THE ASYMMETRIC LONG-RUN RELATIONSHIP BETWEEN CRUDE OIL AND GOLD FUTURES

Yen-Hsien Lee, Chung Yuan Christian University
Ya-Ling Huang, Chaoyang University of Technology
Hao-Jang Yang, Taishin International Bank

ABSTRACT

This study employs the momentum threshold error-correction model with generalized autoregressive conditional heteroskedasticity to investigate asymmetric cointegration and causal relationships between West Texas Intermediate Crude Oil and gold prices in the futures market. The paper examines data from May 1, 1994 to November 20, 2008. The empirical results show that an asymmetric long-run adjustment exists between gold and oil. Furthermore, the causality relationship shows that West Texas Intermediate Crude Oil plays a dominant role. The findings should prove valuable to individual investors and financial institutions who can use the findings here to gold prices based on oil prices.

JEL: C32; G15; Q39; Q49

KEYWORDS: Momentum Threshold Error Correction Model, Asymmetric Causality Relationship, Crude Oil, Gold, Futures Market

INTRODUCTION

Oil and gold supply, demand and prices affect every nation. Melvin and Sultan (1990) fist researched the link between oil and gold. Hammoudeh and Yan (2008) indicated that oil and metals are complements in consumption and that oil and gold prices have been rising in unison. Narayan et al. (2010) examined the long-run relationship between gold and oil spot and futures markets. These previous studies confirm that the causality relationship between oil and gold is an important research topic.

Oil prices and inflation are often seen as being connected in a cause and effect relationship. As oil prices move up or down, inflation follows in the same direction. For example, analysis from economists at the Bank of England shows that a $1 rise in oil adds 0.1% to inflation after two years. The value of the currency declines, as the currency loses value against gold. Additionally, a literature review on the oil price shocks and the macroeconomics can be found in Jones et al. (2004). Hammoudeh et al. (2007) find oil prices have a greater speed of adjustment to equilibrium than other commodities. Thus, oil price spikes are often associated with inflationary pressures. There is a corresponding increase in demand for gold since gold is regarded as a more secure way for storing wealth. Thus investors find gold is a good inflation hedge tool. However, few researchers directly study the relationships between oil and gold.

We are interested to know whether oil futures prices have forward influences on the prices of gold futures contracts.This study explores whether there exists a long-run relationship between the oil and gold markets. Most previous studies examining the traditional time series model assumed that underlying variables exhibit linear and symmetrical adjustment processes. However, Balke and Fomby (1997), Enders and Granger (1998), and Enders and Siklos (2001) have demonstrated a low power problem of traditional cointegration tests in situations involving asymmetric adjustment.

They have used nonlinear techniques to capture this asymmetry effect when the variable is adjusting towards its long-run equilibrium. Unfortunately, the standardized model innovations assumed to be normally distributed may also fail to explain the excess kurtosis of financial data. Thus, this study applies TECM-GARCH with generalized errors distribution (GED) describing leptokurtic phenomenon of returns of financial assets. The method of Lee and Hung (2007) is used to investigate the asymmetric cointegration relationship between the oil and gold markets.

The remainder of this paper is organized as follows. Section 2 introduces methodologies. Section 3 then describes data and analyzes the empirical findings. Finally, conclusions are presented in Section 4.

LITERATURE

As highlighted earlier, few researches study the relations between oil and gold prices. However, long and short-run relationships between oil and gold are important issues. Cai et al. (2001) investigate the effect of macroeconomic announcements on intraday patterns of the gold market. They found interest rates, oil prices, consumer demand, the Asian financial crisis, and tensions in South Africa influenced large price changes in the gold market. Hammoudeh et al. (2007) applied GARCH models to examine the impact of crude oil and interest rate shocks on the volatility behavior of gold, silver and copper strategic commodities. They found the impact of past oil shocks on gold, silver and copper is different. Past oil shocks affect the transitory volatility (conditional volatility) of gold market in CCGARCH (EGARCH) model, but do not effect the conditional mean of gold market in three model. Cheng, et al. (2009) used a jump model to capture stochastic and jump volatility, and then used the combined BHK and power GARCH models to investigate value-at-risk (VaR) forecasts in gold market by considering oil shocks. They found the importance of oil jump volatility and the flexibility in power term model are required for VaR forecasting in the gold market.

Soytas et al. (2009) used a VAR model to examine the long and short-run relationship between world oil prices, interest rate, exchange rate, gold and silver in Turkey. They find the world oil price does not lead the gold price in Turkey. However, innovations in world oil prices impact gold markets by generalized impulse response functions. Narayan et al. (2010) use cointegration tests by Gregory and Hansen (1996) to examine the long-run relationship between gold and oil spot and futures markets. They find the oil price leads gold prices in short-run. In terms of various maturities, they identified the long-run relationship between spot (futures) by residual-based tests. Overall, the problem of the low power of traditional cointegration tests is a concern. Therefore, this paper investigates the asymmetry cointegration effect between gold and oil prices.

