohi, Z. (2011). Assessing the effect of oil price on world food prices: Application of principal component analysis. *Energy Policy*, *39*(2), 1022-1025.

Harri, A., Nalley, L., & Hudson, D. (2009). The relationship between oil, exchange rates, and commodity prices. *Journal of Agricultural and Applied Economics, 41*(2), 501-510.

Hochman, G., Rajagopal, D., & Zilberman, D. (2010). Are biofuels the culprit? OPEC, food, and fuel. *The American Economic Review*, 183-187.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of economic dynamics and control, 12*(2), 231-254.

Johansen, S., Mosconi, R., & Nielsen, B. (2000). Cointegration analysis in the presence of structural breaks in the deterministic trend. *The Econometrics Journal, 3*(2), 216-249.

Myers, R. J., Johnson, S. R., Helmar, M., & Baumes, H. (2014). Long-run and Short-run Co-movements in Energy Prices and the Prices of Agricultural Feedstocks for Biofuel. *American Journal of Agricultural Economics*, aau003.

Saghaian, S. H. (2010). The impact of the oil sector on commodity prices: correlation or causation? *Journal of Agricultural & Applied Economics, 42*(3), 477.

Schwert, G. W. (2002). Tests for unit roots: A Monte Carlo investigation. *Journal of Business & Economic Statistics*, *20*(1), 5-17.

Senauer, B. (2008). Food market effects of a global resource shift toward bioenergy. *American Journal of Agricultural Economics, 90*(5), 1226-1232.

Zhang, Z., Lohr, L., Escalante, C., & Wetzstein, M. (2010). Food versus fuel: What do prices tell us? *Energy Policy, 38*(1), 445-451.

Gasoline Price Changes: The Dynamic of Supply, Demand, and Competition: A Federal Trade Commission Report (2005)

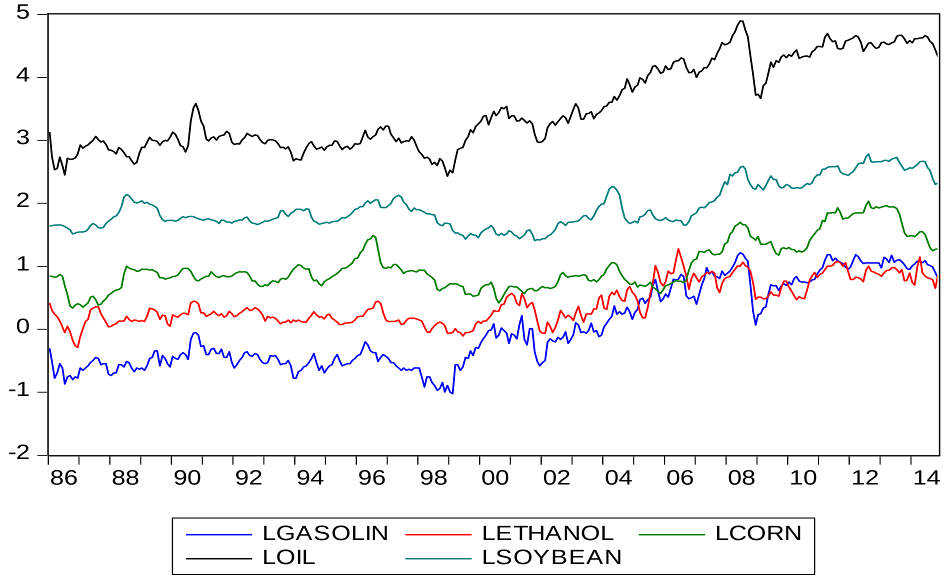

Figure1. Log of corn and soybeans, oil, gasoline, and ethanol prices

Table 1
Summary statistics for data from 1986-2014

Variables	Mean	S.D.	Minimum	Maximum
Panel A: Agricultural commodities (unit: dollar per Bushel**)**				
CP	2.97	1.40	1.4	7.63
SP	7.42	2.94	4.09	16.2
Panel B: Energy products (unit: dollar per Barrel for oil and dollar per gallon for gasoline)				
OP	42.62	31.11	11.35	133.88
GP	1.27	0.88	0.36	3.37
Panel C: Biofuel products (unit: dollar per gallon)				
EP	1.59	0.57	0.75	3.58

