Asymmetric Cointegration: Barley and Crude Oil Price in United States

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ABSTRACT

This paper examine whether asymmetrics cointegration present in the relationship between barley and crude oil price. The result suggest that an asymmetric cointegration statistically found barley price and oil price are cointegrated and adjustment mechanisms exist in the case between these two variables.

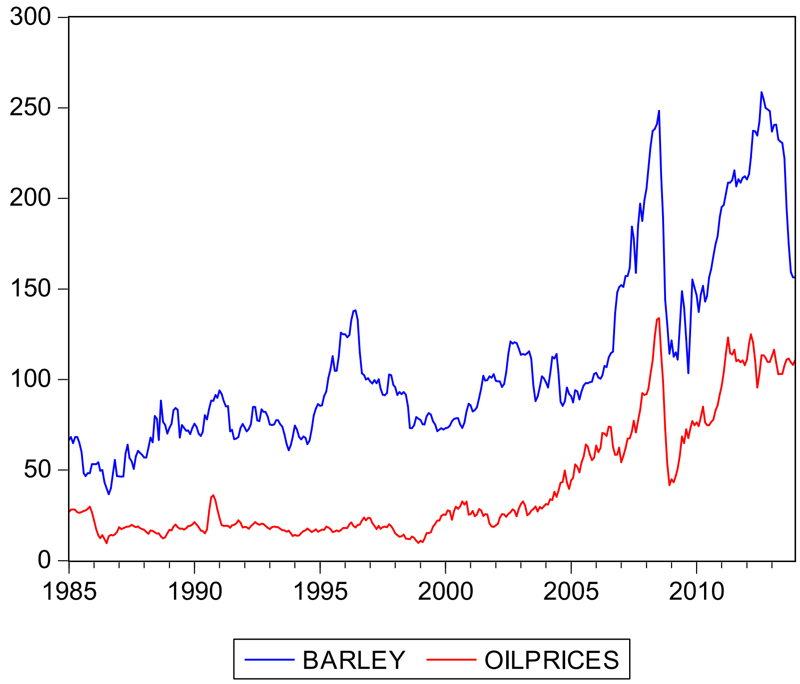
Key words: *barley price, oil price, asymmetrics cointegration, threshold adjustment*
JEL Classifications: C32, C36, C5, F1

1. OVERVIEW

Barley is the most tradable item for United States after corn and wheat. Production of barley is important to fulfill the demand for foods and industrial uses. United States exporting barley to Middle East and North America, whereas China is expected to become largest imported countries for the next 10 years. Taylor and Boland (2005) observed that United States export barley mostly to the country including Tunisia, Morocco amounted 14,500 tons as well as Japan amounted 13,000 tons. USDA (2014) projected total export for barley will increase from 9 million bushels (2012/2013) to 10 million bushels (2013/2014). According to FAOSTAT (2009), European Union, Canada, United States and Australia are among the largest barley producer in the worlds. In 2011 the world output of barley is amounted 133 million tonnes. Declined was due to prolonged dryness across European countries and elsewhere North Africa has recovered from drought.

A number of econometrics issues address of crude oil price and commodity prices. The widespread use of crude oil has increase dramatically in United States. This is due to increase in consumption particularly in the transportation sector. Department of Energy (2014) announced crude oil price was $ 97.86 per barrel compare that a price of $ 10.12 under a year ago. The sharp growth of crude oil increase pressure on commodity prices. Therefore, the objective of this paper is to identify whether there is exit cointegration between oil price and barley. For that reason, we plot the commodity prices and oil price using monthly data ranging from January 1985 to December 2013 (Figure 1.0).