DATA AND METHODOLOGY

The sample period for this study runs from May 1, 1994 to November 20, 2008. Daily prices of the WTI crude oil and gold futures traded in New York Mercantile Exchange (NYMEX) transaction data were collected and transformed into daily returns, yielding 3,414 observations. The full 14-year period was divided into two separate time periods based on the oil price $40. Thus, the first period covers the dates from May 1, 1994 to May 10, 2004, and the second period covers the dates from May 11, 2004 to November 20, 2008. The daily financial data were obtained from Bloomberg.
Using the threshold cointegration test of Enders and Granger (1998), the completion of the threshold autoregressive (TAR) model required two steps. By assuming variables x_t and y_t are integrated of order 1 (I(1)) process, the first regression takes the form

$$y_t = \alpha + \beta x_t + \varepsilon_t \quad , \tag{1}$$

where ε_t is the stochastic disturbance term. A regression with the form

$$\Delta\varepsilon_t = I_t \rho_1 \varepsilon_{t-1} + (1 - I_t)\rho_2 \varepsilon_{t-1} + \sum_{i=1}^{l} \gamma_i \Delta\varepsilon_{t-i} + \mu_t \ , \tag{2}$$

is then taken, where $\{\varepsilon_t\}$ are the regression residuals from Eqn.(1), μ_t is an i.i.d. disturbance with zero mean, and I_t is the Heaviside indicator such that

$$I_t = \begin{cases} 1 & if \quad \varepsilon_{t-1} \geq 0 \\ 0 & if \quad \varepsilon_{t-1} < 0 \end{cases} \quad \text{or} \quad I_t = \begin{cases} 1 & if \quad \varepsilon_{t-1} \geq \tau \\ 0 & if \quad \varepsilon_{t-1} < \tau \end{cases} , \tag{3}$$

where τ is the threshold value.

When $\varepsilon_{t-1} > \tau$, Eqn.(3) becomes $\Delta\varepsilon_t = I_t \rho_1 \varepsilon_{t-1} + \sum_{i=1}^{l} \gamma_i \Delta\varepsilon_{t-i} + \mu_t$,

otherwise $\Delta\varepsilon_t = \rho_2 \varepsilon_{t-1} + \sum_{i=1}^{l} \gamma_i \Delta\varepsilon_{t-i} + \mu_t$ is used. For any value of τ, some authors have demonstrated the sufficient and necessary conditions for ε_t to be stationary are $\rho_1 < 0$, $\rho_2 < 0$, and $(1-\rho_1)(1-\rho_2) < 1$.

This representation not only captures the asymmetric effect, but can also test the long run relationship between x_t and y_t. Enders and Granger (1998) and Caner and Hansen (1998) claim that it is also possible to allow the Heaviside indicator to depend on the change in ε_{t-1} (namely, $\Delta\varepsilon_{t-1}$) rather than the level of ε_{t-1}; Momentum-Threshold Autoregressive (M-TAR) model. The Heaviside indicator of Eqn. (3) then becomes,

$$I_t = \begin{cases} 1 & if \quad \Delta\varepsilon_{t-1} \geq 0 \\ 0 & if \quad \Delta\varepsilon_{t-1} < 0 \end{cases} \quad \text{or} \quad I_t = \begin{cases} 1 & if \quad \Delta\varepsilon_{t-1} \geq \tau \\ 0 & if \quad \Delta\varepsilon_{t-1} < \tau \end{cases} . \tag{4}$$

The M-TAR model implies that the adjustment mechanism of ε_t is dynamic, since the momentum of the series is greater in one direction than the other. Thus, for any large and smooth changes, the M-TAR model can explain the series more efficiently. This study adopts the method of Chan (1993) to obtain a consistent estimate of the threshold used by Enders and Siklos (2001).