Table 2
DF-GLS Unit Root Test Result

Variables	constant	Constant and trend
log PC	-1.78*	-2.48
log PS	-1.17	-2.49
log PO	-0.93	-2.31
log PG	-0.75	-2.36
log PE	-1.96*	-2.47

* denote the 10% significance level. All the prices are in logs.

Table 3
Cointegration Test for Different Price Series

Cointegrating Relationship	Trace Statistic	5% Critical Value	P-Values
None*	80.11	47.85	0.00
At most 1*	30.20	29.79	0.04
At most 2	11.57	15.49	0.17
At most 3	2.34	3.84	0.12

Notes: all the prices are in logarithms. Lag length for each set of prices determined using BIC criteria.

Table 4
Estimation Result of VECM without Considering Structural Changes

Loading Matrix (α`)				Cointegration Matrix (β`)					Exogenous Variables
logCP	logSP	logEP	logGP	logCP	logSP	logEP	logGP	Constant	log ΔOP
-0.038**	-0.054**	-0.005	0.027	1	-1.06***	-0.05	0	1.05	0.014
(-1.93)	(-1.96)	(-0.19)	(1.54)	-	(-7.87)	(-0.37)	-	-	(0.41)
0.014	0.002	0.10***	0.022***	0	-0.03	-1.99***	1	0.85	0.802***
(1.19)	(0.12)	(6.27)	(2.11)		(-0.23)	(-12.87)	-	-	(16.27)

Notes: all the prices are in logarithms. ** And *** respectively indicates significance in 5% and 1% levels.

Table 5
Estimation Result of VECM without Considering Structural Changes

Price Series	Structural Break Date
log CP	2007M02
log SP	2007M10
log EP	2005M07
log GP	2004M04

Notes: all the prices are in logarithms.

Table 6
Cointegration Test for Different Price Series

	Cointegrating Relationship	Trace Statistic	5% Critical Value	P-Values
First Period (1986-2004)	None*	71.98	47.85	0.00
	At most 1	25.5	29.79	0.08
	At most 2	6.6	15.49	0.38
Second Period (2007-2014)	None*	50.99	47.85	0.02
	At most 1	25.95	29.79	0.13
	At most 2	13.24	15.49	0.10

Table 7
Estimation Result of VECM with Considering Structural Changes

	Loading Matrix (α`)				**Cointegration Matrix (β`)**					**Exogenous Variables**
	logCP	**logSP**	**logEP**	**logGP**	**logCP**	**logSP**	**logEP**	**logGP**	**Constant**	**log ΔOP**
Full Sample (1986-2014)	-0.038** (-1.93)	-0.054** (-1.96)	-0.005 (-0.19)	0.027 (1.54)	1 -	-1.06*** (-7.87)	-0.05 (-0.37)	0 -	1.05 -	0.014 (0.41)
	0.014 (1.19)	0.002 (0.12)	0.10*** (6.27)	0.022*** (2.11)	0	-0.03 (-0.23)	-1.99*** (-12.87)	1 -	0.85 -	0.802*** (16.27)
First Period (1986-2004)	-0.016* (-1.92)	-0.01** (-2.33)	-0.05*** (-4.72)	0.008 (0.59)	1	-1.79*** (-4.47)	3.19*** (4.64)	-2.27*** (-5.04)	0.58 -	-0.04 (-1.09)
Second Period (2007-2014)	-0.007 (-0.39)	0.001 (0.11)	-0.09*** (-4.18)	0.003 (0.19)	1 -	-4.14*** (-3.25)	3.88*** (3.78)	-1.55* (-1.84)	4.63 -	0.17* (1.89)

Notes: all the prices are in logarithms. Lag length for each set of prices determined using BIC criteria.