Figure 1.0 Barley Price and Oil Prices



Source: Author calculation

2. LITERATURE REVIEW

The grew of literature review on oil price and food commodity price supported by Zilberman et al., (2012) frequently risen in agricultural sector. Wang, Chongfeng, and Yang (2014) found out that during food crisis oil prices and commodity prices increase simultaneously during 2006-2008. They confirm research outcome trough structural vector autoregressive (SVAR) mainly attributed to aggregate demand shocks. Similarly, Wang and McPhail (2014) provide new evidences on the impact of oil prices shock in United States agricultural commodity prices. Data gather from 1948-2011 adopting structural vector autoregressive (SVAR).Their study suggested that there is slowing in agricultural productivity which attribute to commodity shock.

Another dimension may have to do with commodity prices and fundamental industries like Zhang and Chen (2014) that did a case study in China. They are employed EGARCH method to measure volatility of commodity prices index. It is not surprising, that researcher reveal industrial index much more constant than commodity index due to imperfection of petroleum pricing mechanism. While practical consideration may seem considering utilizing technology which employs soybeans, corns and wheat to produce bio-energy. In facts, Nazlioglu (2011) pick up this issues undertaking non-linear causality (Diks–Panchenko) applying weekly data from 1994-2010. Their results show that there is non-linear relationship between world oil prices and commodity prices. The movement of non-linear start from oil price to the corn prices and ending with soybeans prices.

Exclusive attentions have been given to the study related to agricultural commodity prices in 10 Asian countries. Imai, Gaiha, and Thapa, (2011) investigated selected agricultural commodity including maize, wheat, rice, fruit, vegetables and oilseeds. They apply partial equilibrium approaches. Result appears to be inverse relationship between agricultural commodity price and oil prices. Parallel to this extension West and Wong (2014) looks insights two simple model linked metal, energy and commodity prices. Their study have found the evidence that factor model performance is suitable for energy price but not suitable for metal while agricultural prices falling in between these two model.

Mensi, Beljid, Boubaker, and Managi, (2013) applied most recent VAR-GARCH model to investigate the transmission effects between commodity price indices. Items incorporated were; energy, food, gold and beverages covering the period from 2000 until 2001. The evidence of these results shows volatility and correlation exists due to optimal hedging activites not concerned with the stock market but appears also in the commodity market. As discussed by Back, Prokopczuk, and Rudolf, (2013) commodity market display significant seasonal pattern using sample of soybean, corn, heating oil and natural gas. Their results show that seasonal volatility improves options valuation performances.

3. ECONOMETRICS MODEL

The data is on monthly basis ranging from January 1985 to December 2013 gathered from Mundix Index databases commodity prices fluctuate randomly as proposed by (Samuelson, 1965). In a paper related to ours, latest study done by (Nguyen, 2005) for the soybean market, and by Trolle and for crude oil (Schwartz, 2009; Trolle, 2009).

$$LCP_t = B_0 + \beta_1 LCO_t +_{u_t} \tag{3.1}$$

LCP represent natural logarithm of the specific commodity price (barley) whereas LCO represent natural logarithm of the crude oil price. All variables are transformed into natural logarithm. We perform three stability tests: Jarque-Bera normality test, CUMUS of Squares and Recursive Residual. The Jarque-Bera normality test does not reject the normality hypothesis (p-value of 0.05) (Figure 1.0). CUMUS of Squares and Recursive Residual result are presented in Figure 2.0 and Figure 3.0. At this point, CUSUM does not depart from the band sample. This is indicative that the CUSUM test may not detect coefficient instability occurring late in the sample period within a 5% significance level. Nevertheless, the test of residual able to detect the consistent estimate of recursive residual estimation are stable and lies along with their ± 2.0 standard deviation bands. These three stability test implies there is no structural break for the conditional equation.

2.1. Unit Root Test

The way a test is performed in applied work depends on the motive behind the test. Dickey and Fuller simulated the correct test statistics for H_0: $\hat{\pi} = 0$, under the assumption of a random walk process. This test has as the null that the series is I (1), which in general might be hard to reject. The ADF and PP unit root tests, presented in Table 3.1, clearly indicate that all variables are integrated of order 1, or I (1). The lag order of the VAR specification is obtained by using Schwarz (SC) information criteria.