Based on the threshold cointegration found in the previous section, we apply TECM-GARCH with GED by Lee and Hung (2007) to investigate the asymmetric cointegration relationship between the oil and gold markets. TECM-GARCH with GED takes the form:

$$\Delta Y_{it} = \alpha + \gamma_1 Z_{t-1}^{+} + \gamma_2 Z_{t-1}^{-} + \sum_{k=1}^{k_1} \delta_i \Delta Y_{1t-k} + \sum_{k=1}^{k_2} \theta_i \Delta Y_{2t-k} + \sqrt{h_{it}} \nu_{it} \tag{5}$$

$$h_{it} = A + \sum_{j=1}^{p} B_j \nu_{1t-j}^2 + \sum_{j=1}^{q} C_j h_{it-j}$$

where $Y_i =$ (Oil, Gold), $\nu_{it} \sim N(0,1)$, $Z_{t-1}^{+} = I_t \hat{u}_{t-1}$, $Z_{t-1}^{-} = (1-I_t)\hat{u}_{t-1}$ such that $I_t = 1$ if $u_{t-1} \geq \tau$, $I_t = 0$ if $u_{t-1} \leq \tau$ and ν_t is a white-noise disturbance. The density function of GED, $\nu_t \sim \text{GED}(d)$, is：

$$f(\nu_t) = d \cdot e^{-\frac{1}{2}\left|\frac{\nu_t}{B}\right|^d} \Big/ B \cdot 2^{1+\frac{1}{d}} \Gamma\left(\frac{1}{d}\right) \tag{6}$$

where $B = \sqrt{2^{-2/d}\,\Gamma(1/d)/\Gamma(3/d)}$, $\Gamma(\cdot)$ is the gamma function and d is a scale parameter, can be estimated, controlling the shape of the GED. From the system, the Granger-Causality tests are examined by testing whether all the coefficients of $\Delta Y_{1,t-i}$ or $\Delta Y_{2,t-i}$ jointly differ statistically from zero based on a standard F-test and/or whether the γ_j coefficients of the error-correction are also significant.

EMPIRICAL ANALYSIS

Descriptive statistics for WTI and Gold futures returns are reported in Tables 1. This study finds the average returns of WTI and Gold were 0.0359 and 0.0002 when the oil price is below \$40, and 0.0196 and 0.0628 when the oil price is above \$40. The Jarque-Bera statistics indicates that the distribution of these three commodities returns in both time periods has a fatter tail and sharper peak than the normal distribution. The statistics also show that most returns in the first and second periods are negatively skewed except for gold in the first period. The leptokurtosis implies that the distribution of returns has a fatter tail than the normal distribution. As to Ljung-Box Q^2 test examining the serial correlation of square returns, the statistics in both periods with 38 lags are significant at the 1% level. These results indicate that returns exhibit autocorrelation, linear dependence and strong ARCH effects.

Table 1: Summary Statistics of Returns

Iterms	Oil Price is Below \$40		Oil Price is Above \$40	
	WTI	Gold	WTI	Gold
Mean	0.0359	0.0002	0.0196	0.0628
SD	2.4075	0.8869	2.3526	1.3134
Skewness	-0.2812***	1.3970***	-0.0953	-0.1987***
Kurtosis	6.5491***	24.0571***	6.0517***	6.9172***
Jarque-Bera Test	1255.2749***	43813.5044***	430.8387***	713.7674***
Q^2 (38)	208.1181***	61.1244***	518.6853***	344.6743***

*Notes 1. SD denotes standard error. 2.$Q^2(N)$ is Ljung-Box Q^2 statistics with N lags. 3. Jarque-Bera Test denotes the normality test. 4. *** denotes rejection of the hypothesis at the 1% level.*

This study uses the Augmented Dickey-Fuller, Phillips and Perron and Kwiatkowski, et al. unit root tests on prices and their differentials with respect to the WTI and Gold. These tests are designed to indicate whether the WTI and Gold are non-stationary in terms of their levels and stationary in terms of their first differences. This study thus suggests that they are integrated of order one, I(1).

The momentum threshold cointegration test is estimated and the results are provided in Tables 2. Using the method of Chan, the obtained best threshold values are -0.07117 and 0.09811for M-TAR in the first and second period, respectively. The joint null hypothesis of no cointegration with M-TAR adjustment is rejected for each spread given that the $\hat{F}_C$ -statistic exceeds the respective critical value. Given this finding, the following null hypothesis of symmetric adjustment was tested and rejected for each spread given the $\hat{F}_A$ -statistic exceeds the critical value in favor of the alternative for all three spreads in the two different periods. Thus, each threshold signals the change in the spread needed to adjust asymmetrically back to the long-run position. In order to better understand the relationships between these three different commodities, TECM-GARCH with GED are estimated.

Table 2: Momentum Threshold Cointegration Test between WTI and Gold Markets

Items	Oil Price is Below \$40	oil Price is Above \$40
Threshold Value	-0.07117	0.09811
$\hat{F}_C$	5.40859***	12.28992 ***
$\hat{F}_A$	8.307170***	23.465421***
AIC	656.9335	-657.2172
SBC	679.9273	-642.2327
Lag	2	1

*Notes 1. *** denote significance at the 1% levels. 2. $\hat{F}_C$ and $\hat{F}_A$ denote the null hypothesis of no cointegration and symmetry.*

Table 3 shows the estimates of TECM-GARCH with GED between WTI and Gold. The Q^2 tests of diagnostic residuals are all insignificant in asymmetric ECM-GARCH, implying that no serial correlation exists. We also found coefficients of *d* are significant and *d* is small at 2, implying the GED density has fatter tails and is more peaked in the middle (leptokurtic) than the normal density.