	Level		First Difference	
Variables	ADF	PP	ADF	PP
LLCP	0.422161	0.457866	-15.47888***	-15.32765***
LLCO	0.402943	0.518755	-14.28018***	-13.88868***

Table 3.1 Unit Root Test
*Notes: *** denotes 1% significant level*

2.2. Engle Granger and Cointegration Test

In this section, we estimate the long equation using OLS. Here, is the estimated long run equation:

$$LR_t = 2.9008 + 0.4953LCO + u_t$$

(46.6604) (27.9493) (3.2)

$R^2 = 0.69365$ Durbin Watson=0.10364

The figure in bracket denotes t-statistic. Based on the regression, barley price is positively and significantly associated with crude oil price. We, proceed next step with Engle-Granger cointegration test is conducted. From the OLS equation, residuals are tested for unit root. Cointegration allow to occur only when the residual are stationary. The residuals(u_t) are tested with ADF stationary test without including trend and intercept. The estimated residuals are obtained as follow:

$$\Delta u_t = -0.056515 + u_{t-1}$$

(-3.261975) (3.3)

$R^2 = 0.080976$ Durbin Watson=2.013501

Based on the result above, we reject H_0, unit root at 1% significance level. Therefore, we conclude that long run relationship exist connecting barley price and crude oil price. Given these two variables are cointegrated, we proceed with asymmetric cointegration test.

2.3. Asymmetric cointegration test

As an alternative test for cointegration, we run the Johansen test and Engle and Granger's two step-procedures. The Johansen test is central for testing cointegration. In this regression we assume that that all variables are I (1) and might cointegrated to form a stationary relationship. If the variables are cointegrating, they will share a common trend and form a stationary relationship in the long run. Furthermore, under cointegration, due to the properties of super converge, the estimated parameters can be viewed as correct estimates of the long-run steady state parameters and the residual (lagged one) can be used as an error correction term in an error correction model.

The second step, in Engle and Granger's two-step procedure, is to test for a unit root in the residual process of the cointegrating. Under the null of no cointegration, the estimated residual is I(1) because x1,t is I(1), and all parameters are zero in the long run. The test statistics for H_0: $\pi = 0$ (no co-integration) against Ha: $\pi < 0$ (co-integration). Result of these two cointegration test, reported below as in Table 3.2.

Variables	EG Test	JJ Test	Null Hypotheses r=0
LLCP	-3.261975	Trace Max	11.53775 10.65084
LLCO	-2.896248	Trace Max	11.53775 10.65084
Critical Values			
5%	-4.259	Trace Max	15.49471 14.26460

Table 3.2 Engle Granger and Johansen
Notes: The SIC is used to select the optimal lag.VAR lag order is used for JJ test

We precede the symmetric cointegration test and error-correction modelling due to (Enders and Siklos, 2001) shown in equation (3.4).

$$\Delta\mu_t = \rho\mu_{t-1} + \sum_{i=1}^{q} \delta_t \Delta X_{t-1} + v_{it} \quad (3.4)$$

Nevertheless, the adjustment can also be asymmetric adjustments for barley price and crude oil price. In the asymmetric adjustment, residuals are categorize as above and below threshold. Equation for asymmetrics adjustment shown in Eqution (3.5). Result for TAR and MTAR shown in Table 3.3.

$$\Delta\mu_t = \rho_{1.i} I_t \mu_{t-1} + \rho_{2.i}(1 - I_t)\mu_{t-1} \sum_{i=1}^{q} \delta_t \Delta X_{t-1} + v_{it} \quad (3.5)$$

Heaviside indicator functions, where:

$$TAR_t = \begin{cases} 1 \text{ if } \mu_{t-1} \geq \tau \\ 0 \text{ if } \mu_{t-1} < \tau \end{cases} \quad (3.6)$$

$$MTAR_t = \begin{cases} 1 \text{ if } \Delta\mu_{t-1} \geq \tau \\ 0 \text{ if } \Delta\mu_{t-1} < \tau \end{cases} \quad (3.7)$$

Variables	TAR	TAR Consistent	M-TAR	M-TAR Consistent
ρ1	-0.048631	-0.034619	-0.047537	-0.045185
ρ2	-0.076996	-0.081176	-0.078968	-0.161958
γ1	0.185284	0.183223	0.187916	0.201710
γ2	-0.120275	-0.119908	-0.118729	-0.112033
γ3	-0.028565	-0.030306	-0.029030	-0.037044
γ4	-0.080754	-0.082177	-0.079612	-0.083399
γ5	0.027729	0.030646	0.026997	0.025459
γ6	0.022864	0.023217	0.024067	0.027376
γ6	0.026946	0.027223	0.027008	0.025537
τ	0.000000	0.222312	0.000000	-0.061532
F-stat	6.309411 (5.731596)	6.866137 (6.912175)	6.390181 (6.193017)	9.189086 (8.032428)**
F-equality	0.686844 (2.897341)	1.761519 (6.659239)	0.842758 (3.703595)	6.245621 (8.458964)**

Table 3.3 Estimation of TAR and MTAR cointegration.
Notes: ** denotes 5% significant level

Table 3.0 reports the results of TAR and MTAR model. Based on the result of TAR model using the threshold value =0, the F-statistics is 6.3094 which is less than 6.8661 at 5 % significance level. We fail to reject H_0, there is no cointegration. In addition the threshold value found by Chan (1993) in TAR-consistent is 0.2223 whereas the F-statistic value is 6.8661, failed to reject H_0 at 5 % significance level. We found same conclusion that on both TAR model do not show cointegration.

Nevertheless, according to both MTAR model with threshold value=0 and -0.061532 respectively. At 5 % significance level, we reject H_0. MTAR-consistent model reveal cointegration. This allows us to further test our asymmetric adjustment. Referring to F-equality statistic in M-TAR-consistent, we reject H_0 at 5 % and indicating that barley price and crude oil price are cointegrated and adjustment is asymmetric.

2.4. Long run Asymmetric cointegration test

The method extends the Engle Granger procedure allowing for either TAR or momentum TAR adjustment toward the cointegrating vector. If asymmetry exists, the power of the M-TAR test is higher than that of the Engle Granger test (Enders 2001). A principal feature of cointegrated variables is that their time paths are influenced by extend of any deviation from long-run equilibrium. After all, the system is to return to long-run equilibrium, the movements of at least some of the variables must respond to the magnitude of the disequilibrium.

The relationship between long run and short run illustrate how variables might adjust to discrepancies from the long run equilibrium relationship. The gap can be closed by (1) an increase in the short-term rate and or a decrease in the long term rate (2) an increase in the long term rate but commensurately larger rise in the short term rate or (3) a fall in the long-run rate but a smaller fall in the short term rate. Without a full dynamics specification of the model, it is possible to determine which of the possibilities will occur in the error correction model (ECM). Diagnostic test were included "diagnose" some problem with the models we are estimating. Examples of diagnostic check: Jarque-Berra Normality test, Serial correlation, ARCH test, white test for Heteroscedasticity and any relevant diagnostic check. We further the ECM based on threshold value = -0.061532. Equation (3.8) and (3.9) represent the result for asymmetric error modeling:

$$\Delta LCP_t = 0.00171 + 0.02633 I_t u_t - 0.07809(I_t u_t) + A_{21}(L)\Delta MR_{t-1} + A_{22}\Delta MR_{t-1} + \Delta R_{t-1} + u_{2t} \quad (3.8)$$

R^2 = 0.092001 F-statistic = 3.353782 (0.000353) Durbin Watson= 1.990921
JB= 182.27 LM(1)= 0.156251 (0.6929) LM(2)= 0.102702(0.9024)

and

$$\Delta LCO_t = 0.00338 + 0.02492 I_t u_t - 0.04822(I_t u_t) + A_{21}(L)\Delta MR_{t-1} + A_{22}\Delta MR_{t-1} + \Delta R_{t-1} + u_{1t} \quad (3.9)$$