While traders of WTI and Gold are active in the long-run disequilibrium, we find WTI and Gold adjusts slower to narrowing of the spread ($|\gamma_1|$) than widening ($|\gamma_2|$) when the oil price is below $40. However, the response is slower to widening of the spread than narrowing when the oil price is above $40. Regarding the causality relationship, we find the unidirectional relationship from WTI to gold when the oil price is below $40 ($\delta_1 = \delta_2 \neq 0$) and above $40 ($\delta_1 \neq 0$). The results reveal the oil price is an important indicator for measuring expected inflation, and the price of Gold tends to rise as people switch from currency to gold as a hedge against expected inflation.

Table 3: The Estimates of TECM-GARCH with GED between WTI and Gold Markets

Items	Oil Price is Below $40		Oil Price is Above $40	
	WTI	Gold	WTI	Gold
α	0.0495	-0.0209***	0.1128*	0.0780***
δ_1	0.0109	0.0062***	-0.0615**	0.0172***
δ_2	-0.0680***	0.0021***		
θ_1	-0.0917*	-0.0823***	0.0124	0.0187***
θ_2	0.0012	0.0046***		
γ_1	-0.0820	0.0177***	181.439***	59.4079***
γ_2	-5.8365***	0.4244***	-0.7313	0.2355**
A	0.0325*	0.0021	0.0726	0.0045
B	0.0326***	0.0545***	0.0480***	0.0387***
C	0.9620***	0.9469***	0.9392***	0.9612***
d	1.5421***	1.9482***	1.1658***	1.4940***
F1	7.4234***	7328.661***	254.4703***	11594.03***
F2	7.9442**	12749.31***	255.9826***	127540223.***
F3	3.0169		0.0601	
F4		38106.39***		286.8835***
$Q^2(38)$	46.155	14.723	38.939	25.818
LL	-5149.5309	-2564.2523	-2391.6310	-1671.2239

Note 1., **, and *** denote significance at the 1%, 5%, and 10% levels, respectively. 2. $Q^2(N)$ are Ljung-Box Q^2 statistics with N lags 3. LL is Log Likelihood. 4. F1 is $H_0: \gamma_1 = \gamma_2$, F2 is $H_0: \gamma_1 = \gamma_2 = 0$, F3 is $H_0: \theta_1 = \theta_2 = \ldots = 0$, F4 is $H_0: \delta_1 = \delta_2 = \ldots = 0$.*

CONCLUSION

This study examines the asymmetric long-run and causality relationship between oil and gold. This article uses the threshold cointegration test to investigate the long-run relationship and uses TECM-GARCH with GED to examine the causality relationship between West Texas Intermediate crude oil and gold prices in the futures market from May 1, 1994 to November 20, 2008.

The empirical results show that an asymmetric long-run adjustment exists between WTI and oil. Furthermore, the causality relationship shows that WTI plays a dominant role whenever the oil price is below $40 or above $40 (i.e., Gold were affected by WTI). In other words a unidirectional relationship exists from WTI to Gold, implying the finding could prove valuable to individual investors and financial institutions. Finally, this study found GED density has fatter tails and is more peaked in the middle (leptokurtic) than the normal density.

This paper sets the foundation for research work in the area. Future research can use the MTAR model to investigate out-of-sample forecasts between oil and gold markets. Then future research can explore the asymmetric long and short-run dynamic relationships between oil and other commodity prices.

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BIOGRAPHY

Yen-Hsien Lee, Department of Finance, Chung Yuan Christian University, No.200, Chung Pei Rd., Chung Li 32023, Taiwan R.O.C., Email: yh@cycu.edu.tw Website: https://mail.cycu.edu.tw/yh/ .

Ya-Ling Huang (Corresponding Author), Department of Senior Citizen Service Management, Chaoyang University of Technology, No. 168, Jifeng E. Rd., Wufeng District, Taichung, 41349 Taiwan, R.O.C., Email: ylhuang@cyut.edu.tw

Hao-Jang Yang, Taishin International Bank, Div. of Global Trade Finance, Taipei, No.17, Sec. 2, Jianguo N. Rd., Zhongshan Dist., Taipei City 104, Taiwan, R.O.C., Email: 990871@taishinbank.com.tw