R^2 = 0.092001 F-statistic =3.519594 (0.000196) Durbin Watson= 1.990921
JB= 182.27 LM(1)= 0.156251 (0.6929) LM(2)= 0.102702(0.9024)

Besides, the value of $\rho 1$ and $\rho 2$ in MTAR-consistent suggest convergence, where the speed of adjustment is slower for negative to positive deviation from τ= -0.061532. Therefore, we proceed with asymmetric error-correction modeling.

4. CONCLUSION

The error correction terms of barley price are statistically significant. The barley price adjusts to positive deviation in the spread at around 2.6%. Consistent with current studies by Bakhta and Wurzburg (2013), our result confirm and statistically found barley price and oil price are cointegrated. Therefore, we proceed with asymmetric adjustment mechanism exist in the case between these two variables.

APPENDIX

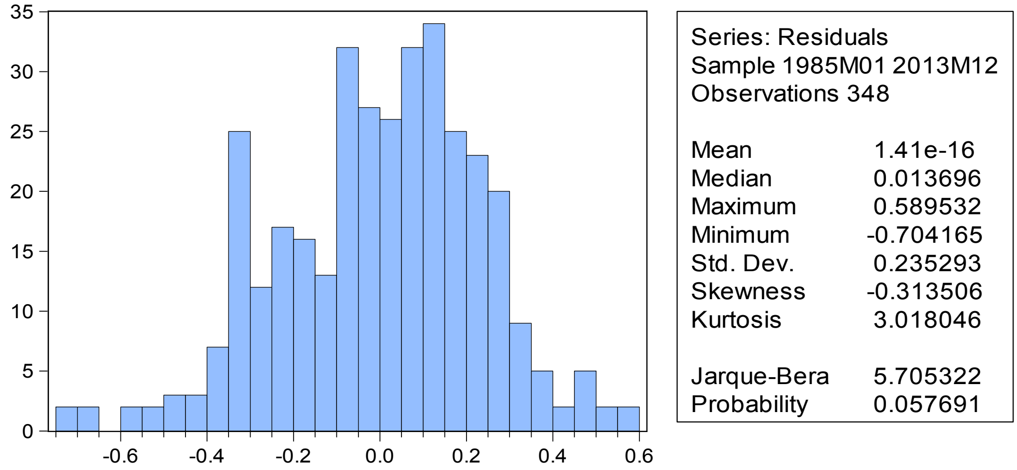


Figure 1.0 Normality Test

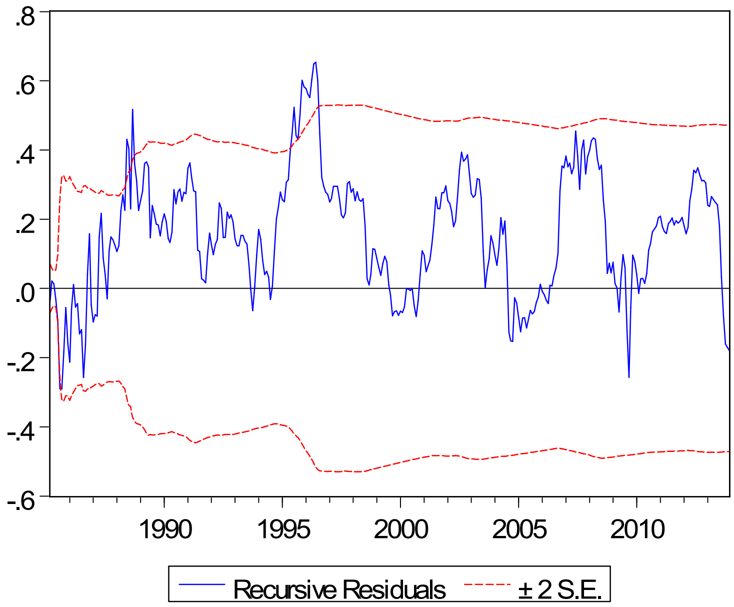


Figure 2.0 Recursive Residuals Graph

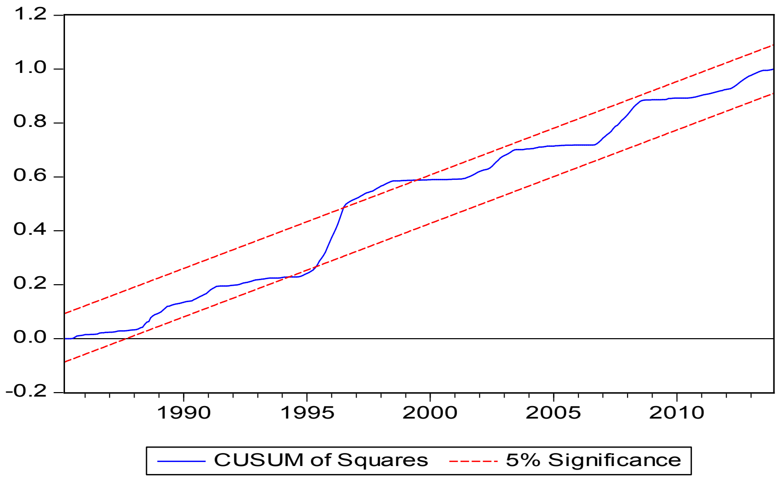


Figure 3.0 CUSUM of Square

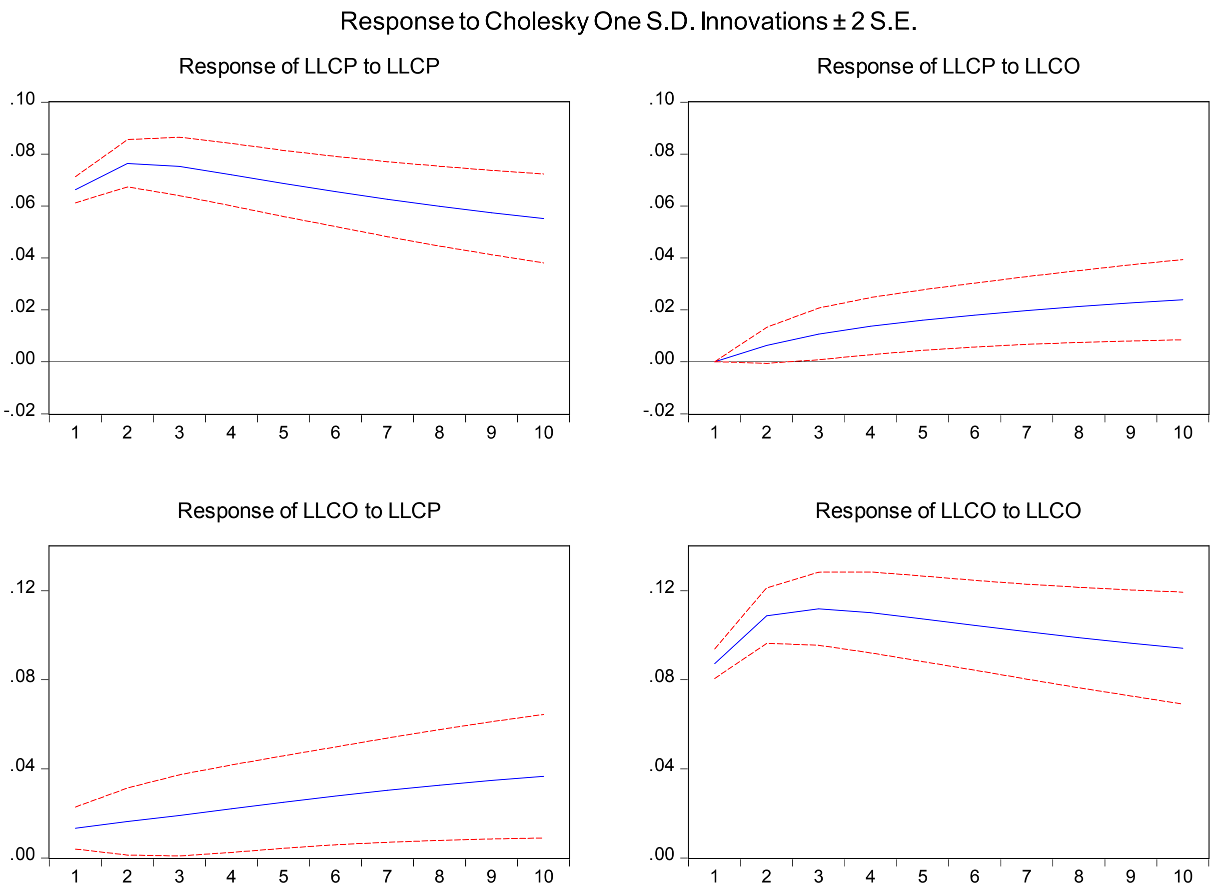
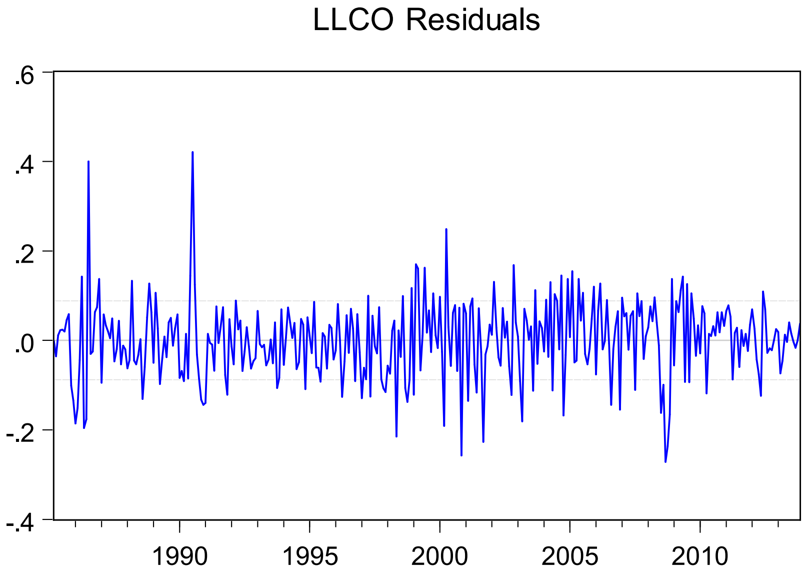


Figure 4.0 Impulse Response



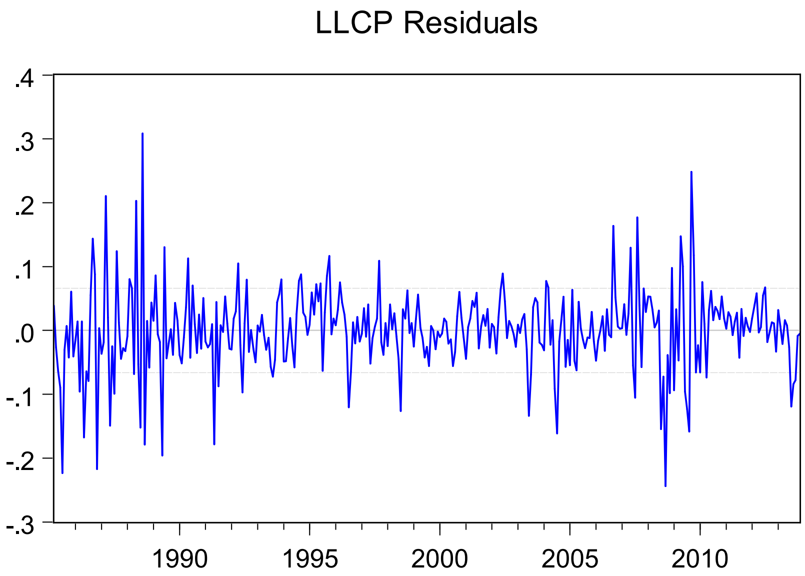


Figure 5.0 Residuals

REFERENCES

Back, J., Prokopczuk, M., & Rudolf, M. (2013). Seasonality and the valuation of commodity options. *Journal of Banking & Finance,37*, 273-290.

Bakhat,M. and Wurzburg, K. (2013). Co-integration of Oil and Commodity Prices: A Comprehensive Approach. *Working Paper WP FA06/2013*. Economics for Energy, Vigo.

Chan, K.S. (1993). Consistency and limiting distribution of the least squares estimator of a threshold autoregressive model. *Annals of Statistics*, *21*, 520-533.

U.S. Department of Energy . (2014, August 29). *Weekly Petroleum Status Report (WPSR)*. Retrieved from National Energy Information Center (NEIC): http://www.eia.gov/petroleum/supply/weekly/pdf/wpsrall.pdf. (last accessed 10.09.2014).

FAO. (2011) *FAO Food Outlook 2011*. Retrieved from http://www.fao.org/docrep/014/al978e/al978e00.pdf. (last accessed 10.09.2014).

Imai, K. S., Gaiha, R., & Thapa, G. (2011). Supply response to changes in agricultural commodity prices in Asian countries. *Journal of Asian Economics,22* , 61-75.

Mensi, W., Beljid, M., Boubaker, A., & Managi, S. (2013). Correlations and volatility spillovers across commodity and stock markets: Linking energies, food, and gold. *Economic Modelling,32*, 15-22.

Nguyen, H. G.N. (2005). Soybean Inventory and Forward Curve Dynamics. *Management Science 51 (7)*, 1076 -1091.

Nazlioglu, S. (2011). World oil and agricultural commodity prices: Evidence from nonlinear causality. *Energy Policy, 39* , 2935-2943.

Samuelson, P. (1965). Proof That Properly Anticipated Prices Fluctuate Randomly. *Industrial Management Review, 6*, 41-49.

Siklos, W. E. (2001). Cointegration and Threshold Adjustment. *Journal of Business & Economic, 19 (2)*, 166-176.

Taylor, M., & Boland, M. (2005). *Barley Profile.* Retrieved from http://www.agmrc.org/commodities__products/grains__oilseeds/barley-profile/. (last accessed 10.09.2014).

Trolle, A.B and Schwartz, E.S. (2009). Unspanned Stochastic Volatility and the Pricing of Commodity Derivatives, *Review of Financial Studie*s, *22,* 4423-4461.

USDA, E. (2014). World Agricultural Supply and Demand Estimates Report (WASDE), United States Department of Agriculture. *Economic Research Service, Washington, DC,* Retrieved from http://www.nationalbarley.com/index.php/statistics/.(last accessed 10.09.2014).

Wang, S. L., & McPhail, L. (2014). Impacts of energy shocks on US agricultural productivity growth and commodity prices A structural VAR analysis. *Energy Economics* , 1-10.

Wang, Y., C. W., & Yang, L. (2014). Oil price shocks and agricultural commodity prices. *Energy Economics,44* , 22-35.

West, K. D., & Wong, K. F. (2014). A factor model for co-movements of commodity prices. *Journal of International Money and Finance, 42*, 289-309.

Zhang, C., & Chen, X. (2014). The impact of global oil price shocks on China's bulk commodity markets and fundamental industries. *Energy Policy* , 32-41.

Zilberman, D., Hochman, G., Rajagopal, D., Sexton, S., & Timilsina, G. (2012). The Impact of Biofuels on Commodity Food Prices: Assessment of Findings. *American Journal of Agricultural Economics* , 275-281.